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1. File Structure and Naming Conventions

1.1 Introduction

All the program modules adhere to specific conventions for the naming of files for a particular experiment. This assures a unique definition of each experiment, facilitates data file management, and allows for ease of interactive processing and troubleshooting. There are four types of files:

1) site-occupation-specific
2) session- or survey-specific
3) global

Each file is distinguished either by its first character (types 1 and 2) or a unique name (type 3). Type 1 files are named using 4-character station codes and the day number of the observations. Type 2 files have a 4-character experiment (survey) or solution name, chosen by the analyst and usually the day number. Type 3 files have specific names that are hard-wired in the software (though these names are often elaborated using links). These naming conventions allow the software to perform the bookkeeping necessary to process large quantities of data.

The next three sections describe the contents and format of the files of each type, and how the file is created and used by the software. Section 1.5 has an alphabetical list of all files and a chart showing what files are read and written by each GAMIT module.

1.2 Site-occupation-specific files

RINEX obs file: Observation data file containing the L1 and L2 carrier beat phases and pseudo-ranges, signal amplitudes, initial station coordinates and antenna offsets, start and stop times, and the identification of the satellites tracked in each receiver channel.

Name: sitedayn.yy
Example: vndn0020.87o. Date from station VNDN (Vandenberg0 on day 2 of 1987.
Type: ASCII
Created by: Programs written by manufacturers, AIUB, or UNAVCO (teqc) to read raw (binary) files downloaded from receivers.
Input to: makex and optionally cview

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RINEX met file: Meteorological data collected at the station.

Name: `sitedayn_yym`
Example: `vndn0020.87m`. Data from station VNDN (Vandenberg on day 2 of 1987.
Type: ASCII
Created by: Programs to read raw (binary) files downloaded from met sensors.
Input to: `model` and `sh_met_util`

X-file: GAMIT observation file, similar to the RINEX file except that the files for all stations used in a session start and stop at the same time (with empty epochs where observations were not obtained.

Name: `xsiten.day`
Type: ASCII
Created by: `makex` and optionally utility `ctox`
Input to: `makek` and `fixdrv`; optionally `bcot` and `cview`

C-file: Primary file for data analysis, created by `model` from an X-file and used as input to `autcln`, `cvview`, and `solve`; contains observations (O's), prefit residuals (O-C's, observed-computed values), partial derivatives, and auxiliary information.

Name: `csiten.day`
Example: `cvndn7.002`
Notes: Direct correspondence to X-files but binary and with partials. If cycle slips needed to be repaired manually with `cvview`, `ctox` may be used to convert the cleaned c-files to x-files for further process, though this is now rare.
Type: Binary
Output of: `model`, `autcln`, `cvview`
Input to: `autcln`, `scandd`, `cvview`, `solve`

K-file: Receiver clock data computed by `makex` or `makek` using nominal site coordinates, broadcast ephemeris, and pseudo-range. It is used by `fixdrv` to estimate the coefficients of a linear or cubic polynomial model for clock behavior during the session.

Name: `ksiten.day`
Example: `kvndn7.002`
Notes: The parameters and format of the station-specific K-file are described in Section 2.9.
Type: ASCII
Output of: `makex`, `makek`
Input to: `fixdrv` and utilities `calck` and `plotk`
P-file : <P>rint file for a model run - provides a record of the run.
   Name : psitey.day
   Example : pvndn7.002
   Notes : Direct correspondence to X- and C-files
   Type : ASCII
   Output of : model

Z-file : Print file written by model to provide to external programs a full
         record of the atmospheric values and models used in the processing.
   Name : zsitey.day
   Example : zvndn7.002
   Notes : Written only if Output net file = Yes in the sestbl.
   Created by : model
   Input to : sh_metutil

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1.3 *Experiment or session-specific files*

These files are specific to a particular session (day) or a group of days corresponding to a single survey (experiment). They always exist, either as files or links, within each day directory. Often a single version of the file will be stored in the /tables directory for a survey and shared among all days via a link.

**Control files**

Processing control file: Used by sh_gamit; includes directory names and some processing control. See Chapter 10.

- **Name**: process.defaults
- **Type**: ASCII
- **Created by**: User from template
- **Input to**: sh_gamit

Site processing control file: Used by sh_gamit; includes controls for use of stations.

- **Name**: sites.defaults
- **Type**: ASCII
- **Created by**: User from template
- **Input to**: sh_gamit

Session control table: Input control file for fixdrv, specifying the type of analysis and the *a priori* measurement errors and satellite constraints. See Section 3.2.

- **Name**: sestbl
- **Notes**: The file name is hard-wired, but links may be used to define different versions of the table.
- **Type**: ASCII
- **Created by**: User from template
- **Input to**: fixdrv

Site control Table: Input control file for fixdrv, specifying for each site the *a priori* coordinate constraints and optionally the clock and atmospheric models. See Section 3.2

- **Name**: sittbl
- **Notes**: The file name is hard-wired, but links can define different versions.
- **Type**: ASCII
- **Created by**: User from template
- **Input to**: fixdrv

Session information or scenario file: Satellites and times to be processed (Section 2.5).

- **Name**: session.info
- **Type**: ASCII
- **Created by**: User or makexp / sh_makexp

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Input to : \textit{makex, fxdrv}
D-file :  *Fixdrv* file - defines the number of sessions in each experiment, the number of receivers per session, the coordinate (L-) file, the ephemeris (T-), station-clock (I-), satellite-clock (J-), and data files (X- or C-) per session, and the order in which the sessions should be processed.

Name  :  *dxxxxx.day* where *xxxx* is the solution name. The rest of the filename is arbitrary but *fixdrv* looks at the sixth character to set up the default value of the year. The three characters of the extent may be the beginning day of the experiment, but this is not necessary.

Example  :  *dcafl7.002*

Notes :  The D-file is the primary input file to *fixdrv*. As such, its name defines all subsequent experiment-specific files. The user can identify the experiment name in any manner. Prior to executing *fixdrv*, the user creates the D-file, using program *makexp* or manually. See Section 3.2.

Type :  ASCII

Created by :  *makexp* or user

Input to :  *fixdrv, grdtab, autcln*

B-file :  Primary <B>atch file - controls the batch (automatic) mode of data processing.

Name  :  *bxxxxx.bat* where *xxxx* are the first five characters of the D-file name.

Example  :  *bcalf7.bat*

Notes :  The primary B-file contains a sequence of secondary B-files which execute in an order prescribed by *fixdrv* the individual modules of the software. Its name corresponds to that of the D-file.

Type :  ASCII

Output of :  *fixdrv*

B-file :  Secondary <B>atch file - controls the execution of one program module.

Name  :  *bxxxxx.nnn* where *xxxx* are the first five characters of the D-file name and *nnn* is the sequence number of the batch file.

Examples :  *bcalf7.001, bcalf7.015*

Notes :  Each secondary batch files contains the input stream for one execution of a program module. For example, the first line of *bcalf7.bat* might be *arc < bcalf7.001*. That is, the program module *arc* will receive its instructions from *bcalf7.001*.

Type :  ASCII

Output of :  *fixdrv*

Input to :  *arc, model, cfmrg, solve*
Files used to model the observations

Station information file: Receiver, antenna, and occupation-time information for each session (see Section 2.3)

Name: station.info
Notes: Prepared from site logs (replaces files hi.raw and sited., no longer used)
Type: ASCII
Created by: User, optionally with make_stnfo or conv_stnfo, or SOPAC
Input to: makex, fixdrv, model

Navigation (or E-) file: Broadcast Ephemeris data in either RINEX or FICA format. It is used by makej, makex, and makek to generate satellite and receiver clock files, and may be used by bctot to create an initial G-file and/or a T-file from the broadcast ephemeris (though IGS products make this rare.)

Name: brdcdayn.yn (or or sitedayn.yn esitey.day)
Example: vndn0020.87n or evndn7.002
Notes: The parameters and format of these files are described in Appendix 2.
Type: ASCII
Output of: RINEX translators or utility ficachop
Input to: makej, makex, makek, bctot

G-file: A file of orbital initial conditions for all satellites on the T-file.

Name: gxxxxy.day
Example: gigsf5.065
Notes: The G-file contains initial conditions and nongravitational force parameters for each GPS satellite at a particular UTC epoch. The G-file initial conditions serve as starting points for a numerical integration of the satellite orbits and the generation of a T-file. The name of the g-file is arbitrary but would normally indicate the source of the orbital information and include the day and year of the initial conditions as in the example above (day 65 of 2005); in any case it should match the name of the corresponding t-file. The filename of the g-file created by solve is the same except that the 6th character is incremented by one letter. The format of the g-file is described in Section 2.10
Type: ASCII
Output of: orbfit / sh_sp3fit, bctot, solve, ttog
Input to: arc

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I-file : Contains a site by site, session by session record of the station clock offset, rate, and acceleration, used optionally by model.

Name : ixxxxx.xxx
Example : icalf7.002
Notes : The I-file name is specified in the D-file.
Type : ASCII
Output of : fixdrv
Input to : model

J-file : Satellite clock parameters transmitted by the satellites and recorded by the receivers.

Name : jxxxxx.day
Example : jca7f7.002
Notes : This file is used by model to compute the receiver clock corrections epoch-by-epoch, and also to correct the modeled phase for large satellite clock drifts (e.g., under SA conditions) when observations are not recorded simultaneously at all sites.
Type : ASCII
Created by : makej
Input to : model

L-file : Station coordinate file - contains a list of the best available coordinates of the sites occupied during a particular experiment (see Section 2.2).

Name : lxxxxx.day in the working directory, where xxxx is the solution name from the D-file name.
Example : lsx4x7.002
Notes : The L-file can be in spherical format (old GAMIT style), with coordinates only, or in Cartesian format (same as GLOBK apr file) with coordinates and optionally velocities. An updated L-file is written by solve
Type : ASCII
Created by : globk/glorg, gapr_to_l, sh_rx2apr, solve, tform
Input to : makex, makek, fixdrv, model, grdtab, tform

T-file : <T>abular ephemeris file for all satellites in a session or series of sessions - contains satellite state vectors at equally-spaced intervals (default 15 minutes for arc) for later interpolation in model. The name should match that of the G-file.

Name : txxxxx.day
Example : tigs4.289, this T-file is associated with a g-file generated by fitting to an IGS Final sp3 file and initial conditions on day 289 of 2004
Type : Binary
Output of : arc, bctot, ngstot, sh_bctot, sh_sp3fit
Input to : fixdrv, model, ttongs, ttoasc

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A-file : ASCII version of the T-file, optionally generated for scrutiny by the analysis or for export.
Name : Axxxxy.day
Type : ASCII
Output of : ttoasc
Input to : None

U-file : Ocean and atmospheric loading and meteorological data for each site in the solution, interpolated from global grids (e.g. otl.grid, atm.grid, met.grid) or read from a file listing values for specific stations (e.g. the IGS network, otl.list, atm.list, met.list).
Name : uxxxxy.day
Type : ASCII
Output of : grdtab
Input to : model

Y-files : <Y>aw files, of two types. An ASCII version (6th character is last digit of year) giving times of eclipses and yaw rates for each satellite observed during the session is written by arc from information in the global file svnav.dat and computed eclipse information. A binary version (6th character is t) giving the angle of departure from nominal yaw at the epochs of the observations in the session is written by yawtab, using the T-file and ASCII y-file as input for the computations. Both of these files are discussed in Section 5.2
Name : yxxxxy.day
Example : ypghost.267
Type : ASCII
Output of : arc
Input to : yawtab

Files used in cleaning the data
Autcln (detailed) output file: Complete record of the editing process; can be ignored and deleted if the solution completed successfully. See sections 4.2 and 5.6.
Name : autcln.out
Type : ASCII
Created by : autcln

Autcln summary file: Summary of editing; useful for evaluating results. See sections 4.2 and 5.6.
Name : autcln.pref.sum or autcln.post.sum
Type : ASCII
Created by : autcln

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V-file : Print file for scanm (one of two files for scanrms - contains a summary of rms values and jumps for each double-difference combination.

Name : vxxxx1.day.sort, vxxxxa.day.sort, vxxxx1.day.worst, vxxxxa.day.worst
Type : ASCII

Files used in estimation

M-file : <M>erge file - sets up the data and parameters for the least-squares analysis in solve.

Name : mxxxx1.day, mxxxxa.day
Example : mcaalfa.002
Notes : The M-file name is derived from the D-file name. The initial M-file is created by cfmrg (using a fixdrv-written batch file) to set up the initial solve, autcln, or cview run. After estimating adjustments to the parameters, solve writes a new M-file with the same name and with the adjustments included. In the usual processing sequence generated by fixdrv, the m-file from the initial (“prefit”) solution is renamed by appending .autcln and can be used in cview to see the residuals used by autcln in the postfit edit.

Type : Binary
Output of : cfmrg
Input to : solve, autcln, scadd

N-file : <N>oise file contains station-specific, elevation-dependent values used to reweight phase observations in solve after postfit editing by autcln. With Release 10.2 in LC_AUTCLN mode, it will also contain the double-difference ambiguities assigned by autcln.

Format : nxxxx1.day nxxxxa.day
Example : ncalf1.002, ncalfa.002
Notes : The file has the structure of the error model: section of the solve batch file. Solve reads it to overrides the batch-file input.

Type : ASCII
Output of : Shell-script sh_sigelv
Input to : solve

Q-file : Print file for a solve run - contains a record of the analysis.

Name : qxxxx1.day, qxxxxa.day
Example : qcalfp.002, qcalfa.002
Notes : The “p” version of the Q-file is produced by the initial (“prefit”) solution, the “a” version by the final (“postfit”) solution.

Type : ASCII
Output of : solve
O-file : Solution output file for a solve run, an abbreviated form of the Q-file used for plotting, statistics and input to sh_met_util.

Name : oxxxx.day oxxxxa.day
Example : ocafl1.002, ocafla.002
Type : ASCII
Output of : solve
Input to : Network-adjustment, statistics, and plotting programs

H-file : Covariance matrix and parameter adjustments for solution generated with loose constraints, used as input to GLOBK.

Name : hxxxxy.day
Example : hcafl7.002
Type : ASCII
Output of : solve
Input to : htoglb, htosnx, htoh
1.4 Global files

These files are global in the sense that they can be used for many experiments over the time interval for which they are valid (usually for at least a year). The name of the files must be exactly specified as indicated below. All of these are found in gg/tables, but except for ftp_info, a link to (or copy of) these files must be in each day directory.

**ftp_info**
- Table of addresses and protocols for downloading files from external archives.
- **Type**: ASCII
- **Created by**: MIT, and modified by user as needed
- **Input to**: sh_get_hfiles, sh_get_nav, sh_get_orbits, sh_get_rinex, sh_get_stinfo, sh_update_eop

**rcvant.dat**
- Table of correspondences between GAMIT 6-character codes and the full (20-character) names of receivers and antennas used in RINEX and SINEX files.
- **Notes**: See Section 4.3 and Appendix 7
- **Type**: ASCII
- **Created by**: MIT, SIO, or user from IGS standards
- **Input to**: model, sh_upd_stnfo/mstinf2

**guess_rcvant.dat**
- Used optionally by sh_gamit to determine the GAMIT code from non-exact 20-character names of receivers and antennas in the RINEX header.
- **Type**: ASCII
- **Created by**: MIT, with modifications by user as needed.
- **Input to**: sh_upd_stnfo/mstinf2

**antmod.dat**
- Table of antenna phase center offsets and, optionally, variations as a function of elevation and azimuth.
- **Format**: Two version allowed, one is GAMIT-specific and soon to be obsolete; the other is IGS ANTEX.
- **Notes**: See Sections 2.3, 3.2
- **Type**: ASCII
- **Created by**: IGS/MIT
- **Input to**: model

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svnav.dat : Table giving NAVSTAR numbers, block number (I or II), spacecraft mass, and yaw parameters for each GPS satellite (listed by PRN number)
Notes : See Section 8.6
Type : ASCII
Created by : MIT
Input to : make, arc, model

svs_exclude.dat : Table giving dates during which a satellite should be excluded from processing.
Type : ASCII
Created by : MIT, SOPAC, user
Input to : sh_sp3fit/orbfit

gdetic.dat : Table of parameters of geodetic datums
Notes : The format of this file is described in Section 7.8. It can be augmented at any time to include additional datums.
Type : ASCII
Created by : MIT, user
Input to : tform

ut1 : UT1 table - contains TAI-UT1 values in tabular form.
Format : ut1. in the working directory; ut1.iers, e.g., in the tables directory
Notes : Should be updated regularly. See Section 8.6.
Type : ASCII
Created by : MIT, SOPAC, or user from, e.g., IERS, USNO using sh_update_eop
Input to : arc, model, sh_sp3fit/orbfit, ngstot, bctot, ttongs

pole. : Pole table - contains polar motion values in tabular form for interpolation in model and arc, and bctot
Format : pole. in the working directory; pole.iers, e.g., in the tables directory
Notes : Should be updated regularly. See Section 8.6.
Type : ASCII
Created by : MIT, SOPAC, or user from, e.g., IERS, USNO using sh_update_eop
Input to : arc, model, sh_sp3fit/orbfit, ngstot, bctot, ttongs

leap.sec : Table of jumps (leap seconds) in TAI-UTC since 1 January 1982.
Format : leap.sec
Notes : See Section 8.6.
Type : ASCII
Created by : SIO, MIT, or user from, e.g., IERS, USNO notices.
Input to : fixdrv, model, arc, bctot, ngstot, ttongs

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nubtabl. : Nutation table - contains nutation parameters in tabular form for transforming between an inertial and an Earth-fixed system
Format : nubtabl. in the working directory; nubtabl.91, e.g., in the tables directory
Notes : See Section 8.6.
Type : ASCII
Created by : MIT
Input to : arc, model, sh_sp3/fit/orbfit, xgstot, hctot, ttlangs

luntab. : Lunar tabular ephemeris
Format : luntab. in the working directory; luntab.95.J2000, e.g., in the tables directory
Notes : Inertial reference frame (B1950 or J2000) must match input controls. Linked by links.com or sh_links.tables. See Section 8.6.
Type : ASCII
Created by : MIT
Input to : arc, model

soltab. : Solar tabular ephemeris
Format : soltabl.in the working directory; soltabl.95.J2000, e.g., in the tables directory
Notes : Inertial reference frame (B1950 or J2000) must match input controls. Linked by links.com or sh_links.tables. See Section 8.6.
Type : ASCII
Created by : MIT
Input to : arc, model

otl.grid, otl.list : Ocean tide components from a global grid or station list..
Type : binary (grid) or ASCII (list)
Created by : Hans-Georg Scherneck at Onsala Space Observatory
Input to : grdtab

atl.grid, atl.list : Atmospheric tide components from a global grid or station list..
Type : binary (grid) or ASCII (list)
Created by : Paul Tregoning at Australian National University
Input to : grdtab

atml.grid, atml.list : Non-tidal atmospheric loading components from a global grid or station list..
Type : binary (grid) or ASCII (list)
Created by : Paul Tregoning at Australian National University from data provided by Tonie van Dam of the University of Luxembourg
Input to : grdtab

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map.grid, map.list  Atmospheric mapping function coefficients based on a global circulation model; currently provided only for VMF1.

Type : binary (grid) or ASCII (list)
Created by : Paul Tregoning at Australian National University from data provided by Johannes Boehm of Vienna University of Technology.
Input to : grdtab

1.5 Summary of files

A - file: ASCII version of the T-file (tabular ephemeris)
B - file: controls the batch mode of data processing
C - file: observed – computed (O-C's), partial derivatives
D - file: driver file of sessions and receivers
E - file: broadcast ephemeris, in RINEX navigation file or FICA Blk 9 format
G - file: orbital initial conditions and non-gravitational parameter values
H - file: adjustments and full variance-covariance matrix for input to GLOBK
I - file: receiver clock polynomial input
J - file: satellite clock polynomial coefficients
K - file: values of receiver clock offset during observation span, from pseudorange
L - file: station coordinates
M - file: controls merging of data (C-) files for solve and editing programs
N - file: data-weight overrides for solve created from autcln.sum.postfit
O - file: record of the analysis (reduced form of Q-file) for post-processing analysis
P - file: record of a model run
Q - file: record of the analysis (solve run)
S - file: no longer used
T - file: tabular ephemeris
U - file: loading and meteorological data for model
V - file: editing output of SCANRMS
W - file: meteorological data in RINEX met-file format
X - file: input observations
Y - file: satellite yaw parameters
Z - file: output meteorological data

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<table>
<thead>
<tr>
<th></th>
<th><strong>INPUT</strong></th>
<th><strong>OUTPUT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>makexp</strong></td>
<td>- RINEX (or X-) files</td>
<td>- D-file</td>
</tr>
<tr>
<td></td>
<td>- station.info</td>
<td>- session.info (optional)</td>
</tr>
<tr>
<td></td>
<td>- session.info</td>
<td>- Input batch files for <strong>makex</strong>, <strong>makej</strong>, <strong>bctot</strong></td>
</tr>
<tr>
<td><strong>makej</strong></td>
<td>- RINEX nav file</td>
<td>- J-file (satellite clock file)</td>
</tr>
<tr>
<td></td>
<td>- C-file (optional--See 4.6)</td>
<td></td>
</tr>
<tr>
<td><strong>makex</strong></td>
<td>- raw observations (RINEX or FICA)</td>
<td>- K-file (receiver clock)</td>
</tr>
<tr>
<td></td>
<td>- station.info (rcvr, ant, firmware, HI)</td>
<td>- X-file (input observations)</td>
</tr>
<tr>
<td></td>
<td>- session.info (scenario file)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- RINEX nav file</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- J-file (satellite clock file)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- L-file (coordinates of stations)</td>
<td></td>
</tr>
<tr>
<td><strong>arc</strong></td>
<td>- arc.bat (batch input file)</td>
<td>- arcout.ddd (output print file)</td>
</tr>
<tr>
<td></td>
<td>- G-file (orbital initial conditions)</td>
<td>- T-file (tabular ephemeris for all sat. ses.)</td>
</tr>
<tr>
<td><strong>fixdrv</strong></td>
<td>- D-file (list of X-, J-, L-, T-files)</td>
<td>- B-file (bexpy.bat : primary batch file)</td>
</tr>
<tr>
<td></td>
<td>- sestbl. (session control)</td>
<td>- B-file (bexpy.nnn : secondary batch files)</td>
</tr>
<tr>
<td></td>
<td>- .sittbl. (site control)</td>
<td>- I-file (rcvr clock polynomials)</td>
</tr>
<tr>
<td></td>
<td>- T, J, L, X (or C) input</td>
<td></td>
</tr>
<tr>
<td><strong>model</strong></td>
<td>- L-file (site coordinates)</td>
<td>- C-file ( residuals and partials )</td>
</tr>
<tr>
<td></td>
<td>- station.info (ant heights)</td>
<td>- P-file (documentation of models)</td>
</tr>
<tr>
<td></td>
<td>- X-file</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- I, J, T-files</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- antmod.dat (PCV models)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- RINEX met file</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- otl.list/grid, atml.list/grid</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>autcln</strong></td>
<td>- C-file</td>
<td>- C-file (cleaned)</td>
</tr>
<tr>
<td><strong>cfmrg</strong></td>
<td>- C-file</td>
<td>- M-file (points to the C-files)</td>
</tr>
<tr>
<td><strong>solve</strong></td>
<td>- C-file</td>
<td>- Q-file</td>
</tr>
<tr>
<td></td>
<td>- M-file</td>
<td>- G-file</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- H-file</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- L-file</td>
</tr>
<tr>
<td><strong>cview</strong></td>
<td>- M-file and C-files</td>
<td>- C-files (<strong>cview</strong> only)</td>
</tr>
<tr>
<td><strong>scandd</strong></td>
<td>- M-file and C-files</td>
<td></td>
</tr>
</tbody>
</table>

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| makek  | - RINEX nav file
|        | - J-file
|        | - L-file
|        | - X-file
|        | - K-file |
| ngstot | - SP3-file          |
|        | - G-file
|        | - T-file |
| bctot  | - RINEX nav file   |
|        | - G-file
|        | - T-file |
2. Creating Data Input Files

2.1 Introduction and file organization

The first and most tedious step in analyzing GPS data, is organizing the data, both field notes and receiver output, in such a way that it can be handled efficiently by the processing programs. It is during this process that you must make tentative decisions about how many days to analyze, what stations should be included and over what time span, and how frequently to sample the data. In short, this is the time to start taking careful notes and to plan your analysis strategy. This is also the time when you discover that you are missing log sheets, data files, or a priori coordinates for particular stations, and you must send frantic e-mail to fill in the holes.

The main GAMIT modules (beginning with fixdrv, arc, and model) require seven types of input:

- Raw phase and pseudo-range data in the form of ASCII X-files (one for each station within each session)
- Station coordinates in the form of an L-file
- Receiver and antenna information for each site (file station.info)
- Satellite list and scenario (file session.info)
- Initial conditions for the satellites' orbits in a G-file (or a tabulated ephemeris in a T-file)
- Satellite and station clock values (I-, J-, and K-files)
- Control files for the analysis (sestbl. and sittbl.)
- "Standard" tables to provide lunar/solar ephemerides, the Earth's rotation, geodetic datums, and spacecraft and instrumentation information (see below).

The X-files are the key organizational structure because all X-files for a given session are written with the same start and stop times, selection of satellites, and sampling interval. This imposed rigidity has certain advantages. The primary one is that the process of creating the X-files (program makex) acts as a filter, catching most of the problems with missing or invalid data, mismatched time tags, and poorly behaved receiver clocks that would cause greater loss of time if discovered later.

The first step is to create working directories for the processing. The recommended organization (and the one used by sh_gamit) is a "survey" or continuous network directory (e.g., emed98, scce99, scign99) under which you will have "day" directories for each day or session (e.g., /312 for day 312). Parallel to the day directories are directories containing the RINEX files (e.g., /rinex), orbit files (e.g., /brdc for navigation files and /igs for IGS SP3 files), and the GAMIT tables relevant to the survey ( /tables ). (The directories for
GLOBK processing of the survey, /gso/n and /gbf, can also go at this level.) With sh_gamit, most of these directories are created automatically if they do not already exist.

You begin the pre-processing by creating links within the day directory to the data files and tables necessary to set up the batch processing. This is usually accomplished in two steps: The first step is to create links to the GAMIT global files: geodetic datums (gdetic.dat), lunar and solar ephemerides (luntab. and soltab.), nutations (nuttab.), Earth rotation (ut1. and pole.), ocean tides (stations.oct and grid.oct), leap seconds (leap.sec), and spacecraft, receiver, and antenna characteristics (svnav.dat, antmod.dat, rcvant.dat). That is, in the /tables directory, execute script links.tables, which will create links for the global files to ~/gg/tables. Second, from each day directory you execute links.day, which will create links for global files and survey-specific files to ../tables. Links.day will also create links from the day directory to ./tables for the six control and survey-specific files needed by GAMIT: station.info, session.info, sestbl., sittbl., autcln.cmd. and file. Hence, you can keep a single copy of these files in /tables, avoiding the possibility of processing different sessions with different input controls. If you are simply performing a test with a single day’s data, you execute links.com to link tables directly to ~/gg/tables and copy all the other files into the day directory. If you are using sh_gamit, then both steps of the standard link tasks are accomplished automatically.

We describe the linking of the RINEX files in Section 2.5, preparation of the L-file, station.info, and session.info Sections 2.2–2.4, and the control files for fixdrv (sestbl. and sittbl.) in Chapter 3. The navigation file is simply a RINEX "n" file, named either aaaaannnn.YYn or eaaaY.DDD and should be linked or copied into the day directory from the /rinex or /brdc directory or directly from an IGS Data Center.

2.2 Preparing the coordinate (L-) file

The L-file contains the coordinates of all the stations to be used in the experiment. With Release 10.1, two forms of the L-file are supported: spherical coordinates at the epoch of the observation (traditional GAMIT format), or Cartesian coordinates and velocities at a specified epoch (GLOBK apr-file format). The latter is now preferred since it allows for motion of the station during the session and for better identification of stations displaced by earthquakes (see Defining earthquakes and renaming stations in Section 3.1 of the GLOBK manual):

* nafd_plate_scec.apr : itrf00_noam + updates from vel_020123a
* North American stations for stabilization

* GOLD_GPS -2353614.1450 -4641385.3890 3676976.4750 -0.00216 0.00649 0.00457 1997.0000
Moj1_GPS -2356424.5422 -4646515.3890 3668462.2248 -0.00216 0.00649 0.00457 1991.0000
MOJ1_GLA -2356424.5553 -4646613.6858 3668462.2288 -0.00216 0.00649 0.00457 1998.9610
GOLD_GHT -2353614.1949 -4641385.3488 3676976.4648 -0.00216 0.00649 0.00457 2000.6690

In this example, there are multiple entries for the 4-character codes GOLD and MOJ1, with the last 4 characters representing positions before (_GPS) and after the Landers (_GLA) and Hector Mine (_GHT) earthquakes. These codes were generated automatically by GLOBK

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based on the dates and radii of influence of the two earthquakes as given in the GLOBK eq_file. To determine which one to use, GAMIT can read an eq_file and compare the date with the date of the data being processed. The date at the end of the line is the epoch of the GLOBK solution, to which the positions and velocities refer.

An old-style GAMIT L-file is generated for a particular epoch from a GLOBK apr file using the program gapr_to_l.

\[ \text{gapr_to_l <globk.apr> <lfile> <full names> <date>} \]

where <globk.apr> is the name of the input GLOBK a priori file,
<lfile> is the name of the output -L-file
<full names> is the name of a file which gives the full site name for each of the GAMIT four character site codes. You can usually omit this file by substituting using double quotes (" ") since the full site name for GAMIT is taken from file station.info, not the L-file
< date > is the date to which the L-file coordinates should by referred. The date may be specified in one of three ways:

1. If a single value is given, then decimal years is assumed,
2. If two values are given, they are assumed to be year and day of year.
3. If three values are given, they are assumed to be year, month, day.

The old-style GAMIT L-file has the following form:

Epoch 1993.5479: From file itrf00.apr
GOLD GOLD GPS N35 14 36.99253 W116 53 21.29202 6371978.7987
MOJ1 MOJ1 GPS N35 09 01.05171 W116 53 26.91387 6371920.4323 Updated from lscec3.282

Here only the initial 4-character code has meaning; the next 12 character are the “name” of the station, used only for display. With this form of the L-file, you must assure that the apr file input to gapr_to_l has only an entry for the position of the station appropriate to the epoch of processing.

The GLOBK_style L-file is free-format, with a non-blank first column indicating a comment. The old-style L-file is a rigid format,

\[(A4,1X,A12,A1,I2,1X,I2,1X,F8.5,1X,A1,I3,1X,I2,1X,F8.5,F14.4)\]

with no explicit provision for a header line or comments. However, the entries are read under format-control only if the first four characters of the line match the name of the site in the processing, so comments may be placed in the file without harm so long as the first four characters are not the same as the site.

Within each day directory, the usual name of the L-file (old- or new-style) is the same as the D-file except for the first character(i.e., projy.ddd), with a link provided to an experiment-wide L-file (lfile.) in ../tables.

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You can obtain coordinates for new stations in your network using the script `sh_rx2apr`, which invokes programs `svpos` and `svdiff` to perform an iterative pseudorange solution from RINEX files:

```
sh_rx2apr   -site <site>   -nav <nav>   -ref <ref>   -apr <apr>   -chi <val>```

where `<site>` is the name of the RINEX file for the station for which you need coordinates, `<nav>` is a RINEX navigation file, `<ref>` is the name of a RINEX file for a known station (preferably but not necessarily close by), `<apr>` is the name of an apr file containing the coordinates of the reference station, and `<val>` is the chi-square value below which the `svpos` (point-position) solution is considered converged. The `svdiff` step may be skipped by entering only the `<site>` and `<nav>` files. Note that the `<site>` file must be within or linked in the current directory (no pathname allowed). The outputs of `sh_rx2apr` are both an old-style GAMIT L-file (default name `lfile.<site>`) and a GLOBK apriori file (`<site>.apr`), which you can append to existing files (`sh_gamit` does this automatically; see Chapter 6).

It behooves you to exert some effort to get good a priori coordinates for processing. The first consideration is to generate pre-fit residuals sufficient for `autcln` to perform robust editing of the data. For this purpose, errors up to 10 m will usually allow enough data to pass through to estimate coordinates to better than one meter; the entire solution can then be repeated with the updated coordinates to obtain a clean edit of the entire span of data for that station. The second consideration is linearity of the least-squares adjustment. The convergence rate for station coordinates is (conservatively) 1/1000, so 1 m errors in the a priori values contribute no more than 1 mm error to the final value. The most exacting requirement is the coordinates used for the fiducial stations, which if constrained in the final solution define the reference frame of the network. If you are using GLOBK for your final solution, then the first two of these requirements (editing and linearity) should be met in the GAMIT L-file, and the last two (linearity and fiducial coordinates) should be met in the GLOBK a priori (.apr) station file. GLOBK apr files of ITRF coordinates can be obtained from `/updates/tables` in the MIT ftp directory.

### 2.3 Creating the station information file

All of the receiver and antenna information specific to a particular site occupation is recorded in file `station.info`, which is read by `makexp`, `makex`, and `model`. The values entered correspond to a single occupation, of either one day or a series of days. With Release 10.1, there is a new format for `station.info` that provides more flexibility and cleaner logic for selecting entries. With the new format, the number of entries (columns) is variable and determined by a list beginning with the keyword `*SITE`. Although the number and order is arbitrary, the width (format) of each entry is rigid and hard-wired into the code (this allows blanks within the alphanumeric entries). An example is shown below:
Each of the data columns must be exactly the width shown and be separated by two spaces. The positioning of the entries in the header (*SITE *) line is arbitrary, but is usually as shown here (aligned with the data columns) for aesthetics. Except for the *SITE line, any line with a non-blank first column is treated as a comment. *SITE is the 4-character code for the observing site (monument), Station Name a 16-character description (carried for documentation only), and Session Start and Session Stop the start/stop times for the entries. In a change from 10.0 and the old-style file, the start and stop times can be simply interpreted as applying to the station given and do not have to match the start and stop times of the session as defined on the X-file. Multiple entries for a station need not be contiguous but must be in chronological order (the program will detect this for you and issue a warning).

Most important among the entries in station.info are the antenna type (AntCod) and specification of how the height-of-instrument (HI) was measured in the field (HtCod) since this directly affects the estimated heights from the analysis. This information is typed into station.info in the form of keywords and later converted by GAMIT to L1 and L2 phase-center offsets. For example, in the station.info given above, station BLHL on day 66 used a Trimble SST (TRMSST) antenna whose slant-height to the bottom of the outer edge of the ground plane (SLBGP) was measured as 1.325 m. Measurements of the direct height to the antenna reference point (RINEX standard) are specified as DHARP. Complete descriptions of all of the antennas allowed by GAMIT and the models used to compute their effective phase centers are given in Appendix 2. To verify current information for your version of the software, see tables hi.dat, rcvant.dat, and antmod.dat (ANTEX file) in gg/tables. and subroutine ant_alias.f in gamit/lib. There are usually entries for the horizontal offsets (Ant N Ant E) of the antenna from the monument, but these have been excised from the example in order to reduce the table width. The station.info values are added to the coordinates of the monument in computing the antenna phase-center position.

Besides documenting the analysis, the receiver type (RcvCod) and firmware/software version (SwVer) are used by makex in filtering the sample time (some receivers have offsets from the even minute) and determining whether a receiver has full- or half-wavelength L2 observations. Note that the firmware codes used by GAMIT are numerical and do not necessarily correspond to the manufacturer's designations; for correct processing, the firmware version does not always need to be strictly correct and in some cases is defined artificially in GAMIT to account for non-standard or erroneous
sampling (see Section 2.8). In the new format, the actual alphameric firmware version can also be included (vers) but currently only for documentation.

In the new format, the receiver and antenna may also be identified by their 20-character IGS names rather than or in addition to the GAMIT keywords. The alphameric firmware version and receiver and antenna serial numbers can also be included but will not be used directly by GAMIT. See gamit/lib/rstnfo2.f for a full description of allowed entries.

For at least the next year, the old-style version of station.info will be supported. An example is shown below:

```
glob siof
(A1,2(A4,1X),A16,F7.4,2(I1,F8.4),2(I1,A6),1x,a5,1X,F5.2,1X,I4,1X,I3,1x,I2,6(1X,I2))

TRCK SITE Station Name Ant Ht Ant N Ant E Rcvr AntCod HtCod Vers Yr Doy SN Start Stop

* Global stations
2353 2353 Wairakei 1.4077 0.0000 0.0000 TRMSST TRMSST DHARP 4.11 1990 334 0 0 0 24 0 0
2353 2353 Wairakei 1.4130 0.0000 0.0000 TRMSST TRMSST DHARP 4.53 1991 332 0 0 0 24 0 0
AIS2 AIS2 Annette Island 2 0.0000 0.0000 0.0000 ASHZ12 ATGEO33 DHARP 8.04 1996 19 0 0 0 24 0 0
AIS2 AIS2 Annette Island 2 0.0000 0.0000 0.0000 ASHZ12 ATGEO33 DHARP 9.40 1996 325 0 0 0 24 0 0
AIS2 AIS2 Annette Island 2 0.0000 0.0000 0.0000 ASHZ12 ATGEO33 DHARP 9.50 1999 173 0 0 0 24 0 0
ZWEN ZWEN Astronomical Obs 0.0460 0.0000 0.0000 AO800A TRBROG DHARP 3.30 2000 265 0 0 0 24 0 0

* Regional occupations
BLHL BLHL Black Hill 1881 1.3250 0.0000 0.0000 TRMSSE TRMSST SLBGF 5.71 1994 66 0 18 30 0 24 0 0
BLHL BLHL Black Hill 1881 1.3250 0.0000 0.0000 TRMSSE TRMSST SLBGF 5.71 1994 67 0 0 0 4 30 0 0

In this format, the 4-character strings on the first line specify respectively the experiment name and orbit (G- or T-) file names to be used by makexp (see Section 2.5) in setting up the processing directory; these strings are now provided in the calling arguments for makexp (or sh_gamit) and hence are no longer read from station.info. The second line is a Fortran-readable format for the station entries beginning on line 4. The third line is comment but is required for proper reading of the file. After this line, any line with a non-blank first character is treated as a comment. The first two columns are redundant for static surveying but describe the receiver track (TRCK) and monument occupation (SITE) for kinematic or dynamic surveying (not currently supported in GAMIT—see program track in the GLOBK suite). Most of the other entries are the same as for the new-format. One important difference is the way that start and stop times are treated. In the new format, there is an explicit and full stop time given. In the old format, the stop time omits the day, leading to the requirement that you observe the following rule:

1) If the start and stop times are 0 0 0 0 0 0 or 0 0 0 24 0 0, the antenna information entered for a day will be used throughout the day and for all days following until a later entry is encountered in the table. Thus, in the example, the initial entry for AIS2 is valid from 0h UTC on day 19 of 1996 until 0h UTC on day 325 of 1996.

2) If the start and stop times are any other values, the information is valid only within the listed times. In the example, the first entry for BLHL is valid from 18h 30m on day 1994 66 until 24h, and the second entry (identical to the first) from 0h to 4h 30m on day 67. With sessions of this type, we strongly recommend that you use the new-style format.

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In most cases the entries in station.info for a field survey must be entered manually from the log sheets, using as a template, e.g., gg/tables/station.info, or, for the new-style format, program make_stnfo. A current station.info for all of the continuous stations processed by SOPAC can be found on the SOPAC web page and in updates/tables in the MIT GAMIT/GLOBK ftp directory. If you are processing RINEX files generated elsewhere and all of the header information is completely correct, then sh_gamit will perform updates of the template station.info for you automatically. If you want to merge several station.info files created for different surveys, you can use the program sh_upd_stnfo; the format of the reference file will be transferred to the merged file.

```
 upd_stnfo f   -ref <rsfile>   -f <rfiles>     -merge <sfiles>  -
```

where <rsfile> is a reference station.info file to be updated, <rfiles> are the names of one or more RINEX files to be read for header information; and <sfiles> There are other options that control the updating, sorting, and interpretation of height values; type the name of the script without arguments to see the full list.

### 2.4 Creating a scenario file

The scenario file (session.info) contains the start time, sampling interval, number of observations, and satellites (PRN #s) to be used in generating the X-files for each day. It does not correspond to the time-dependent scenarios used to program some receiver software, but rather includes all the satellites that you want to use in the analysis—generally all available from any receiver since you can delete satellites later on in the processing. To find out what satellites are available on the raw data files, use the shell script sh_rxscan and program FICASCAN. An example of a session.info file is given below:

```
* session.info: free format, non-blank first column is comment
* Year Day Sess#  Interval  #Epochs  Start hr/min  Satellites
  1986 278  1   30 900 14 04 3 6 9 11 12 13
  1986 350  1 30 900 8 10 3 6 9 11 12 13
  1986 351  1 30 900 8 06 3 6 9 11 12 13
  1987 144  1 120 225 22 52 3 6 8 9 11 12 13
```

(Older versions of session.info used a formatted read, with the format in the second line of the file. These versions can be read successfully by current releases.) The session.info file can be specific to a given experiment or contain all of the scenarios used for all the experiments processed at your facility. An experiment-specific file can be generated automatically by program MAXEXP (see below) using the input start/stop time and the satellites available on the navigation file.
2.5 Using makexp

Once you have assembled the RINEX observation and navigation files and created station.info and (optionally) session.info you can run script sh_makexp (to execute program makexp) in the day directory to generate most of the additional files you will need to complete preprocessing. makexp determines the stations to be included in a session from the RINEX or X-files present in the day directory. For RINEX, it is usually most convenient and efficient not to copy the files into the day directory, but rather to create links to one or more parallel directories in which groups of data files have been collected by source or region. For example, in processing a survey from central California, you might have collected several days of data from the Southern California Continuous Integrated GPS Network (SCIGN), the Bay Area Regional Deformation (BARD) network, and global IGS stations, stored for several days in ../rinex/scign, ../rinex/bard, and ../rinex/igs, respectively. You can then use the script sh_link_rinex to link from each day directory to these data directories. (If you are using sh_gamit, the links from the day directory will always be to a single /rinex directory, but the rnxfnd option allows you to create secondary links from /rinex to other directories.)

```
sh_link_rinex -year <yr> -days <doy> -ndays <n1 n2> -sesfo <shr smin dhr dmin> -dir <dir>
```

- `<yr>` is the 4 char year of observations
- `<doy>` are the 3 char days of the year to be linked
- `<n1 n2>` are the days before and days after the specified doy to link or search
- `<shr smin dhr dmin>` are the start time and duration of the session
- `<dir>` the absolute or relative path to the rinex files [default ../rinex]

Examples:

```
sh_link_rinex -year 1996 -days 016 -sesfo 12 30 6 0 -dir ../rinex/scign
sh_link_rinex -year 1996 -days 016 017 -ndays 1 -dir ../rinex/scign
```

If `sesfo` is specified, the script will search for data within all RINEX files whose names match the start day and any following days within the session. If `ndays` is specified without `sesfo`, the script will automatically link all files within the range of `ndays`. If both `sesfo` and `ndays` are entered, the script will search all the days within the range but link only the data within the session span.

To run makexp, you may type the program name and answer the queries or, for automatic processing, use command-line arguments or the shell script sh_makexp

```
sh_makexp -expt <expt> -orbit <orbit> -yr <yr> -doy <doy> -srin -nav <file> -sinfo <int hh mm nepoch>
```

in which the entries are the 4-character experiment code (`expt`), the 4-character orbit type (e.g., `IGSF` for IGS final), year (`yr`), day-of-year (`doy`), navigation file (`file`), and the session span information—sampling interval (`int`), hour (`hh`), minute (`mm`), and number of epochs (`nepoch`) (a more complete list of options is given as help when you type the name of the shell-script). The option `-srin` tell the script to search the directory for all RINEX files with data matching the input date. To see additional options, type the name of the script.

In interactive use of makexp, you will be asked to enter the year, day-of-year, session number, and navigation file. When invoked, makexp will search the working directory for RINEX (links) or X-files with the input date, compare the 4-character station names
and date with the TRCK codes and dates in station.info, and write to the screen a summary of the available stations. If a scenario file (session.info) exists and sinfo is not specified, makexp will use it to determine the start and stop times and the satellites to be used in the session.

The screen output of makexp contains a summary of the stations found (X-files to be created), satellites included, and the session times. It concludes with instructions for the next steps:

Now run, in order:
sh_sp3fit -f <sp3 file> OR sh_bcfit bctot.inp OR copy a g-file from SOPAC
sh_check_sess -sess 278 -type gfile -file <g-file>
makej <nav-file> <jfile> OR copy a j-file from SOPAC
sh_check_sess -sess 278 -type jfile -file jvent7.278
makex <makex-batchfile>
fixdrv <dfile> OR run interactively

The script sh_sp3fit generates satellite initial conditions (G-file) by fitting the arc model to the tabulated ephemerides in "SP3" format from an IGS analysis center. The input <sp3 file> must be present or linked in the local directory (pathnames are not allowed. Alternatively you can create these files from the broadcast ephemeris in a RINEX navigation file or copy G-files directly from SOPAC. The second step (sh_check_sess) is optional but assures that the satellites requested in session.info are available on the orbital (G- and T-) files. Program makej creates a (J-) file of satellite clock values from the navigation message. Then you may again use sh_check_sess to assure that the satellites requested in session.info are available on the J-file. Program makex creates the GAMIT observation (X-) files from the RINEX files. Each of these steps is described in the following sections of this chapter. Finally, program fixdrv reads the analysis controls, described in Chapter 3, and creates a batch file for GAMIT processing. All of these steps are executed automatically by sh_gamit.

Creating the input files for makej, makex, and fixdrv from templates is not difficult and may be necessary for experiments with multiple sessions or a mixture of RINEX and FICA files.

2.6 Creating G- and T-files from external ephemerides

Orbital information is input to GAMIT in the form of a tabular ephemeris (T-) file, which contains the positions of all the satellites at 15-minute intervals throughout the observation span, or a G-file of initial conditions which are integrated by arc (in the batch run) to create a T-file.

If the satellite orbits are to be adjusted to fit the observations, then the T-file must also contain partial derivatives of position (as a function of time) with respect to six "initial
conditions" and other parameters describing the orbit of each satellite. *Arc* generates the partials by numerically integrating their force equations (termed "variational equations") simultaneously with the equations of motion. If the G-file of initial conditions was obtained from a global orbit solution performed using GAMIT with a compatible version of *arc* (e.g., by SOPAC), it can be used directly in *arc* to produce a T-file consistent with the solution. Integration of instantaneous position and velocity values obtained by evaluating the broadcast message parameters or extracted from an external Earth-fixed ephemeris (in SP #3 format) produced by another software package or an incompatible version of *arc* will not reproduce the original accuracy since model differences will cause the orbit to deviate from the original orbit as the integration proceeds away from the initial epoch. The original accuracy can be obtained, however, by estimating initial conditions for *arc* using externally derived positions and velocities over the full session, or several days, as pseudo-observations. The most accurate and reliable method of obtaining a starting T-file is to follow this procedure using the shell script *sh_sp3fit* and one or more SP #3 files from an IGS analysis center:

```
sh_sp3fit -f <sp3 files> -d <yr doy1 doy2> -o <orbit name> -i <equator prec> -r <radmod> -t
```

where `<sp3 file>` is the list of SP3 files (e.g. `igs08523.sp3` for day 3 of week 852) and `<yr doy1 doy2>` the year and day-of-year over which you wish to perform the fit. Normally, there will be only one SP3 file and only `<yr doy1>` will be specified. However, it is possible to determine orbital initial conditions by fitting over several days (three is the current maximum), a reasonable approach for pre-1990 data for which the global tracking network was week. For a two-day fit, the epoch of the initial conditions will be 12h UTC on the first day; for a three-day fit, 12h UTC on the middle day. `<orbit name>` is the 4-character name for the G- and T-files specified in *sh_makexp*. `<equator prec>` specifies the inertial reference frame and precession constant for the G- and T-files; the defaults are the conventional J2000 IAU76, but you may specify B1950 IAU68 for compatibility with older GAMIT and SOPAC processing (see the discussion of inertial frame in Section 3.2). `<radmod>` specifies the radiation-pressure (non-gravitational force) model to be used with the orbit; the default is BERNE (see sections 3.2 and 5.2). The final argument (`-t`), if entered, causes *sh_sp3fit* to create (integrate) a T-file from the initial conditions (G-file) estimated from the fit. The default is to skip this step, deferring the integration to the first step of the GAMIT batch run. In addition to a G- and (optionally) T-file, *sh_sp3fit* will generate two print files (`sp3fit.fit` and `sp3fit.rms`) summarizing the quality of the fit, and a Y-file of satellite yaw parameters for the orbital span.

An alternative but less accurate means of generating an initial orbit is to use the script *sh_bcfit* to perform a fit of the GAMIT model to the broadcast elements in a navigation file. Before doing so, you should run the program *bccheck* to determine the consistency of the elements and to filter outliers:

```
bccheck <RINEX nav file> <yr> <doy>
```

will produce a new navigation file (`<RINEX nav file>.bcchecked`) containing only elements whose differences from the elements at the midpoint of the day are less than 1000 m.
The print file bccheck.out will give you a summary of the times and differences of the elements in the file, with any deleted marked by an asterisk. Next execute

```
sh_bcfit <input file>
```

where `<input file>` is the bctot.inp produced by `makexp`:

```
b auto2360.94n.bcchecked xpver4.236 tvent4.236 y J2000
```

- `b` indicates batch input
- `auto2360.94n.bcchecked` RINEX navigation file
- `xpver4.236` X-file to determine session scenario
- `tvent4.236` output T-file
- `y` 'yes' to transform the orbit to an inertial frame
- `J2000` designation of the inertial frame

If you don't have an X-file or wish to create a T-file for a longer span, you can do so by changing the input file to match an alternate set of questions asked by `bctot`:

```
b auto2360.94n.bcchecked
```

- `b` indicates batch input
- `auto2360.94n.bcchecked` RINEX navigation file
- `auto2360.94n.bcchecked` blank line to indicate no X-file
- `tvent4.236` output T-file
- `y` 'yes' to input the start and stop epochs
- `94 8 24 1 0 0.` start epoch yy mm dd hh mm sec. in free format
- `900` tabular interval of the T-file in seconds
- `94 8 25 19 0 0.` stop epoch
- `y` 'yes' to transform the orbit to an inertial frame
- `J2000` designation of the inertial frame

`sh_bcfit` will create four files: an earth-fixed T-file (`tprojy.yyy`) obtained by evaluating directly the broadcast elements; an inertial T-file obtained either by rotating this file to an inertial frame (B1950 or J2000); a G-file (`gprojy.yyy`) obtained by interpolating from the inertial T-file for the epoch requested; and a Y-file of satellite yaw parameters.

The G-file consists of two formatted header lines, one or more comment lines, and initial conditions and force parameters for one or more satellites. Shown below is a typical G file:

```
86 279 12 00 00                   GPST B1950 IAUT68 SPHRC
8 X Y Z XDOT YDOT ZDOT DRAD YRAD ZRAD
G-file generated from ebrdc6.279    1-10-1987  18:16:20
ANY OTHER COMMENT LINES
END
PRN 06
-.24748600267000D+05
0.88024642750000D+04
0.47948566210000D+04
-.11532236900000D-01
```

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The first line gives the epoch of the ICs in GPST or UTC (year, day-of-year, hours, minutes, seconds), followed by the time type (GPST or UTC), the inertial frame for the ICs (J2000 or B1950), the precession constant used (IAU76 or IAU68), and the model for non-gravitational ("radiation") accelerations (SPHRC for "spherical" in the example shown (see Section 5.2). The second line gives the number of ICs plus force-model parameter to be read from the G-file. This is followed by one or more comment lines, terminated by END. The initial conditions for each of the satellites are given as Cartesian components of the position and velocity vectors in units of km and km/s. The last three ICs of each group in this example are dimensionless coefficients multiplying the modeled direct solar radiation force (DRAD) and forces along the y- (YRAD) and z- (ZRAD) axes of the spacecraft. The coefficients RAD2 and RAD3 express these forces as fractions of the nominal direct solar radiation force.

2.7 Creating satellite clock (J-) files

In order for model to account properly for clock effects in the phase observations, additional information must be supplied about the behavior of the satellite and station clocks. How these effects are computed and tabulated depends on the level of dithering imposed by selective availability (SA) and whether the ground stations are sampling the phase simultaneously. For normal processing you run makej by typing the name of the program followed by the navigation file and the output J-file name:

```
makej   auto2980.98n  jcalif8.298
```

Alternatively, you can run the program interactively. The first question will ask you to choose the source of the satellite clock information:

```
Choose source of SV oscillator frequency corrections:
1  E-file broadcast message.
2  Second order fit to C-file from site with H-maser
Pick a number.
```

For networks with simultaneous sampling, it is sufficient to create a satellite clock (J-) file using simply the coefficients transmitted in the broadcast message. These can be
obtained from the RINEX navigation file, or the Block 9s of a TI FICA file (see program `ficachop`), from any station that observed for most of the session or from the combined files distributed by IGS analysis centers. Select option 1 at the prompt and then enter in response to prompts the name of the output J-file, the name of the RINEX navigation file or GAMIT E-file (RINEX or FICA format), and the interval at which you want to tabulate the clock values. Once per hour (3600 s) is usually a sufficient interval. If SA is on, then the difference in the signal propagation time to different sites (up to ~10 ms) or, more seriously, several-second differences in the nominal sampling times can introduce significant errors if the oscillator variations are not modelled on the time-scale of the sampling differences. A technique for generating such a model using the phase residuals computed for sites with atomic oscillators is described in *Feigl et al.* [1991] and more extensively in Chapter 2 of *Feigl* [1991]. This option is invoked by selecting 2 at the prompt and is described in more detail in Appendix 4.

Part of a sample J-file is shown below:

```
SV clock corrections written by king   Program:  6.1 of 90/05/18 01:58:50 (apollo)
YR  DOY  HR  MN  SEC(UTC)  WRNO  SOW(GPST)  PRN  XEAF0  XEAF1  XEAF2
(I4,1X,I3,1X,F5.2,3X,I3,1X,F9.2,2X,I2,2X,3D16.8)
1988  311  17  59  55.00  461  64800.00  3   0.39050030E-03 -0.68212103E-12 0.00000E 00
1988  311  17  59  55.00  461  64800.00  13  0.37502684E-03  0.23874236E-11 0.00000E 00
1988  311  18  59  55.00  461  68400.00  3   0.39049797E-03 -0.68212103E-12 0.00000E 00
```

The first line is a header constructed by `makej`, and the second line contains titles to guide the analyst. The third line is a format statement used to read the entries that follow. Each data line contains the coefficients transmitted by the satellite for its own clock. The formula to be used in computing the SV clock offset is

\[ \Delta t_s = t_s' - t_s = a^{(0)} + a^{(1)}(t-t_0^{(c)}) + a^{(2)}(t-t_0^{(c)})^2 \]

where \( t_s' \) is the time read by the satellite's clock and \( t_s \) is "true" GPS time. The coefficients \( a^{(0)}, a^{(1)}, a^{(2)} \) are given in the last three columns (XEAF0, XEAF1, XEAF2) and refer to the reference epoch \( t_0^{(c)} \) given in columns 6 and 7 as GPS week number and seconds of week. The numbers in the first 5 columns give the reference time in GPST.

The J-file is also used by `makex` to generate a K-file of station clock offsets, used in turn by `fixdrv` to generate an I-file of station clock coefficients for `model`.

---

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2.8 Running makex

Program *makex* takes as input the scenario file (*session.info*), station information file (*station.info*), satellite clock (J-) file, navigation file, station coordinates (L-) file, and raw data files (in RINEX or FICA format), and creates X- and K-files for input to *fixdrv* and *model*. K-files, though normally created by *makex* can be re-created later if necessary by program *makek* (Section 2.10).

To run *makex* after running *makexp*, you need type only *makex <control-file>* where <control-file> is the name of a control file with name *expt.makex.batch*, where *expt* is the day of year designating the session to be processed. The control file contains pointers to the input files and a list of station-days to be processed. An example for RINEX input is shown below:

```
infor 1
sesfo 1 ./session.info
rinex 1 /
ficaf 0
coord 1 ../tables/lfile.
stnfo 1 ./station.info
xfile 1 ./x
svclk 1 ./jtrex0.091
clock 1 ./k
extra 0
rdorb 1 ./vndn0911.90n
extra 0
site year doy sn sw ver
(a4,1x,a4,1x,a3,1x,a1,2x,a3,1x,f4.2)
vnd2 1991 091 1 GES 1.9
yknf 1991 091 1 GES 1.9
mojm 1991 091 1 COR 4.8
vndn 1991 091 1 TRM 3.25
```

The first 12 lines indicate which of the input and output files are to be used and the directories in which they reside. The first six columns are not read by the program but provide hints to the users (all lines must be present in the order given). A "1" following the name indicates that the file is to be used (input or output), a "0" that it will not be used. Complete file names are useful for documentation, but if the file (or link) is in the working directory (i.e., the one in which *makex* is being run), an abbreviated filename may be used (see, e.g., the *rinex* and *stnclk* entries above). For the input RINEX or FICA files, no filename is given since *makex* constructs the filename from the station and day names which follow in the input stream. FICA files must be named [*site*]*[y]*.[*day*].fic (note that only the last digit of the year is used, with no session number), and RINEX files [*site*]*[day]*.[*f*].[*yr*]., where *f* is the file sequence number and o indicates that it is an "observation" file. Similarly, for X- and K- files, only the first letter is given. In the above example, if the input data file were FICA, the *rinex* entry would have been "0" and

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".

The first line gives the information file,

Line 13 of the batch input is a comment that provides column headers for the list of station files which follow. Line 14 gives the format for reading the key characters of the site file name. The format shown in the example allows reading of a four-character site code (Vin2), the year (1991), session number (1), and the day number (091). In the current GAMIT release, the session number should always be 0 or 1 (treated equivalently inside GAMIT) since the software does not yet support multiple sessions in the naming of X-files (multiple sessions can be combined by solve in estimation, but that's another story—see Section 3.6). Makex will scan all RINEX or FICA files for data within the span requested in session.info, so you can include within the day directory multiple RINEX filenames with arbitrary session numbers. If you have not used one of the sh_link_rinex scripts and want to have makex search for data, you can specify one or more directories in the rinex or fica lines of the batch file; e.g.,

The receiver software (or firmware) and version in the last two fields of the makex batch input file are required in order to have time tags correctly matched. The 3-character software ID is derived by makexp from the receiver type and software version entered into station.info. Designators for software versions currently supported, and their sampling times are listed in Table 4.1 and documented in subroutine gamit/makex/settim.f. In several cases, we have arbitrarily added an additional digit to the version number in order to distinguish time tags set by the operator.

To run makex, type the program name and enter a batch file name, or use the input file (makex < makex.inp) created by makexp. After completing each station, the program will write to the screen and the .infor file a summary of the observations selected:

```

Good observations per channel : Total Number and Maximum Gap
PRNS  OBS  OBS  OBS  OBS  OBS  OBS  OBS
     6    606 511 419 619 240 395 375
GAPS 0   0    1    2    0    0    0
```

3165 observations written to x-file 35 observations rejected as unreasonable.

The upper chart gives the number of epochs for which there are the given number of satellites. In the example, there are 507 epochs of 4-satellite data. The minimum number
of satellites to be useful is two, since the phases from at least two satellites must be differenced in order to cancel station clock effects.

If no observations were selected, you should check the .infor file to be sure that 1) there are data within the times requested in the scenario file, and 2) the sampling epoch matches that implied by the software version number given in the makex batch file. If there is a change in sample time in the middle of the input file (not unheard of) or if the input file begins and ends before the requested time, you may have to examine the RINEX or FICA file with the editor and/or run the utility ficascan to determine the problem. Renaming the input file test.makex.batch will cause makex to write additional information to the screen, a useful feature if you cannot discern the source of a problem using the procedures already described.

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Table 2.1  Receiver software designations used by MAKEX

<table>
<thead>
<tr>
<th>Receiver</th>
<th>Software</th>
<th>Abbrev.</th>
<th>Version</th>
<th>Sampling time (seconds after the GPST minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TI 4100</td>
<td>GESAR</td>
<td>GES</td>
<td>1.0-1.9</td>
<td>59.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>25.2, 4.1, 4.7, 4.11, 4.12*, 4.13</td>
<td>59.74, 59.08, 59.08, 59.00, 59.08, 59.00, 59.08 and 59.08 in same file, 4.8, 5.7</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>4.12*</td>
<td>59.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>4.13</td>
<td>59.00 and 59.08 in same file</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>4.8</td>
<td>0.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.7</td>
<td>59.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.8</td>
<td>0.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.9</td>
<td>0.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.10</td>
<td>0.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.11</td>
<td>0.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.11*</td>
<td>59.00</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.12</td>
<td>59.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.12*</td>
<td>59.08</td>
</tr>
<tr>
<td>CORE</td>
<td>COR</td>
<td></td>
<td>5.13</td>
<td>59.00, 59.08 in same file</td>
</tr>
<tr>
<td>ROM</td>
<td>ROM</td>
<td></td>
<td>1.11</td>
<td>59.00</td>
</tr>
<tr>
<td>GSM</td>
<td>GSM</td>
<td></td>
<td>1.11</td>
<td>59.00</td>
</tr>
<tr>
<td>MACROMETER II</td>
<td>MAC</td>
<td></td>
<td></td>
<td>59.08</td>
</tr>
<tr>
<td>MINI-MAC</td>
<td>MIN</td>
<td></td>
<td>1.49</td>
<td>0.001</td>
</tr>
<tr>
<td>MINI-MAC</td>
<td>MIN</td>
<td></td>
<td>1.50</td>
<td>0.001 - (GPST–UTC)</td>
</tr>
<tr>
<td>MINI-MAC</td>
<td>MIN</td>
<td></td>
<td>1.59</td>
<td>59.001</td>
</tr>
<tr>
<td>MINI-MAC</td>
<td>MIN</td>
<td></td>
<td>1.61–1.64</td>
<td>0.000</td>
</tr>
<tr>
<td>MINI-MAC</td>
<td>MIN</td>
<td></td>
<td>1.89</td>
<td>59.001 **</td>
</tr>
<tr>
<td>TRIMBLE 4000 SLD,SST</td>
<td>NAV+SIG</td>
<td>TRM</td>
<td>3.11–3.25, 4.1 ff</td>
<td>variable</td>
</tr>
<tr>
<td>TRIMBLE 4000 SST/SSE</td>
<td>NAV+SIG</td>
<td>TRM</td>
<td>3.11–3.25, 4.1 ff</td>
<td>variable</td>
</tr>
<tr>
<td>TRIMBLE 4000 SLD,SST</td>
<td>NAV+SIG</td>
<td>TRM</td>
<td>3.11–3.25, 4.1 ff</td>
<td>variable</td>
</tr>
<tr>
<td>TRIMBLE 4000 SST/SSE</td>
<td>NAV+SIG</td>
<td>TRM</td>
<td>3.11–3.25, 4.1 ff</td>
<td>variable</td>
</tr>
<tr>
<td>TRIMBLE 4000 SLD,SST</td>
<td>NAV+SIG</td>
<td>TRM</td>
<td>3.11–3.25, 4.1 ff</td>
<td>variable</td>
</tr>
<tr>
<td>TRIMBLE 4000 SST/SSE</td>
<td>NAV+SIG</td>
<td>TRM</td>
<td>3.11–3.25, 4.1 ff</td>
<td>variable</td>
</tr>
<tr>
<td>ASHTECH XII, TOPCON</td>
<td>ASH</td>
<td></td>
<td>1.0, 2.0, 6, 7, 8, 9***</td>
<td>0.0</td>
</tr>
<tr>
<td>ROGUE SNR 8</td>
<td>ROG</td>
<td></td>
<td>1.51, 2.30, 2.31 ff</td>
<td>0.0 – (GPST–UTC)</td>
</tr>
<tr>
<td>MINI-ROGUE</td>
<td>ROG</td>
<td></td>
<td>1.11, 1.50, 2.31, 2.4, 5.5, 5.6, 5.61, 6.11, 7.00ff</td>
<td>0.0</td>
</tr>
<tr>
<td>TURBO-ROGUE SNR-8000</td>
<td>TRB</td>
<td></td>
<td>1.0, 2.00–3.20</td>
<td>0.0</td>
</tr>
<tr>
<td>SERCEL TR5S</td>
<td>SRT</td>
<td></td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>SERCEL NR52</td>
<td>SRN</td>
<td></td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>LEICA SR299/399/9500</td>
<td>LEI</td>
<td></td>
<td>2.0ff</td>
<td>0.0</td>
</tr>
<tr>
<td>GEOTRACER 2000/2200</td>
<td>GEO</td>
<td></td>
<td>8.0 (L1), 9.0 (dual)</td>
<td>0.0</td>
</tr>
<tr>
<td>UNAVCO L1</td>
<td>CMC</td>
<td></td>
<td>2.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

* COR 4.12 indicates one of two anomalous frequency plans used during GOTEX and at Yellowknife during March 1990.

** MIN 1.89 indicates MiniMac data sampled at 59.001 but tagged in the RINEX file as 59.000. The time tags are corrected in MAKEX and software version gets changed to 1.59 in XTORX.

***The Ashtech software designations are somewhat arbitrary: 1.0 indicates a codeless receiver; 2.0 the L-XII3 P-code tracking receiver with firmware 7A26; 3.0 the single-frequency GG-XXIV receiver with firmware GM00; 6.0 the L-XII3 with firmware 6Cxx, 6Gxx, 6Ix, or 6Mxx; 7.20 the P-XII3 with firmware 7Bxx; 8.0-9.50 the Z-12; 9.50-9.7x the UZ-12; 9.8 the Z-18; 9.90 the Z-XII3T. (see comments in gamit/makex/settim.f).
2.9 Description of the X-file

A sample X-file created by `makex` is shown below:

GPS Phase & Pseudorange from TI 4100 receivers

MAKEX (Apollo 92-06-01) run on 1991-06-17 16:50:44

GESAR/PHASER HEADER INFORMATION

UNPACK 1.3 of 87/10/06 mill7.007a.fic 1987-10-15 18:04:23

END

COORDINATE FILE INFORMATION

STATION_NAME____   LATITUDE    LONGITUDE   HEIGHT  RCVR  SWVER
_DG MN SS.SSSSS __DG MN SS.SSSSS ____(M).___
MILLER CADT        N34 19 50.33849  W120 13 48.02332 6371422.962 GES 1.0

ANT OFFSETS (M) L1    UP     NORTH   EAST   L2    UP     NORTH   EAST
1.491       0.000   0.000         1.466   0.000   0.000

6 SATELLITES

CHANNEL 1 PRN# 3 NAVSTAR 11 LAMBDA -1 -1 1 1
CHANNEL 2 PRN# 6 NAVSTAR 3 LAMBDA -1 -1 1 1
CHANNEL 3 PRN# 9 NAVSTAR 6 LAMBDA -1 -1 1 1
CHANNEL 4 PRN# 11 NAVSTAR 8 LAMBDA -1 -1 1 1
CHANNEL 5 PRN#12NAVSTAR 10 LAMBDA -1 -1 1 1
CHANNEL 6 PRN# 13 NAVSTAR 9 LAMBDA -1 -1 1 1

DATA TYPES

1 2 3 4

FIRST EPOCH (UTC) GPST-UTC= 4.0

YR DAY HR MN SECS INTERVAL(SECS) DATA INTERVAL SESSION
87 7 6 41 55.080 120 30 1

225 EPOCHS

EPANDED DATA FORMAT STATIC

EPOCH DCB IER CH  L1 PHASE AMP  L2 PHASE AMP  L1 PSEUDORANGE  L2 PSEUDORANGE
1 0

The first group of records (to END) are header lines, accumulated by the succession of programs that have handled the data up to this point. These are followed by the name of the station, its coordinates as read from the L-file, and the antenna offsets read from station.info (or sited.) file. The list of satellites given next specifies the order in which they appear in the X-file (not necessarily the channel assignments in the receiver). DATA TYPES specifies which of the allowable types of observations are present:

1 = L1 phase
2 = L2 phase
3 = L1 P-code pseudorange
4 = L2 P-code pseudorange
5 = L1 C/A code pseudorange

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The **LAMBDA**, or "wavelength" codes given for each channel indicate, for each data type, whether it is ambiguous and whether the ambiguity spacing is full or half wavelength. All phase observables are converted to full wavelength on the X-file.

- 0 = observable is not present for this channel
- -1 = ambiguity spacing is one wavelength (e.g., 19 cm for L1 phase)
- -2 = ambiguity spacing is one-half wavelength
- 1 = no ambiguity
- 2 = no ambiguity (original observable was half wavelength)

The usual value of **LAMBDA** is -1 (code-correlating receivers) or -2 (L2 from codeless receivers) for phase observations, 1 for pseudo-range observations. X-file data are required to be evenly spaced, so the observation times are specified by a start epoch, an observation interval, and the number of epochs. **INTERVAL** is the actual interval on the X-file; **DATA INTERVAL** refers to the raw data file interval (usually the receiver sampling interval) and is used by the editing routines to determine if gaps in the X-file are due to sparse sampling or missing data. The observations at each time are identified by an epoch number, an integer which specifies the number of satellites for which there are data at that epoch, and the GPS time (or UTC prior to Release 9.28). The station coordinates and antenna offsets are repeated at each epoch to allow for kinematic processing. For static processing with a change of antenna height during the session, the X-file will also reflect the change, but values read from station.info during actual processing (by program **model**) override those in the X-file. Then for each channel, there are nine numbers given: a flag indicating the differential code bias (DCB) status (see the description at the top of table **relevant.dat**), a flag indicating whether the data are valid (=0) or have been flagged (set non-zero—see gamit/includes/errflg.h for a key) by other modules; the channel number; the L1 phase (cycles); the amplitude of the L1 signal using RINEX conventions; the L2 phase; the L2 amplitude; the L1 pseudo-range (meters); and the L2 pseudo-range. Note that phases in the X-files are in the "Doppler" convention (increasing phase is decreasing range), and therefore have the opposite sign to phases in the corresponding RINEX files.

2.10 Creating station clock (K- and I-) files

The offset from GPS time (or UTC) of each receiver's clock must be accounted for in modeling the theoretical value of the phase observations at each epoch. If the positions of the receiver and a satellite are known, along with the offset of the satellite's clock, then the pseudorange observation provides a direct measure of the receiver clock offset:

\[
\Delta t_r = \frac{p_1 - \rho}{c} + \Delta t_s
\]

where \(\rho\) is the calculated range to the satellite, \(p_1\) is the observed pseudo-range and \(c\) is the speed of light. Recall (Section 2.1) that an accuracy of about one microsecond in receiver-clock offset is necessary to achieve an accuracy of one millimeter in the

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estimated baseline vector. In order to achieve this accuracy, the computation is performed in *model* using the station and satellite positions (from the L- and T-files) calculated for the theoretical phase observable. In this case, one microsecond (300 m) in the theoretical values is easily achieved. Sufficient accuracy in the measured pseudorange is also achieved easily if P-code range is available. If only C/A code is available, and particularly under conditions of selective availability (SA), some care must be exercised. At present, *model* computes the receiver-clock offset using an average of values calculated from all of the satellites visible at each epoch, detecting and removing anomalous values caused by pseudorange outliers or bad SV clock values.

Strictly speaking, it is not necessary to provide GAMIT with any more information about a receiver's clock than that incorporated in the pseudoranges at each epoch. There are a few practical reasons, however, why it is useful to generate a more explicit model of the receiver-clock behavior at an earlier stage in the processing. Doing so provides a way of detecting poor receiver performance, for example. Also, for receivers with poor and unmodeled clocks numerical problems are sometimes created in *solve* when there are several-hour gaps between observations. Hence we input to *model* tables of coefficients which effectively model these variations. For the receiver clock, *makex* generates an estimate of the offset at an epoch interval of 120s for Ashtech and Trimble receivers, whose clocks reset often, and 600s for other receivers, using satellite elements from the broadcast ephemeris. These estimates are written into the K-file:

<table>
<thead>
<tr>
<th>RDRK</th>
<th>14</th>
<th>1992</th>
<th>73</th>
<th>19</th>
<th>43</th>
<th>53.0000</th>
<th>0.07132594</th>
<th>0.00018337</th>
<th>0.00007289</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDRK</td>
<td>18</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>43</td>
<td>53.0000</td>
<td>0.07109620</td>
<td>-0.00000169</td>
<td>0.00007330</td>
</tr>
<tr>
<td>RDRK</td>
<td>19</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>43</td>
<td>53.0000</td>
<td>0.07405061</td>
<td>0.00000424</td>
<td>0.00007332</td>
</tr>
<tr>
<td>RDRK</td>
<td>14</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>45</td>
<td>53.0000</td>
<td>0.07153746</td>
<td>0.00018337</td>
<td>0.00001910</td>
</tr>
<tr>
<td>RDRK</td>
<td>18</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>45</td>
<td>53.0000</td>
<td>0.07095191</td>
<td>-0.00000169</td>
<td>0.00001955</td>
</tr>
<tr>
<td>RDRK</td>
<td>19</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>45</td>
<td>53.0000</td>
<td>0.07389223</td>
<td>0.00000424</td>
<td>0.00001934</td>
</tr>
<tr>
<td>RDRK</td>
<td>14</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>47</td>
<td>53.0000</td>
<td>0.07175308</td>
<td>0.00018337</td>
<td>0.00006434</td>
</tr>
<tr>
<td>RDRK</td>
<td>18</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>47</td>
<td>53.0000</td>
<td>0.07080949</td>
<td>-0.00000169</td>
<td>0.00006493</td>
</tr>
<tr>
<td>RDRK</td>
<td>19</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>47</td>
<td>53.0000</td>
<td>0.07373656</td>
<td>0.00000424</td>
<td>0.00006463</td>
</tr>
<tr>
<td>RDRK</td>
<td>14</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>49</td>
<td>53.0000</td>
<td>0.07197269</td>
<td>0.00018337</td>
<td>0.00008099</td>
</tr>
<tr>
<td>RDRK</td>
<td>18</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>49</td>
<td>53.0000</td>
<td>0.07066900</td>
<td>-0.00000169</td>
<td>0.00009050</td>
</tr>
<tr>
<td>RDRK</td>
<td>19</td>
<td>1992</td>
<td>73</td>
<td>19</td>
<td>49</td>
<td>53.0000</td>
<td>0.07358361</td>
<td>0.00000424</td>
<td>0.00009035</td>
</tr>
</tbody>
</table>

The first column gives the station code, followed by the satellite PRN number, year, day of year, hours, minutes, and seconds (always UTC). The eighth column is the observed pseudo-range to the satellite at the time given, in units of seconds, followed by the offset of the satellite clock (from GPS time) computed from the transmitted clock corrections. The final number is the receiver clock correction computed using the formula above.

Any differences in receiver clock values computed using the data from different satellites at the same time are due to errors in the pseudo-range measurements, the satellite clock models, or the geometrical models (station coordinates and satellite ephemeris). In the above K-file, for example, the corrections computed at 19h 43m 53 s using data from satellites 14, 10, and 19 differ by up to 0.4 microseconds, equivalent to a radial position error of 120 meters (probably due to errors in the broadcast ephemeris). Differences between receiver clock values computed for a given satellite at different times could reflect model errors but are usually dominated by actual receiver clock drift. In our
example, there is a change between 19h 43m and 19h 45m of 54 microseconds, indicating a drift in the receiver oscillator of 4.5 parts in $10^7$ ($54 \times 10^{-6} / 120$). This high drift rate is typical of the crystal oscillators in many of today's lightweight receivers (the above example was a Trimble 4000 SST). More stable (thermally controlled) crystals can achieve stabilities of 1 part in $10^8$ (TI 4100) or better (Macrometer II). Rubidium, cesium, or hydrogen-maser oscillators can achieve even higher stabilities ($10^{-11}$ to $10^{-15}$).

The ~1 ms jump in clock value at 19h 47m 53.s is a feature of the Trimble 4000 SST and Ashtech P12 receivers, indicating that the clock has been reset to keep it within 1 ms of the nominal sampling time. Both the recorded sampling time and the pseudorange measurement will show a discontinuity of exactly 1 ms. Some RINEX translators can be set to remove the discontinuity at translation, but this is not necessary since `model` will account for it in its epoch-by-epoch estimate of the receiver clock offset, and `fixdrv` will remove the discontinuities in fitting the low-order polynomial used in modeling the phase observations.

It is possible to have anomalous ("bad") values in the K-file—computed clock offsets that are many milliseconds off due to bad pseudorange measurements. The presence of these anomalous blunder points will be indicated by very large residuals (> 500 microseconds) in the polynomial clock fit done by `fixdrv`. You can tabulate and plot the fit residuals using the script `sh_plotk`, but usually the quickest way to find the problem is just to scan visually the last column of the K-file; most often the bad values are among the first few of the session. If `sh_plotk` or the polynomial fit in `fixdrv` shows the clock behavior to be bad, and you determine that the problem is not a bad K-file, then you should proceed but be on the alert for a problem with this station in the analysis. Rapidly drifting clocks are more likely to cause an abnormal number of cycle slips (see the `autcln.sum` file, described in Section 4.2). Large jumps in the clock or rapid drift accompanied by several-hour gaps in the data may cause the residuals to get large, introducing numerical problems in `solve`. The best remedy for this is to use the `apply_phase_clk` option in `autcln` (see Section 4.2).

`Fixdrv` will read the K-file for each site and create a session I-file, similar to the J-file for satellite clocks, tabulating the coefficients of a low-order polynomial for each receiver's clock. If you want to recreate a K-file after running `makex`, you can do so easily by running `makek`, which will prompt you for the name of input navigation, L-, and X-files and for the tabulation interval.
3. Batch Processing

3.1 Introduction

Batch processing is accomplished by invoking sequentially and with appropriate input files the GAMIT modules that perform the required computations. The command or "batch" files to invoke the modules are created, for each standard type of analysis, by program fixdrv. The batch run set up by fixdrv would typically go through the following steps:

- generation of an orbital ephemeris with partials (arc)
- generation of residuals and partials (model)
- automatic edit of residuals (autcln)
- solution (cfmrg/solve)
- regeneration of residuals and partials with an improved model (model)
- automatic edit of residuals (autcln)
- solution (cfmrg/solve)

The double pass through model, autcln, and solve serves two purposes: 1) the model obtained from the first solution can be used to flatten the residuals, allowing for improved editing and also the display of post-fit (one-way) residuals for evaluation; 2) adjustments to station coordinates are reduced to a few centimeters, assuring that non-linearities do not degrade the final estimates. In most cases, the results of processing can be assessed through inspection of the print output (Q-file) of the final solution and the data statistics compiled by autcln (autcln.sum.post). (These values are echoed in the sh_gamit_[day]summary file and mailed to you by sh_gamit.) If there are problems, then one or more steps of the batch job can be run individually, or fixdrv (and occasionally makexp) can be run to repeat the complete processing sequence.

If you have prepared the data in a "day" directory as described in Chapter 2, then you should have available as files or links all of the tables necessary to run fixdrv and to execute the GAMIT batch run: station and scenario tables (station.info and session.info), ephemerides (G- and T-files), raw observations (X-file), satellite and station clock values (J- and K-files), a priori station coordinates (L-file), lunar and solar ephemerides (luntab. and soltab.), and tables for earth rotation values (nutabl., ut1., and pole.), TAI-UTC (leap.sec), geodetic datums (gdetic.dat), ocean tides (stations.oct and grid.oct), antenna phase-center offsets or models (antmod.dat), receiver and antenna names (rcvant.dat), and satellite yaw parameters table (svnav.dat). Three additional files are needed: the list of X-files to be processed (D-file), and control tables for the analyses (sestbl. and sittbl.) These can be easily created from templates (from gamit/example), as described below. If you have used makexp for data preparation, you will have already a D-file. If you are using sh_gamit (see Chapter 10), all of these steps will be performed automatically.
3.2 Running fixdrv

Fixdrv has three primary inputs: 1) a D-file containing the names of the satellite ephemeris (T-), clock (I- and J-), and observation (X- or C-) files to be used; 2) a session control table (sestbl.) containing analysis commands; and 3) a site control table (sittbl.) specifying a priori constraints for coordinates and station-specific models.

An example of a D-file (named dvent7.278) is given below, with comments added at the right:

1 number of solutions
2 number of sessions
lvent7.278 L-file for all sessions
tvent7.278 T-file for all sessions
ivent7.278 I-file for all sessions (end of global files)
jvent7.278 J-file for session 1
3 number of stations (x-files) in session 1
xcato7.278
xsafe7.278
xlove7.278
jvent7.279 J-file for session 2
2 number of stations (x-files) in session 2
xcato7.279
xsafe7.279

The integer on the first line gives the number of independent solutions to be performed; if greater than one, it indicates that you have concatenated essentially independent runs for serial processing. The integer on the second line indicates the number of sessions in this solution; in the example the data from two sessions (days) are to be used simultaneously to estimate the station coordinates and orbital parameters. With widespread use of GLOBK, GAMIT runs involving more than one session or solution are rare, so in most cases the first two lines of the D-file will each contain "1" and the last four lines shown above will be omitted. Lines 3–6 contain the name of the coordinate (L-) file to be read, the ephemeresis (T-) file to be read or created, and the name of the I-file to be read or created. The I-file is now optional and can be left blank or set to 'NONE' if you don't have K-files readily available from which to calculate clock rates. In this case, you must specify 'Use I-file = N' in the sestbl. (see below). The use of an I-file is recommended because modeling of the dominant drift in the receiver clock minimizes the danger of numerical problems in solve due to large jumps across gaps of several hours. For each session there is the name of the satellite clock (J-) file to be used, an integer giving the number of stations, and the names of all of the X-or C-files for that session. The names of other files to be read or created are assigned by fixdrv: the G-filename from the T-file name; the K- and P-file names from the X- (or C-) file name; and the H-, M-, O-, Q-, and V-file names from the D-file name.
A session control table (\texttt{sestbl}) with only the required and commonly used entries is shown below. (See Table 3.1 for a complete list of entries.)

Session Table

Processing Agency = MIT

Choice of Experiment = RELAX. ; BASELINE/RELAX./ORBIT

Satellite Constraint = Y/N (next two lines are free-format but 'all' must be present) all a w e i n w M radi1 rad2 rad3 rad4 ... rad9;

Choice of Observable = LC_AUTCLN ; L1_SINGLE/L1&L2/L1ONLY/L2 ONLY/LC ONLY/

Type of Analysis = 1-ITER ; 1-ITER/0-ITER (no postfit autcln)/PREFIT

Use N-file = Y ; Y/N (default no): automatic procedure to reweight by station

Decimation Factor = 4 ; For solve, default = 1

Quick-pre observable = LC ; No ambiguity resolution for 1st solution

Quick-pre decimation factor = 10 ; Decimate severely in 1st solution

Delete AUTCLN input C-files = Y ; Y<es>/N<o>; default Y

Zenith Delay Estimation = Y ; Y<es>/N<o> (default no)

Interval zen = 2 ; Interval in hrs between zenith delay parameters

Atmospheric gradients = Y ; Y<es>/N<o> (default no)

Met obs source = GPT 50 ; Hierarchical list: RNX ufile GPT/STP [humid value] ' to match 10.2, use STP 50; new default is GTP 50

Output met = N ; Write the a priori met values to a z-file (Y/N)

Antenna Model = ELEV ; Model for antenna PCVs NONE/ELEV(default)/AZEL

Tides applied = 31 ; Binary coded: 1 earth 2 freq-dep 4 pole 8 ocean

Etide model = IERS03 ; IERS96/IERS03(default)

Use otl.grid = Y ; Read ocean tidal loading from a grid

Apply atm loading = N ; Y/N for non-tidal atmospheric loading

Use atm.list = N ; Read atmospheric loading from a list (overriding grid values)

Use atm.grid = N ; Read atmospheric loading from a grid

Estimate EOP ; Binary coded: 1 wob 2 ut1 4 wob rate 8 UT1 rate; default 15

Wobble Constraint ; [pole] [pole rate] default = 3. 0.3 (arcsec) (arcsec/day)

UT1 Constraint ; [UT1] [UT1 rate] default = 0.00002 0.02 (sec) (sec/day)

Ambiguity resolution WL = 0.15 0.15 1000. 10. 500. ; Defaults; ignored for LC_AUTCLN

Ionospheric Constraints = 0.0 mm + 1.00 ppm ; ignored for LC_AUTCLN

Ambiguity resolution NL = 0.15 0.15 1000. 10. 500. ; Defaults

Update tolerance = 0.3 ; Min. adj. for updating L-file coordinates, default .3 m

Scratch directory = /tmp ; Directory for scratch files (default /tmp)

Each command is recognized by the keywords at the beginning of the line. They must begin in column one (\textit{note difference from globk command files}) and be spelled out completely and correctly but are not case sensitive. The keyword answer must begin exactly one space after the equal sign. The order of the commands in the files is not important except for the satellite constraints, which must follow the Satellite Constraint keyword. After the semi-colon on each line is a summary of keywords for all the options available. These are simply comments in the session table.

In the example shown, the first input is a 3-letter code for the analysis group. This is required in order to force identification of a solution on the h-file.

Next, the user specifies how orbits are to be handled. With \texttt{Choice of Experiment = RELAX}, orbital parameters are estimated, and the \textit{a priori} constraints should be set by
including the parameter identifying header following either by a single line beginning
with all, or a series of lines listing the constraints for each satellite

<table>
<thead>
<tr>
<th>Satellite Constraint = Y</th>
<th>; Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>ch#</td>
<td>a</td>
</tr>
<tr>
<td>NO.1 =</td>
<td>0.01</td>
</tr>
<tr>
<td>NO.2 =</td>
<td>0.01</td>
</tr>
<tr>
<td>. . .</td>
<td></td>
</tr>
<tr>
<td>NO.30 =</td>
<td>0.01</td>
</tr>
</tbody>
</table>

In both examples, there should be entries for 9 non-gravitational force ("radiation-
pressure") parameters (only 5 are shown because of the limited page width). The
constraints are given in parts per million (ppm) for the initial conditions and percent
for the non-gravitational force parameters (in contrast to GLOBK which expects m and m/s
for initial conditions and a fraction of unity for the non-gravitational force parameters).
The values shown (0.01 ppm or 20 cm for initial conditions, 5% for the direct radiation-
presssure and y-bias coefficients, and 1% for the third axis coefficient and the once-per-
rev parameters) are roughly appropriate for SOPAC or IGS orbits since late 1994. For
recent IGS orbits and regional networks, you may wish to fix the orbits by setting Choice
of Experiment = BASELINE, in which case the constraints are ignored. The orbital
constraints to be applied are one of most important decisions you have to make in setting
up the analysis. In deciding upon constraints, remember that solve will perform two sets
of solutions—one ("constrained" or "tight") which uses directly the input constraints and
one ("loose") which uses hard-wired, loose constraints (10 ppm). The "tight" solution is
displayed in the Q-file, used for updating the L- (station-coordinate) and G- (orbital
parameter) files and for writing the M-file of parameter adjustments that is used for
scanning and manually editing the post-fit residuals. If you are not using GLOBK, this
GAMIT-produced "tight" solution provides the final estimates of parameters. The
"loose" solution is not displayed in the Q-file (except for its constraints and statistics, at
the bottom), but is written into the H-file for input to GLOBK. If you are using GLOBK
for your final analysis, you set the orbital (and station) constraints there, and the GAMIT
settbl values have no direct effect on the GLOBK solution. They can have an important
indirect effect, however, since resolution of phase ambiguities ("bias-fixing") is
performed by solve as part of the constrained solution, with the resolved integer values
carried forward to the loose solution. So in deciding what values to use in the settbl for
orbital constraints, you need to consider both the expected accuracy of your a priori orbit
and the strategy you plan to use for your analysis. Moreover, you will probably want to
perform several different analyses, using chi-square, coordinate uncertainties, and
success in resolving ambiguities to determine the optimal value of the orbital constraints
for the GAMIT solution. See Section 3.4 below for further discussion.

The seven command lines beginning with Choice of Observable establish the basic
structure of the batch run:

Choice of Observable = LC_AUTCLN means that the observable is the ionosphere-free linear combination ("LC" or "L3") and that the final solve solution uses assignment of ambiguity parameters (site/sat combinations) and the resolution of widelane (WL) ambiguities made by autcln using the pseudoranges, a new feature in Release 10.2 and the current default. An alternative, default prior to 10.2, is for solve to resolve the
widelane phase ambiguities using both an ionospheric constraint and pseudorange data if available. With modern receivers using P-code for both the L1 and L2 ranges, the new scheme will almost always work better, particularly for long baselines. With cross-correlating receivers, satellite-dependent range biases between C1 and P2 can lead to poor or incorrect resolution of the widelane ambiguities, so some care should be exercised or you should adopt a more conservative approach and use ionospheric constraints (LC_HELP). For networks extending over less than a few kilometers, you can set Choice of Observable = L1,L2_INDEPEND to use the L1 and L2 phase observations directly, an approach that will result in smaller measurement noise as long as the ionospheric contribution is negligible. For orbit determination with only widely spaced stations, setting Choice of Observable = LC (no ambiguity resolution attempted) will save computation time.

The next command controls the number of passes through model, autcln, and solve to obtain a final solution. The preferred approach is Type of analysis = 1-ITER, which (usually) results in two passes through model, autcln, and solve, the first to obtain a preliminary solution (written the Q-file named with 6th character “p”) that serves to get coordinate and orbital parameters close to their final values, thereby flattening the residuals for editing and reducing errors from large adjustments (see Section 2.3). In the first pass autcln operates on prefit residuals, and in the second one uses the adjustments written on the M-file by solve to perform a "postfit" edit. Since in postfit editing autcln estimates clock parameters, this mode allows you to see and compute statistics of the one-way residuals for individual stations (rather than just double differences), which can be especially helpful for characterizing station performance, weighting the data for each station appropriately, and understanding problems in the solution. Reweighting is invoked by setting Use N-file = Y, which causes script sh_sigele to read the noise characteristics from autcln.post.sum and write them into the N-file read by solve. The 1-ITER option also creates batch commands for a third solution if the quality of fit improves significantly between these two solutions (ratio of nrm values > 1.5), thus assuring linear adjustments in the final solution. The second (or third) solution is written into the Q-file named 6th character “a”. To override the check on nrm and possible third solution, add the command AUTCLN Postfit = Y, replacing the implicit AUTCLN Postfit = R (for “redo”). To perform only a prefit cleaning (without clock correction) and a single final solution, set Type of analysis = 0-ITER. Note that with 1-ITER you need to specify appropriate postfit controls in the autcln.cmd file, described in Section 4.2.

The remaining commands of this block serve to control computational cost of the run. Since the phase observations are temporally correlated, it is not necessary to use a sampling interval for the solution as small as that used for cleaning the data. If the data used for cleaning are sampled at 30s intervals, using every 4th epoch (120s) provides a robust (and probably still over-sampled) solution. In the standard 1-ITER approach, the preliminary solution need be only approximate, so we save time by reducing even further the number of observations read by solve (factor of 10 in the case shown) and skipping ambiguity resolution (Quick-pre observable = LC). The final entry in this group is used to control whether the C-files created by model and read by autcln are saved or
regenerated. To take full advantage of the iterative scheme, you should set `Delete AUTCLN input C-files = Yes`. This option is also most conserving of disk space but will increase run time a small amount compared with the saving the initial C-files temporarily (Intermediate) or permanently (No). Unless you suspect a problem with `autcln` and want to examine all the input and output C-files, there is no need to elect this last option.

The most appropriate way of handling the atmosphere depends on the size of the network and the accuracy desired. For networks less than a few kilometers in extent, the atmospheric delay effectively cancels between stations, so you do not want to estimate any atmospheric parameters. For larger networks, you should estimate one or more zenith delay parameters for each station (`Zenith Delay Estimation = Y`). The zenith delay parameters for regional stations will be highly correlated, but there is sufficient precision in the estimation algorithm that these high correlations will not degrade your estimates of station coordinates and the differences in zenith delay between stations will be well determined. (If you wish to see in the output the uncertainty of the differences, then you can add tight constraints to one of the zenith delays in the `solve` batch file; see Section 5.5). The default is to estimate a single zenith delay for each station with an a priori constraint of 0.5 meters. You may allow a variation in the zenith delay during the observation span by specifying a piecewise-linear model with stochastic constraints. You can set the number of “knots” in the model explicitly with the `Number Zen` command, or implicitly (as shown) by specifying the knot spacing in hours with the `Interval Zen` command. For example, for a new value every 3 hrs of a 24-hr session, you could set `Number Zen = 9` or `Interval Zen = 3`. A knot spacing between 1 and 4 hours is reasonable for most situations, the trade off being resolution versus program size and run time. The allowed variation between tabular points in the estimation is defined by a Gauss-Markov process with a default value of 0.02 m / √hr. The default correlation time is set to 100 hr, making the process effectively a random walk. Specification of these parameters is documented in Table 3.1 and discussed further in Section 7.3. With Release 10.2, the average zenith delay for the session is estimated separately and written into the H-file for GLOBK, and the parameters of the piecewise-linear model represent differences from the average. (In the O-file, used for post-processing of atmospheric parameters, the average zenith delay is omitted and the estimates and uncertainties of the parameters of the piecewise-linear function represent the total, as with earlier releases.) You can also estimate, as a constant or piecewise-linear function, a north-south and an east-west gradient in atmospheric delay, given as the differences in meters at 10 degrees elevation (see Section 7.4). The next entry specifies the a priori model used for the zenith delay. With Release 10.3, this is now the “global pressure and temperature” (GPT) model developed by Johannes Boehm (REF). It generates surface pressure and temperature values as a function of location and time of year based on a spherical harmonic fit to 20?? Years of meteorological data, and reduces biases in height estimates compared with adopting standard temperature and pressure (STP) for all stations at all times. GPT (or STP) is followed by a number setting the a priori wet delay using relative humidity (%). If you have available actual meteorological data from some or all stations, they will be used if you list `RNX` (RINEX met file) first after the equal sign. Similarly, by including `ufile` in the list, you can use values from

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the U-file written by *grdtab* from a global grid or station list. The final atmospheric entry allows you to the *a priori* values used for each satellite and epoch into a Z-file for each station. This file is read by *sh_metutil* to generate values of precipitable water vapor for meteorological studies. It is not necessary for geodetic analyses. Note that elevation cutoff for observations is now specified solely in the *autcln.cmd* file.

Antenna Model and SV antenna model refer to the use a tabular model (antmod.dat) for receiver and satellite phase center variations (PCVs). For large-scale or global analyses or with mixed antenna types in any size network, an elevation-dependent model (ELEV) for the ground antenna is important. For global analyses, the new (2006) absolute PCV models for both ground and satellite antennas should be used. For small regional networks with matched antennas, a PCV model may not be

The next group of entries prescribe the models used for the time-variable displacements in station coordinates due to tides and non-tidal atmospheric loading. *Tides applied* is a binary-coded variable allowing you to easily select any combination you want to use or test. The first (1) and second (2) bits control the IERS/IGS standard models for diurnal and semi-diurnal solid-Earth tides and should always be set. The default is now the IERS 2003 model [McCarthy and Petit, 2004]. The third (4) and fifth (16) bits control the pole tide, the 4-bit turning these on and the 16-bit removing a mean values according to IERS standards. Both bits should be set if your final solution will come from GAMIT and not GLOBK. If you plan to use GLOBK, the setting doesn’t matter because the pole tide has only long-period (primarily annual and 460 days) effects on station coordinates and can be added by GLOBK. (GLOBK will detect whether it has been applied in GAMIT and apply it or not, as instructed, to make the H-files from different processing compatible.)

The most complicated part of the tide model is loading due to ocean tides because this effect must be computed (external to GAMIT) using a convolution of a model of the ocean tides themselves and the geometry of the land-sea interface. With assistance from Hans-Georg Scherneck of Chalmers University (Sweden) and Koji Matsumoto of the National Astronomical Observatory (Japan), a variety of models are available to GAMIT users (see http://www.oso.chalmers.se/~hgs for more details). To apply ocean tidal loading, set the 4th (8) bit and also set *otl.list* and/or *otl.grid* to *Y* to use a list by stations of OTL components or to interpolate components from a global grid. This setting will command *grdtab* to read a list or grid file and write the components for each station in the session into the U-file for *model*. If both a list and grid file are available, *grdtab* will first look for a station within 10 km of a station in the list file before reverting to the grid. The actual model used is selected by linking these hard-wired file names to files available in *gg/tables* (e.g. *otl_FES2004.grid* or *otl_NAO99B.grid*). The sixth (32) bit of the *Tides applied* entry is reserved for (heat-driven) diurnal and semi-diurnal tides, which are not yet available. However, with Release 10.2 we have incorporated code developed by Paul Tregoning of Australian National University to include non-tidal atmospheric loading corrections based on global pressure data tabulated on a spatial grid at 6-hour intervals. This model is invoked by setting the *Use atml.grid* entry to *Y* and linking this file name to a file valid for the year you are processing (e.g. *atmdisp_cm.2003*). (See the ATML_NOTES file in the GAMIT/GLOBK distribution directory.)

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By default corrections to Earth rotation parameters are estimated for each session \((\text{Estimate EOP} = 15)\). If your solution includes 24-hr tracking from a global set of stations, then you can estimate well pole ("wobble") position and UT1 rate but not a UT1 offset since this is perfectly correlated with the nodes of the satellites' orbits. In order to have a full covariance matrix available for GLOBK, however, it is preferable (and necessary in versions prior to January, 1995) to turn on all six EOPs but with tight constraints on the UT1 offset in the GAMIT solution. The default constraints for UT1 rate and pole position and rate are rather loose, so these should be tightened to match the uncertainty in your a priori tables (~ 0.0001 sec/day, 0.001 arcsec, 0.0005 arc/day for IERS Bulletin A or B finals) if you have only a regional network and want to assess carefully the results of the GAMIT analysis.

The next group of entries controls resolution of phase ambiguities in the solution. Unfortunately, no GPS analysis group or software package (to our knowledge) has automated ambiguity resolution to the point where you can uncritically apply a particular algorithm to all situations. The default settings are fairly conservative and work reasonably well for most networks. Tuning the algorithm for your particular network and evaluating the results is discussed in Section 3.4.

The final to entries apply to \textit{solve}. Update tolerance controls whether or not station coordinates are updated between the preliminary and final solutions. The default is 30 cm, assuring that no adjustments greater than this (and hence subject to errors from non-linearity) occur in the final solution. You may want to see it larger, however, for tests when you want to directly compare adjustments from several days. The entry allows you to write the temporary solution matrices somewhere other than your system /tmp directory, which may not be large enough to accommodate them.

There are a number of optional entries in the \texttt{sestbl} that may be invoked for special cases and to exercise greater control over the processing. These are summarized in Table 3.1 and further discussed below.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|}
\hline
\textbf{Processing Agency} & \textbf{0-ITER: ARC (optional), MODEL, AUTCLN, SOLVE} \\
\textbf{Station Number} & \textbf{1-ITER: Two sequences of 0-ITER (default)} \\
\textbf{Satellite Number} & \textbf{Data Status} \\
\textbf{Station Constraint} & \textbf{RAW: Include AUTCLN before each SOLVE run} \\
\textbf{Satellite Constraint} & \textbf{CLEAN: Do not include AUTCLN in the processing sequence} \\
\hline
\textbf{Analysis controls} & \textbf{Choice of Observable} \\
& \textbf{LC_AUTCLN: Ambiguity-free and ambiguity-fixed solutions with LC} \\
& \textbf{LC_HELP: Same as LC_AUTCLN but with using ionospheric constraints} \\
& \textbf{LC_ONLY: Ambiguity-free solution with LC} \\
& \textbf{L1ONLY: Ambiguity-free and ambiguity-fixed solutions with L1} \\
& \textbf{L2ONLY: Ambiguity-free and ambiguity-fixed solutions with L2} \\
& \textbf{L1,L2_INDEPEND: Ambiguity free and fixed solutions with L1 & L2} \\
\end{tabular}
\caption{Summary of \texttt{sestbl} entries}
\end{table}

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Choice of Experiment

RELAX: Include station, orbital, and Earth-rotation parameters
BASELINE: Do not include orbital or EOP parameters

Data weighting

Station Error

UNIFORM [sigma] : Weight all phase data equally, [sigma] = L1 or L2 in mm, default = 10.
BASELINE [a] [b] : Weight proportional to baseline length [var] [tau] : Variation and correlation parameters in Gauss
ELEVATION [a] [b] [elev] : Weight by elevation angle; 1-way
Satellite Error

UNIFORM [sigma] : Satellite error added quadratically to station error; default = 0.

Use N-file

YES : Reweight the data in the final solution using the ELEVATION model with coefficients estimated by AUTCLN in postfit editing

Ambiguity Resolution

Ionospheric Constraints

0.0 mm + 1.00 ppm [see below and Section 5.5]

Ambiguity resolution WL default = 0.15 0.15 1000. 10. 500. [see below]

Ambiguity resolution NL default = 0.15 0.15 1000. 10. 500. [see below]

Atmospheric Parameters

Zenith Delay Estimation

Yes/No to estimate zenith delay parameters; default = No

Number Zen

Number of zenith-delay parameters per station; default = 1

Interval Zen

Interval in hours between zenith-delay parameters (use instead of Number Zen)

Zenith Model

PWL: Piecewise-linear (default for Number Zen > 1)
CON: Constant from time of knot (i.e., step model)

Zenith Constraints

Overall a priori constraint in m; default = 0.5
[var] [tau] : Variation and correlation parameters in Gauss

Markov model; default = 0.02 m/sqrt(hr) and 100 hrs.

Atmospheric Gradients

Yes/No to estimate a N-S and E-W gradient; default = No

Num Grad

Number of E-W or N-S gradient parameters in PWL model; default = 1

Gradient Constraints

Gradient at 10 deg elevation in meters; default = 0.03 m
Hierarchical list: RHX ufile GPT/STP [humidity value] to match 10.2, use STP 50; new default is GTP 50

Dmap

Hydrostatic mapping function GMFH (default) NMFH / VMF1

WMap

Wet mapping function GMFW (default) / NMFW / VMF1

Use map.grid = N

Read mapping function coefficients from a grid

Use map.list = N

Read mapping function coefficients from a station list

Use met.grid = N

Read met data from a grid

Use met.list = N

Read met data from a station list

Tropospheric Constraints

YES/NO: Spatial constraints, default = No (see Sec 8.3)

Orbit parameters

Initial ARC

YES: Re-integrate the final estimated ICs
NO: Use existing T-file (default for BASELINE)

Final ARC

YES: Use existing T-file (default for RELAX)
NO: Suppress re-integration of the final estimated ICs (default)

Inertial frame

B1950: Old T-file and SOPAC frame

Radiation Model for ARC

BERNE: 9-parameter model (GAMIT and SOPAC default)
BERN1: same as BERNE but with AIUB 1997 non-adjustable terms
BERN2: 6-parameter AIUB 1997 model
SPRHC: 3-parameter model (old GAMIT and SOPAC default)
SRDYB: same as BERNE but with no once-per-rev terms added
SVY52: 3-parameter direct y/z model with ROCK4 x/z terms added
SVYXY3: 3-parameter x/y/z model with ROCK4 x/z terms added

Reference System for ARC

IGS92: Gravitational constants from IGS 1992 standards (default)
WGS84: Gravitational constants from WGS84 standards (BC ephemeris)

Tabular interval for ARC

Output interval on T-file in seconds; default = 900.

Stepsize for ARC

Integration stepsize in seconds; default = 75.

Export Orbits

YES/NO: Create or not an Earth-fixed SP3 file for export (def = No)

Orbit id

4-char code for export orbit

Orbit Format

SP1/SP3 (NGS Standard Products), default = SP3

Orbit organization

3-char code for processing agency for export orbits

Reference System for Orb

5-char code for Earth-fixed reference system for export orbits

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**MODEL parameters**

- **Antenna Model**
  - NONE: No model for phase-center variations
  - ELEV: Elevation-dependent model in antmod.dat (default)
  - AZEL: Elevation- and azimuth-dependent model in antmod.dat

- **Tides applied**
  - 31: Binary coded: 1 earth 2 freq-dep 4 pole 8 ocean
  - 16: remove mean for pole tide
  - 32: atmosphere; default = 31

- **Etide model**
  - IERS96/IERS03 (default)

- **Use otl.grid**
  - Y: Read ocean tidal loading from a grid

- **Use otl.list**
  - N: Read ocean tidal loading from a list (overriding grid values)

- **Use atm1.list**
  - N: Read atmospheric loading from a list (overriding grid values)

- **Use atm1.grid**
  - N: Read atmospheric loading from a grid

- **Yaw Model**
  - SV yaw used from svnav.dat; YES/NO default = YES

- **Use I-file**
  - Reference clock polynomial; YES/NO default = YES

**SOLVE parameters**

- **Estimate EOP**
  - Binary coded: 1 wob 2 ut1 4 wob rate 8 UT1 rate; default 15

- **Wobble Constraint**
  - [pole] [pole rate] default = 3.0 0.3 (arcsec) (arcsec/day)

- **Select Epochs**
  - [start] [stop] default = 0.00002 0.02 (sec) (sec/day)

- **Decimation Factor**
  - Default = 1 (no decimation)

- **H-file solutions**
  - LOOSE-ONLY: Write only the loose solutions on the H-file (default)
  - ALL: Write both the constrained and loose solutions on the H-file

- **Correlation print**
  - Threshold for printing parameter correlations (default 0.9999)

**Cleaning parameters**

- **AUTCLN Command File**
  - Default none

- **Quick-pre observable**
  - Options same as Choice of Observable; set = LC to save time

- **Quick-pre elevation cutoff**
  - Set lower to see low-el residuals flatter in AUTCLN postfit

- **AUTCLN Postfit**
  - POST: Add delete commands for 30 min after eclipse (default)

- **Delete eclipse data**
  - NO: Do not delete data during or after eclipse.

- **SCANDD control**
  - BOTH: Run SCANDD after each solution
  - FIRST: Run SCANDD only after the quick solution
  - FULL: Run SCANDD only after the full solution

- **Run CTOX**
  - Default = NO

**File handling**

- **X-compress**
  - Uncompress/compress X-files default = NO

- **Delete all input C-files**
  - Y/N default = N

- **Delete MODEL input C-files**
  - Y/N default = N

- **Delete AUTCLN input C-files**
  - Y/N/Intermediate default = Y

- **Update T/L files**
  - T_AND_L (default), T_ONLY, L_ONLY, NONE

- **Update tolerance**
  - Minimum adjustment for updating L-file coords, default 0.3 m

- **Run CTOX**
  - Make clean X-files from C-files default = NO

**Analysis controls.** The Type of Analysis, as discussed above, is almost always 1-ITER now that there is iteration on station coordinates using AUTCLN Postfit. Among the Choice of Observable selections, the only one not already explained is L1&L2. With this choice ambiguities are resolved simultaneously for L1 and L2 (as in the L1,L2_INDEPEND option) but with an ionospheric constraint which remains in the final solution. This option has not been recently tested and so should be used with caution. Choice of Experiment is discussed above.

**Data weighting.** For analysts who wish to experiment with non-uniform weighting of the phase data, several options are available. If you are not estimating orbital parameters and expect a non-negligible contribution from orbital errors, you may wish to weight the data.
observations according to baseline length, as described by Bock et al. [1986] —see references in the Introduction to GAMIT/GLOBK. In this case you specify Station error = BASELINE a b, where a is the constant component in mm and b the baseline-length component in parts per million; the two terms are combined quadratically. A second (and mutually exclusive) approach is to assign errors according to elevation angle: Station error = ELEVATION a b, where a is again a constant and b^2 multiplies a term inversely proportional the sine of the elevation angle. The default values (4.3 and 7.) are chosen (rather arbitrarily) such that an observation at 40° (the median elevation of a typical session at mid-latitudes) has the same weight as with UNIFORM option with the one-way L1 sigma equal to 10 mm, and an observation at 20° has half the weight. This option can be invoked on a station-by-station basis by editing the solve batch file (see Section 5.5) but can only be invoked uniformly for all stations from the sestbl. The most powerful and now recommended option is to weight the data by elevation angle based on the actual scatter of the residuals from each station. This option is implemented via the N-file in which the coefficients a and b of the ELEVATION model have been estimated by autcln from postfit editing. To invoke this option, Type of Analysis = 1-ITER and Use N-file = Yes in the sestbl, and insert the appropriate postfit-edit commands in the autcln.cmd file, as described earlier in this chapter. With any of the three station-weight options, you can specify an additional term by which a particular satellite’s observations can be downweighted. Set Satellite error = UNIFORM a, where a is a constant in mm to be added quadratically to the station error.

**Ambiguity resolution.** These inputs allow you significant control over the criteria used to resolve phase ambiguities. With Choice of Observable = LC_HELP, the Ionospheric Constraints entry specifies the constraint applied to the ionosphere in estimating the wide-lane (L2–L1) phase ambiguity. In this input, unlike most of the others in the sestbl., you must follow the format to the right of the = sign exactly. The two Ambiguity resolution entries specify the decision-function and chi-square search parameters to be used for widelane (WL) and narrow-lane (NL) resolution. The fourth parameter is the maximum baseline length (in km) over which you want to attempt to resolve ambiguities. Strategies for choosing these parameters are discussed in Section 3.5. With the LC_AUTCLN option, the Ambiguity resolution WL entries are ignored.

**Atmospheric parameters.** Most of the entries for this group were explained in the standard setup. There are additional entries for the hydrostatic or “dry” (Dmap) and wet (Wmap) mapping functions (allowed only in the sittbl prior to Release 10.3). These are discussed in Chapter 7. The final entry is Tropospheric Constraints, which allows you to assume a spatial correlation among zenith delay parameters using the structure function described by Treuhaft and Lanyi [1986] (see Section 7.6). We have tested this constraint in only a limited way (with slightly positive results). It is currently coded only for a single zenith-delay parameter per station.

**Orbit parameters.** The first two entries control whether or not arc is run to create a T-file prior to the first model run (Initial ARC) and after the final solve (Final ARC). As indicated above, you may suppress the initial integration if you already have a T-file.
You do not need to create a T-file from the estimated orbital parameters unless you need it for further processing or wish to create an SP3 file for export (see Appendix A.2.2). The next entry sets the inertial frame for the orbital integration in arc, the orbital ephemerides themselves (T-file), and the calculation of the theoretical observable in model. In a fundamental sense the frame is arbitrary: as long as you transform coordinates and ephemerides consistently between the Earth-fixed and inertial frames, the choice of inertial frame matters only if you are combining inertial orbital parameters with those from an external source. The current convention for astronomical and IGS use is the equator and equinox of Julian epoch 2000.0, designated J2000 and corresponding to 0h UTC on 1 January, 2000. If you plan to use G- or T-files from SOPAC and/or you are starting anew in you processing and want to be consistent with the rest of the world, you should specify J2000, which is the current GAMIT default. The default for releases 9.4 or earlier was 'B1950', designating Bessilian epoch 1950.0. You should specify this if you wish to repeat a solution you have previously run. If you specify J2000 but have a B1950 G-file (or vice versa), arc will automatically convert the G-file before integrating, saving the old file with an additional extent (.B1950 or .J2000). The next two entries specify the dynamical model to be used in the integration of initial conditions. The default gravitational field (Reference system for ARC = IGS92) is from the IGS/IERS 1992 standards (see McCarthy [1992]), but you can specify the WGS84 field if you wish to perform comparisons with a DoD orbit. There are two commonly used models for non-gravitational ("radiation pressure") accelerations on the satellites. Prior to mid-1995, GAMIT and SOPAC orbits were generated with "spherical" or "flat-plate" model that had three adjustable parameters: coefficients representing a "direct" (Sun-facing), "y-bias" (along the spacecraft y-axis), and "z" (along the Earth-facing spacecraft axis) accelerations. A more comprehensive and demonstrably better model uses 9 adjustable parameters including both constant and once-per-revolution accelerations (as described by Colombo [1986]). The particular form of this model we employ is close to that described by Beutler et al. [1994] and hence is designated BERNE. These and two other models available are described in Section 7.2. The last two entries in this group control the integration step-size and T-file tabular interval. The default from release 9.2 forward is a 75-second step-size and 900-second (15-minute) tabular interval. The final group of entries are used if you wish to create an SP3 format ephemeris file (see Section from the final arc integration (done routinely at SOPAC processing but rarely elsewhere). The 4-character Orbit id gets used in the export file name. The Orbit organization and Reference system for Orb are written onto the header of the file (see the SP#1 and SP#3 format descriptions). Since these are Earth-fixed orbits, the reference system refers to the terrestrial frame used to define the station coordinates in the GAMIT or GLOBK solution (e.g. ITR00 for ITRF2000).

model parameters. Besides the antenna phase-center, Earth tides, and loading models discussed above, there are controls to specify the models used for Earth rotation, satellite yaw, and receiver clocks. Earth Rotation allows you to disable the addition of diurnal and semi-diurnal terms to the UT1 and pole angles read from tables. With Release 9.8, we changed from an older model [Herring and Dong, 1994] to a more recent one [J. Ray, private communication, 1998]. In order to distinguish these models in the GAMIT output (including h-files for GLOBK), we added a third (4) bit, so that the current default

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value is 7. **Yaw Model** allows you to disable modeling of satellite yaw (rotation of the antenna away from the Earth-pointing position). With the modifications in Release 9.7 of the yaw code to have all stations read a common table of yaw values, we have found no cases for which the yaw model degrades the solution (which occasionally occurred before in regional processing due to different stations getting different yaw angles because of different satellite rise times). Finally, you have the option (**Use I-file**) of not including in the theoretical observable a piece-wise polynomial model of the station clock, computed by `fixdrv` from the K-file samples written into the I-file. Since the receiver clock rate cancels in double differences (all channels are sampled simultaneously), it does not need to be modeled. However, using the I-file is recommended to prevent numerical problems which sometimes occur in `solve` if there is a large station clock drift and a long gap in the data from a satellite (from its setting and then rising again). The only time you might want to omit the I-file is if you have inadvertently deleted it or the K-files and don't want to recreate them using `makek` or `makex`.

**solve parameters.** Estimation of Earth rotation parameters (**Estimate EOP**) should be considered in most analyses, as discussed above. The estimation control is binary coded, with the "1" bit used for pole position, the "2" bit for UT1 offsets, the "4" bit for pole rate, and the "8" bit for UT1 rate. The units of the *a priori* constraint are arcseconds and arcseconds per day for pole and (time) seconds and (time) seconds per day for UT1. By default, corrections to the constant and rate of UT1 and pole position are estimated for each session (**Estimate EOP = 15**) but you may want to tighten the constraints if you have only regional data in your analysis. The two remaining commands for `solve` allow you to use only part of the data, either for sensitivity tests or to reduce the run time. To use a partial span, enter the stop and start epoch numbers (determined from the X-file or using `cview`) after `Select epochs =`. To use only every *n*th point set `Decimation factor = n`. These two controls may be used together. Note, however, that they cannot be used with `LC_AUTCLN` since `autcln` has defined the ambiguity (bias) parameters, which will not be consistent with a reduced data set in `solve`. **H-file solutions** controls what solutions are written into the H-file for use by GLOBK. The default is now to write only the two (biases free and biases-fixed) loosely constrained solutions, not the solutions produced by the input GAMIT constraints, in order to reduce the size of the H-files. If you need to have the constrained solutions in the H-file (e.g., for debugging or post-processing with FONDA), then you should specify `H-file solutions = ALL`.

**Cleaning parameters.** There are eight controls for cleaning the data—seven listed here and one under File Control. The use of `AUTCLN Command File`, `AUTCLN Postfit`, and the File Control entry `Delete AUTCLN input C-files` has been discussed earlier in this section. There are three options for handling eclipse data, implemented by edits to the `autcln` command file invoked by `sh_autedit`. The default is `Delete eclipse data = POST`, which will unweight observations occurring during the first half-hour following an eclipse, the period during which the yaw model always fails. **ALL** will unweight data during the eclipse as well, and **NO** will keep all of the data. The **Iteration command** controls whether the second `model/autcln` sequence in a 1-ITER run uses the original X-files (default) or the C-file created from the last run. Finally, since a `scandd` run is one of the most time-consuming parts of the processing and may be useful only at the end, and
then only when the normalized rms from *solve* suggests the presence of cycle slips, SCANDD control allows you to specify when in the batch sequence *scandd* gets executed. For unclean data, *fixdrv* always writes a line for *scandd* into the batch file after each solution, but SCANDD control determines whether or not it is dummyed by a comment character (#). With SCANDD control = *IFBAD* (the default) *scandd* will be executed only if the normalized rms is greater than 1. Option *FIRST* causes execution after the quick solution only, *FULL* after the full solution only, and *NONE* after neither. Option *IFBAD* will write into the batch file csh commands to look at the normalized rms in the Q-file; only if the nrms is greater than 1.0 will *scandd* be run.

**File handling.** These entries allow you some control over the files used or created in your batch run, and hence the amount of disk space required to process a survey. If *x-compress* = *yes*, then the batch script will expect the X-files to be compressed at the beginning of the run and will decompress them again at the end. The next group of entries allows you to delete the input C-files from one or more processing steps. The default is to save all C-files so that you check the editing for each iteration. At the other extreme, setting *Delete all input C-files* = *yes* will assure that no more than two sets of C-files are resident at the same time and will leave only the last set on the disk at the end. The *update T/L files* command allows you to use the adjusted values of coordinate and/or orbital parameters in successive iterations. The most command case for most users occurs when you want to update the coordinates for new stations for postfit editing and in order to achieve final adjustments are within a linear range for least-squares estimation (see Section 4.2). In this case you would set *Update T/L files* = *L-ONLY* and use the *Update tolerance* command to limit the updates to those stations with large adjustments (default is 0.3 m). Finally *Run CTOX* = *yes* creates at the end of the run a set of X-files with cleaned data, allowing you in principal to delete the last set of C-files if you have no further need to re-run *solve* with different constraints or to examine the post-fit residuals with *scandd* or *cview*. The correctly edited data on these X-files can be used as subsequent inputs to GAMIT processing with *Data status* = *clean*.

The form of the site control table (*sittbl.*) is shown below. The columns occupied by each entry are indicated by the keywords and dashes at the top of the file, and since these are used to read the entries, the order is arbitrary. Most of the entries are also optional, with the required information picked up from defaults or from corresponding (station-independent) entries in the *sestbl.* The example below shows the most commonly used entries; the omitted ones specify the atmospheric models and are described in Chapter 7.

```
<table>
<thead>
<tr>
<th>STATION</th>
<th>FIX</th>
<th>--COORD.CONSTR</th>
<th>CLK</th>
<th>KLOCK</th>
<th>CLKFT</th>
<th>APHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAFE San Fernando</td>
<td>NNN</td>
<td>100. 100. 100.</td>
<td>NNN</td>
<td>3</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>WSFD WSFD GPS</td>
<td>NNN</td>
<td>0.01 0.01 0.01</td>
<td>NNN</td>
<td>3</td>
<td>L</td>
<td>NONE</td>
</tr>
<tr>
<td>YKNF YELLOWKNIFE</td>
<td>NNN</td>
<td>0.01 0.01 0.01</td>
<td>NNN</td>
<td>3</td>
<td>L</td>
<td>NONE</td>
</tr>
<tr>
<td>RICH RICHFRPA</td>
<td>NNN</td>
<td>0.05 0.05 0.10</td>
<td>NNN</td>
<td>3</td>
<td>L</td>
<td>ELEV</td>
</tr>
<tr>
<td>TROM TROMGPSM</td>
<td>YYY</td>
<td>5.00 5.00 5.00</td>
<td>NNN</td>
<td>3</td>
<td>L</td>
<td>AZEL</td>
</tr>
</tbody>
</table>
```

The table may contain any number of stations, whether used in the experiment or not. The 4-letter code must match that used in the D-file; the 12-letter descriptor is arbitrary.

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and not used (the full station names for the q-file are read from station.info). The third column (in the example shown) indicates which, if any, of the three station coordinates are to be fixed/free (Y/N) in the solution. Any a priori coordinate constraints are given under COORD.CONSTRI in units of meters for latitude, longitude, and radius. Whether one uses coordinate constraints or not is specified in sestbl. (as described earlier). You should think carefully about this entry since this is your opportunity to define the reference system for the analysis by constraining the coordinates of one or more fiducial stations. If you plan to use GLOBK for your final analysis, you should avoid absolute fix of any stations, but rather use a priori constraints.

The next three entries control the way the receiver clock is handled. The CLK entry indicates whether or not an offset, rate, or acceleration term is to be estimated by solve. Almost always the answer is "No" (N). KLOCK selects the way the clocks are modeled and can be quite important for certain receivers. For all receivers except MiniMacs you should normally select option 3 to indicate that the receiver clock offset is to be estimated epoch-by-epoch using the pseudorange (see Section 4.7), and that the effect of oscillator variations on the phase is to be modeled with a low-order polynomial. Since the MiniMac receivers keep their clocks synchronized with the GPS satellites, it is preferable to assume an offset of 0. by selecting option 1. The third option (2) uses the low-order polynomial for both the epoch offset and oscillator variations. This approach will model receiver clock offsets as well as will Option 3 if the receiver clock stability is sufficient (better than \( \sim 10^{-8} \)) to keep deviations from the polynomial less than 1 microsecond throughout the observation span. The crystals in the TI 4100 and MACROMETER II usually meet this requirement but those in the newer low-power receivers do not unless they are locked to an external atomic oscillator (as at some IGS tracking stations). The order of the polynomial to be used by fixdrv may be specified under CLKFT as linear (L) or cubic (C), or left for fixdrv to decide from the fit by leaving this column blank. If KLOCK is not specified, the the way the clock is handled is determined by the receiver type, with all receivers except MiniMacs set to option 3 (epoch-by-epoch estimation).

The final column shown in the example is for invoking a model for variations in the phase center of the receiving antenna (APHS). The use of a model for all stations can be controlled using the sestbl. entry, but the sittbl. entries override the sestbl. if the former are present. So to avoid confusion, you may want to omit this column from the sittbl. except for those analyses in which you need to control the model separately for each station.

The usual way to run fixdrv is to give the name of the D-file as a command-line argument. In this case, there are no further prompts necessary. If an I-file exists, it will be used; if not, it will be created by fitting polynomials to the clock values given in the K-files. If you wish to choose an alternate I-file, or recreate the I-file even though it exists, you should run fixdrv interactively by not specifying the D-file as a command-line argument. In this case, fixdrv will prompt you for the name of the D-file. It will then ask what you want to do about the I-file: use the old one, save the old one and create a new one, or overwrite the old one. Most of the time you probably want to "Use the old one" (option 3) and avoid a time-consuming recalculation of all the clock coefficients, but if you have added a station to the D-file since last running fixdrv or have updated the K-file
by rerunning `makex` or `makek` with improved station coordinates, you should create a new I-file.

When you run `fixdrv` to create an I-file, you will get a display for each station indicating how well the station clock (as represented by the values in the K-file) fits a linear polynomial representing unexpected clock jumps or, for many receivers, programmed resets of 1 or 2 milliseconds to keep the sampling time synchronized with GPS time. Typical rms values for field receivers are several milliseconds for the linear fit (without jumps) and 50-1000 microseconds for the cubic fit with jumps. See the discussion in Chapter 2.10 to determine whether larger values may cause problems in your processing.

### 3.3 Executing the batch run

The output of `fixdrv` is a command file (c-shell script) named `$expmt.bat` which invokes the GAMIT modules in the appropriate order for the type of analysis you have requested (see the example on the following page). To execute the analysis run in foreground type `csh $batch file name`; in background type `gbat $batch file name`. (If your system recognizes the batch file as a command file [use `chmod +x` under UNIX], you can of course omit the `csh` when running in foreground.) All of the required modules will then be executed automatically to perform the processing sequence you have defined with `fixdrv`. For most of the modules, the command references a secondary B-file containing the input stream for one execution of the specified module. In the case of `yawtab`, `grdtab`, and `autcln`, there are command-line arguments rather than a secondary batch file given. (See Chapter 5 for more detail on the inputs to each module.)

As each module runs, it writes into files `GAMIT.status`, `GAMIT.warning`, and `GAMIT.fatal` messages recording the progress of the run, allowing you to monitor progress and/or to determine at the end where problems arose. The first code executed by `arc`, `model`, `cfmrg`, and `solve` is a check for the existence of `GAMIT.fatal`; if it's found, indicating that the previous step in the batch sequence has failed, the current module will terminate to avoid a confusing trail of failures. Prior to Release 10.3, the first lines of the batch file removed any existing `GAMIT.status`, `GAMIT.warning`, `GAMIT.fatal`. We have moved these commands to `sh_gamit`, however, as part of changes to make clearer to users viewing the `sh_gamit.log` file where failures occur. Consequently, if you execute any of the batch files manually (not in `sh_gamit`), you will have to manually delete at least the `GAMIT.fatal` file, if it exists, before each run.

An example of a primary B-file for a 1-ITER analysis with postfit editing by `autcln` is shown below.
bvent7.bat

#!/bin/csh
#
# Initial orbital integration
arc  < bvent7.001
#
# Generation of yaw file
yawtab yvent7.278 tvent7.278 yventt.278 120
#
# Generation of u-file
grdtab dvent7.278 1987 278 0.3 otl.list otl.grid
#
# Initial solution
model  < bvent7.002
model  < bvent7.003
model  < bvent7.004
model  < bvent7.005
model  < bvent7.006
model  < bvent7.007
model  < bvent7.008
sh_autedit -base autcln.cmd
autcln autcln.cmd.prefit . dvent7.278 7 >! autcln.out
if( -e GAMIT.fatal ) exit
mvcf 7 a
cfmrg  < bvent7.010
solve < bvent7.011
sh_chksolve -s 1
if( -e GAMIT.fatal ) exit
#
# Post-fit editing and solution
/bin/rm c????a.???
model  < bvent7.012
model  < bvent7.013
model  < bvent7.014
model  < bvent7.015
model  < bvent7.016
model  < bvent7.017
model  < bvent7.018
sh_autedit -base autcln.cmd -post
autcln autcln.cmd.postfit . dvent7.278 b >! autcln.out
if( -e GAMIT.fatal ) exit
mvcf b c
/bin/cp mventa.278 mventa.278.autcl
cfmrg  < bvent7.019
sh_sigelv -acmd autcln.cmd.postfit -nfile nventc.278
solve < bvent7.020
sh_chksolve -s 2
#
# Re-do AUTCLN and SOLVE with updated M-file
# if the ratio of the pre-fit to the post_fit nrms exceeds 1.5
[not shown]

Listed below are explanations for each module execution in the batch file.

arc Generate an orbital ephemeris (T-file) with partials using as initial conditions a G-file produced by sh_sp3fit, sh_bcfit, or copied from SOPAC. This step can be skipped if you've already created a T-file using sh_sp3_fit or sh_bcfit or copied one from SOPAC.

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yawtab  Generate a table of yaw values for each SV at each observation epoch using as input the T-file and short table of yaw values written by arc.

grdtab  Generate a U-file by reading one or more list or grid files for ocean tidal loading, atmospheric loading, and meteorological data.

model  Compute prefit residuals ("O-C's") and partial derivatives for the observations on each X-file; create C-files with the same names (except for the first letter) as the X-files.

autcln  Read the C-files output by model and search for cycle slips and outliers in the pre-fit one-way and double-difference residuals, inserting extra biases at all questionable gaps; create the "a" series C-files (i.e., with the year digit replaced by "a") with these corrections to the phase data and prefit residuals.

cfmrg  Set up the M-file for the least squares fit: define and select the parameters to be adjusted and the C-files to be read.

solve  Perform a least-squares estimate of station coordinates and orbital parameters; update the M-file with the parameter adjustments (in order to edit post-fit residuals); write the "a" L-file with an adjusted set of coordinates and the "a" G-file with an adjusted set of orbital initial conditions. The M-file and Q-file from this prefit solution are named with the sixth character "p".

model  Recompute O-C's and partials from the original X-files using updated coordinates. Write the "b" series C-files.

autcln  Re-clean the data using the flatter residuals obtained from the new coordinates. Overwrite the "b" series C-files.

cfmrg  Create a new M-file with the names of the "b" series C-files; the "regular solution" M-file always has "a" as its sixth character.

sh_sigelv  Write the data noise (weights) from autcln.post.sum and the resolved WL ambiguities into the N-file.

solve  Perform a least-squares estimate of station coordinates and orbital parameters, attempting to resolve phase ambiguities if specified by the type of analysis. This execution of solve will also update the M-file with the parameter adjustments in order to view or edit the post-fit residuals. It will also write overwrite the "a" L-file and create a "b" G-file. Like the M-file, the Q-file from the this solution is named with the sixth character "a".

Unless AUTCLN Postfit = N or Y in the sesbl file, there will be a check after the postfit solution to see if the prefit nrms has decreased by more than 30%; if so, there will be
another iteration through model, autcln, and solve. These steps are omitted above for brevity.

The shellscript executed just before each autcln run copies a "base" autcln command file (specified by autcln_cmd in the sestbl., usually autcln.cmd) into either autcln.cmd.prefit or autcln.cmd.postfit, uncommenting in the latter case the commands for post-fit editing (see Section 4.2) and in both cases adding (optionally) commands to exclude data corrupted by eclipses (Delete eclipse data in the sestbl.).

If you encounter problems in the run, you can repeat particular steps by pasting the commands into your terminal input or commenting out parts of the batch file. Be sure, however, that the C-files for the steps you want to repeat have not been removed (see the Delete C-files options in the sestbl.). It is also important to keep in mind the naming conventions for the various files. These are established by fixdrv and are summarized in Table 3.2.

Table 3.2 6th character and disposition of C-files in batch processing

<table>
<thead>
<tr>
<th>Initial O-C and edit</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>model</td>
<td>in (X)</td>
<td>yr</td>
</tr>
<tr>
<td></td>
<td>out</td>
<td>yr</td>
</tr>
<tr>
<td>autcln</td>
<td>in</td>
<td>yr</td>
</tr>
<tr>
<td></td>
<td>out</td>
<td>a</td>
</tr>
<tr>
<td>cfmrge, solve</td>
<td>in</td>
<td>a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Postfit editing and repeat solution</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>model</td>
<td>in (X)</td>
<td>yr</td>
</tr>
<tr>
<td></td>
<td>out</td>
<td>b</td>
</tr>
<tr>
<td>autcln</td>
<td>in</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>out</td>
<td>c</td>
</tr>
<tr>
<td>cfmrge, solve</td>
<td>in</td>
<td>c</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Optional rerun</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>model</td>
<td>in (X)</td>
<td>yr</td>
</tr>
<tr>
<td></td>
<td>out</td>
<td>d</td>
</tr>
<tr>
<td>autcln</td>
<td>in</td>
<td>d</td>
</tr>
<tr>
<td></td>
<td>out</td>
<td>e</td>
</tr>
<tr>
<td>cfmrge, solve</td>
<td>in</td>
<td>e</td>
</tr>
</tbody>
</table>
Finally, we display the contents of the secondary B-files created in our example:

**File bvent7.001 (arc)**

PRN 3
PRN 6
PRN 9
PRN 11
PRN 12
PRN 13
END
IGS92 BERNE 900.0 75.0
arcout.002
gvent7.002

87 23 21 37 23.000000
87 9 16 37 23.000000
Y
tvent7.002

**File bvent7.002 (model)**

S Static Mode
pcato7.278 Print file
ivent7.278 Station clock polynomial (I-) file
lvent7.278 Coordinates (L) file
xcato7.278 Input X, C, or S file
ccato7.278 /tmp Output C-file / Scratch directory
N Delete input C-file?
tvent7.278 T-file
I Inertial frame
RINEX met file
Z-file
jbrdc7.278 Satellite clock polynomial (J-) file
0 31 7 IERS03 N N Datum / Tides applied / SP EOP / E-tide model / Atm
load / Hydrol load
0.0 NONE NONE Elevation angle cutoff (now ignored in MODEL) /
antenna model / SV antenna model
3 yventt.278 Clock model / Yaw file
STP 50 Met options (source hierarchy + humidity) or P T H
SAAS SAAS NMFH NMFW Met models (dryzen wetzen drymap wetmap)

**File bvent7.021 (cfmrng)**

BATCH
cato 4 letter station code
love 4 letter station code
moja 4 letter station code
pver 4 letter station code
safe 4 letter station code
wsfd 4 letter station code
yknf 4 letter station code

3 6 8 9 11 12 13 Total PRN Numbers
ccatoe.278 C-file
cloovee.278 C-file

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File bvent7.013 ( solve )

* << key-word-controlled batch file format >> *
* symbol ":" must exist in command lines as separator *
* any non-blank character at first column means comment line *
* empty after ":" means comment line too *

* Part 1 -- Files and Global Controls *
FIXDRV version:  10.08
operation mode:    batch
owner:  MIT
Q-file name:       qventa.278
H-file mode:       0
datum code:        0
M-file name:       mventa.278
quick solution choice:    full
biases:            explicit
phase difference options: double difference
combination mode:   LC_AUTCLN
    bias search approach: decision function
    search path:    narrow lane
    search criteria: 0.15 0.15 1000.00 10.00 500.
start and end epochs:      1 225 1
set cutoff_elevation:
cutoff: all _sites 15.0

* Part 2 -- Parameters *
set parameters:
estimate: all_sites all_parameters
fix: all_sites clock
fix: all_sites grad
estimate: all_sats all_parameters
fix: all_sats clock radiation
fix: global all_parameters

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exit set:
*
---------------- Part 3 -- A priori Constraints

set a priori constraints:
  tight_apr_coord:  cato 100.000 100.000 100.000
  tight_apr_coord:  love 100.000 100.000 100.000
  tight_apr_coord:  moja 100.000 100.000 100.000
  tight_apr_coord:  pver  0.010  0.010  0.010
  tight_apr_coord:  safe 100.000 100.000 100.000
  tight_apr_coord:  wsfd  0.010  0.010  0.010
  tight_apr_coord:  yknf  0.010  0.010  0.010
  loose_apr_coord:  all_ 100. 100. 100.
zenith delays: all_sites  4 PWL
  tight_apr_zenith:  cato 0.500  0.005  100.0
  loose_apr_zenith:  cato 0.500  0.005  100.0
  tight_apr_zenith:  love 0.500  0.005  100.0
  loose_apr_zenith:  love 0.500  0.005  100.0
  tight_apr_zenith:  moja 0.500  0.020  100.0
  loose_apr_zenith:  moja 0.500  0.020  100.0
  tight_apr_zenith:  pver 0.500  0.020  100.0
  loose_apr_zenith:  pver 0.500  0.020  100.0
  tight_apr_zenith:  safe 0.500  0.020  100.0
  loose_apr_zenith:  safe 0.500  0.020  100.0
  tight_apr_zenith:  wsfd 0.500  0.020  100.0
  loose_apr_zenith:  wsfd 0.500  0.020  100.0
  tight_apr_zenith:  yknf 0.500  0.020  100.0
  loose_apr_zenith:  yknf 0.500  0.020  100.0
  tight_apr_grad:  cato 0.030  0.030
  loose_apr_grad:  cato 0.030  0.030
  tight_apr_grad:  love 0.030  0.030
  loose_apr_grad:  love 0.030  0.030
  tight_apr_grad:  moja 0.030  0.030
  loose_apr_grad:  moja 0.030  0.030
  tight_apr_grad:  pver 0.030  0.030
  loose_apr_grad:  pver 0.030  0.030
  tight_apr_grad:  safe 0.030  0.030
  loose_apr_grad:  safe 0.030  0.030
  tight_apr_grad:  wsfd 0.030  0.030
  loose_apr_grad:  wsfd 0.030  0.030
  tight_apr_grad:  yknf 0.030  0.030
  loose_apr_grad:  yknf 0.030  0.030

*  units are ppm for elements, percent for rad parms (The next two lines are truncated here by page width)
  tight_apr_orbit: all_ 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  loose_apr_orbit: all_ 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10.

exit set:
*
------------------- Part 4 -- Session Options

set session_1 options:
  include:       all_sites all_sats
  error model
    stn_error: all_sites elevation 10. 0.0
    sat_error: all_sats 0.0
  noise file name: nventc.167

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atmosphere constraint:     N
ionosphere constraint:     0.0  1.0
wide lane ambiguity criteria:   0.15  0.15  1000.0  10.00  500.0
pseudorange ambiguity criteria:  0.05  0.05  1000.0

exit set:

----------- Part 5 -- Solution Options

set tight_free solution option:
  print out solution:    q-file ofile
  update file option:  m-file l-file g-file
  input_m file name:     mventa.278
  output_m file name:    mventa.278
  input_l file name:     lvent7.278
  output_l file name:    lventa.278
  coord_upd_tol:         0.03
  input_g file name:     gventa.278
  output_g file name:    gventa.278
  correl_pr:            0.999900

exit set:

set tight_fix solution option:
  print out solution:    q-file ofile
  update file option:  m-file l-file g-file
  input_m file name:     mvent1.278
  output_m file name:    mvent1.278
  input_l file name:     lvent7.278
  output_l file name:    lventa.278
  coord_upd_tol:         0.03
  input_g file name:     gvent7.278
  output_g file name:    gventa.278
  correl_pr:            0.999900

exit set:

set loose_free solution option:
  update file option:
  exit set:

set loose_fix solution option:
  print out solution:
  exit set:

3.4 Evaluating the solutions

There are two first-order criteria for determining if a solution is acceptable: 1) are there adequate data to perform a reasonable estimate, and 2) do the data fit the model to their noise level. The primary indicator that the first criterion has been met is the magnitude of the uncertainties of the baseline components. If these are larger than you expect with the \textit{a priori} constraints you have applied to station coordinates and orbital parameters, then a quick look in the Q-file or autcln.sum file will usually reveal that large quantities of data have been discarded by \textit{autcln}. For the second criterion, the primary indicator is the "normalized rms" (nrms) of the solution; i.e., the square root of chi-square per degree of freedom. If the data were randomly distributed and the \textit{a priori} weights were correct, the
nrms would be close to unity. In practice with the default weighting scheme, a good solution usually produces a nrms of about 0.25. Anything larger than 0.5 means that there are cycle slips that have not been removed or associated with extra bias parameters (see Sections 2.1 and 6.1), or that there is a serious modeling problem (e.g., bad coordinates of the fixed stations or an unmodeled satellite "burn"). If the final solution of a batch sequence meets these two criteria, there is usually no need to look carefully at any other output, though the rms of (one-way) residuals in autcln.sum.post will tell you the relative quality of stations in your network. These statistics are included in the email message sent by sh_gamit at the completion of the run for each session.

To illustrate the information available from the Q-file, we use as an example an analysis of data obtained with 120s sampling over 8 hrs using TI4100 receivers in a 7-station network in North America on day 278 of 1987. (This is the "standard" example provided in the gamit/example directory; though the results are less accurate than with modern data, we retain it here for consistency.) In this solution the coordinates of three fiducial stations (Palos Verdes, Yellowknife, and Westford) were given a priori constraints of 10 mm. Wide-lane ambiguity resolution is performed with an ionospheric constraint (LC_HELP) so that we can discuss the subtleties of this approach, which is necessary with codeless receivers.

Program SOLVE Version 9.88 99/04/16 09:30:00:00 (SunOS)
SOLVE Run on 1999/ 5/26 15:52: 2
OWNER: MIT OPERATOR: rwk

Geocentric Coordinates Option
Epoch interval: 1 - 225
Decimation interval: 1

LC solution with ionosphere constraint bias-fixing

Tracking stations:
1 CATO Castro Peak
2 LOVE Loma Verde P
3 MOJA MOJAVE GPS
4 PVER PVER7268
5 SAFE San Fernando
6 WSFD WSFD GPS
7 YKNF YELLOWKNIF

Satellites observed:
1.. PRN 3
2.. PRN 6
3.. PRN 8
4.. PRN 9
5.. PRN 11
6.. PRN 12
7.. PRN 13

Cutoff elevation angle in SOLVE batch file (degrees):
Station Cutoff angle
1 CATO Castro Peak 15.00
2 LOVE Loma Verde P 15.00
3 MOJA MOJAVE GPS 15.00
4 PVER PVER7268 15.00
5 SAFE San Fernando 15.00
6 WSFD WSFD GPS 15.00

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<table>
<thead>
<tr>
<th>Station</th>
<th>Model</th>
<th>Std dev</th>
<th>Elev</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATO Castro Peak</td>
<td>uniform</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LOVE Loma Verde P</td>
<td>uniform</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>MOJA MOJAVE GPS</td>
<td>uniform</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>PVER PVER7268</td>
<td>uniform</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>SAFE San Fernando</td>
<td>uniform</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>WSFD WSFD GPS</td>
<td>uniform</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>YKNF YELLOWKNIF</td>
<td>uniform</td>
<td>10.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station</th>
<th>Std dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRN 3</td>
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</tr>
<tr>
<td>PRN 6</td>
<td>0.00</td>
</tr>
<tr>
<td>PRN 8</td>
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</tr>
<tr>
<td>PRN 9</td>
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<td>PRN 12</td>
<td>0.00</td>
</tr>
<tr>
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<td>0.00</td>
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</table>

<table>
<thead>
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<th>Longitude</th>
<th>Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATO Castro Peak</td>
<td>100.000</td>
<td>100.000</td>
<td>100.00</td>
</tr>
<tr>
<td>LOVE Loma Verde P</td>
<td>100.000</td>
<td>100.000</td>
<td>100.00</td>
</tr>
<tr>
<td>MOJA MOJAVE GPS</td>
<td>100.000</td>
<td>100.000</td>
<td>100.00</td>
</tr>
<tr>
<td>PVER PVER7268</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>SAFE San Fernando</td>
<td>100.000</td>
<td>100.000</td>
<td>100.00</td>
</tr>
<tr>
<td>WSFD WSFD GPS</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>YKNF YELLOWKNIF</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
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<table>
<thead>
<tr>
<th>Station</th>
<th>ZEN_APR (m)</th>
<th>ZEN_VAR (m/sqrt(hr))</th>
<th>Correlation time (hrs)</th>
<th># of delays</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATO Castro Peak</td>
<td>0.500</td>
<td>0.005</td>
<td>100.000</td>
<td>4</td>
</tr>
<tr>
<td>LOVE Loma Verde P</td>
<td>0.500</td>
<td>0.005</td>
<td>100.000</td>
<td>4</td>
</tr>
<tr>
<td>MOJA MOJAVE GPS</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
<td>4</td>
</tr>
<tr>
<td>PVER PVER7268</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
<td>4</td>
</tr>
<tr>
<td>SAFE San Fernando</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
<td>4</td>
</tr>
<tr>
<td>WSFD WSFD GPS</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
<td>4</td>
</tr>
<tr>
<td>YKNF YELLOWKNIF</td>
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<td>0.020</td>
<td>100.000</td>
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<table>
<thead>
<tr>
<th>Station</th>
<th>North-South</th>
<th>East-West</th>
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<tbody>
<tr>
<td>CATO Castro Peak</td>
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<td>0.01000</td>
</tr>
<tr>
<td>LOVE Loma Verde P</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>MOJA MOJAVE GPS</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>PVER PVER7268</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>SAFE San Fernando</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>WSFD WSFD GPS</td>
<td>0.01000</td>
<td>0.01000</td>
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<tr>
<td>YKNF YELLOWKNIF</td>
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Keplerian a priori orbital errors (dimensionless except semi-major axis (km))

<table>
<thead>
<tr>
<th>Sat#</th>
<th>Semiaxis</th>
<th>Eccen.</th>
<th>Incl.</th>
<th>Asc.node</th>
<th>Perigee</th>
<th>M.anom.</th>
<th>rad1</th>
<th>rad2</th>
<th>..</th>
<th>rad9</th>
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<tbody>
<tr>
<td>PRN 3</td>
<td>260.0000</td>
<td>1.0E-02</td>
<td>1.0E-02</td>
<td>1.0E-02</td>
<td>1.0E-02</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>..</td>
<td>1.0E-05</td>
<td></td>
</tr>
<tr>
<td>PRN 6</td>
<td>260.0000</td>
<td>1.0E-02</td>
<td>1.0E-02</td>
<td>1.0E-02</td>
<td>1.0E-02</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
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<td>1.0E-05</td>
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<tr>
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<td></td>
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<tr>
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<tr>
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<td>1.0E-05</td>
<td>..</td>
<td>1.0E-05</td>
<td></td>
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<tr>
<td>PRN 13</td>
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<td>1.0E-02</td>
<td>1.0E-02</td>
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<td>1.0E-05</td>
<td>1.0E-05</td>
<td>..</td>
<td>1.0E-05</td>
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</tbody>
</table>

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Apriori SV antenna offset errors (m)

<table>
<thead>
<tr>
<th>Sat#</th>
<th>dX</th>
<th>dY</th>
<th>dZ</th>
</tr>
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<tr>
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<td>0.100</td>
<td>0.100</td>
<td>0.100</td>
</tr>
<tr>
<td>2</td>
<td>0.100</td>
<td>0.100</td>
<td>0.100</td>
</tr>
<tr>
<td>3</td>
<td>0.100</td>
<td>0.100</td>
<td>0.100</td>
</tr>
<tr>
<td>4</td>
<td>0.100</td>
<td>0.100</td>
<td>0.100</td>
</tr>
<tr>
<td>5</td>
<td>0.100</td>
<td>0.100</td>
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<tr>
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<tr>
<td>7</td>
<td>0.100</td>
<td>0.100</td>
<td>0.100</td>
</tr>
</tbody>
</table>

A priori pole position errors in arcs and arcs/day

\[ X_p \quad X_p \text{ rate} \quad Y_p \quad Y_p \text{ rate} \]
\[ 0.003000 \quad 0.000100 \quad 0.003000 \quad 0.000100 \]

A priori earth rotation errors in sec and sec/day

\[ UT1 \quad UT1 \text{ rate} \]
\[ 0.000020 \quad 0.000100 \]

Session 1

Stations used

1 2 3 4 5 6 7
Y Y Y Y Y Y Y

Satellites used

1 2 3 4 5 6 7
Y Y Y Y Y Y Y

Assumed ionosphere error
constant : 0.0 ppm : 1.00

<table>
<thead>
<tr>
<th>C-file</th>
<th>Elev</th>
<th>Number of double differences for each satellite PRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBS</td>
<td></td>
<td>Cutoff   3  6  8  9 11 12 13</td>
</tr>
<tr>
<td>OBS 1</td>
<td>CCAT07.278</td>
<td>15.00</td>
</tr>
<tr>
<td>OBS 2</td>
<td>CLOVE7.278</td>
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</tr>
<tr>
<td>OBS 3</td>
<td>CMOJA7.278</td>
<td>15.00</td>
</tr>
<tr>
<td>OBS 4</td>
<td>CPVER7.278</td>
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<td>CSAFE7.278</td>
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<td>OBS 6</td>
<td>CWSFD7.278</td>
<td>15.00</td>
</tr>
<tr>
<td>OBS 7</td>
<td>CYKNF7.278</td>
<td>15.00</td>
</tr>
</tbody>
</table>

Fix dependent bias param. of index 223

Fix dependent bias param. of index 258

Number of good oneway phases: 4240
Number of single differences: 0
Number of double differences: 2335

Inspection of the observation summary will reveal whether or not there were adequate data obtained from each of the satellites to determine its orbit. Often there are not from a single session, particularly if it is less than 24 hours long or has only a continental-scale fidicial network. In the example shown, no double differences could be formed with Yellowknife for PRN 3, so that its orbital parameters are poorly determined from the data. The summary of double difference observations is also important because a small number for a given station or satellite may prevent resolution of ambiguities for combinations involving that station or satellite. The message near the end means that the absence of data for certain station/satellite combinations forced solve to "fix" (remove from the solution) one or more ambiguity parameters that it had defined prior to reading in the data. The message is no cause for concern.
The next part of the Q-file begins the display of information associated with ambiguity resolution. The procedure invoked by Choice of Observable = LC_HELP is a modification of the one discussed by Dong and Bock [1989], the primary differences being the constraint of orbital and station parameters and the simultaneous use of pseudo-ranges in determining the wide-lane biases. This procedure has six steps:

1) Use the LC observable to estimate all parameters, including (real-valued) "biases" for each independent double difference combination. This solution becomes the "biases-free" solution recorded in the Q-file.

2) Fix all geodetic parameters at the values estimated in step 1), and estimate only the "wide-lane" (L2-L1) biases, this time using the L1 and L2 observations separately with constraints on the ionosphere.

3) Using the algorithms described below, fix as many of the wide-lane biases as possible to integer values.

4) With the wide-lane biases determined in step 3) held fixed, use the LC observations to estimate geodetic parameters and "narrow-lane" (L1) biases.

5) Using algorithms similar to those used in step 3, fix as many of the narrow-lane biases as possible to integer values.

6) With the narrow-lane biases determined in step 5) held fixed, use the LC observations to estimate geodetic parameters. This step produces the "biases-fixed" solution recorded in the Q-file.

Each of these steps can be best understood by reference to the Q-file output. If precise P1 and P2 pseudoranges are not available, then the wide-lane ambiguity parameters are separated from ionospheric effects by constraining the differential ionosphere at each epoch. The value of 1 ppm is appropriate for a relatively quiet ionosphere, as might be present in the daytime at mid-solar cycle, or at night near solar maximum (as was the case here). Values of the ionospheric constraint as large as 8 ppm can be effective in resolving wide-lane ambiguities and are realistic for daytime observations near solar maximum. Using the ionospheric contraints and precise pseudoranges, if available, solve estimates real-valued wide-lane ambiguity parameters ("biases"). These parameters are then "fixed" to integer values using the decision function described by Dong and Bock.

The parameters (input or default) and specific algorithm used are echoed in the Q-file:

--- estimate and fix wide-lane (L2-L1) ambiguities ---

Algorithm: LC_HELP

L2-L1 biases estimated from phases and ionospheric constraint using the decision function and chi-square search. If a bias is not fixed using the decision function and P2 pseudo-range (PR) is available, the PR wide-lane estimate is used with the PR decision function if

|PR estimate - phase estimate| < 0.4 cycle

Finally, for biases fixed with the decision function, the PR estimates overrides if PR estimate is a factor of two closer to an integer than the phase estimate. For codeless receivers, half-integer values are allowed.

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The first two parameters listed for wide-lane bias fixing criteria are the deviation from an integer (cutdev) and standard deviation (cutsig) that define the rounding area described in Dong and Bock (Figure 4 and Appendix A). The third parameter (decision function) is the inverse of the probability for making a type I error (fixing the ambiguity at the wrong integer value). The decision-function rounding algorithm is sensitive primarily to the value chosen for cutdev. Decreasing or increasing it from the default value of 0.15 cycles has the effect of making your resolution of ambiguities more or less conservative. Though the algorithm is less sensitive to cutsig, it makes sense to change it to match the value of cutdev when specifying these parameters in the sestbl. The fourth parameter displayed (wlrat) is the cutoff ratio for the chi-square searching algorithm that may be invoked after rounding. The current coding of this algorithm ignores correlations among the ambiguity parameters; hence the value of the ratio that represents a significant increase in chi-square is very sensitive to the number of parameters in the solution (i.e., the size of the network). For this reason we have set the default to 99., which effectively turns off the decision function part of the algorithm.

If a wide-lane ambiguity is not resolved with the decision function and precise pseudoranges are available, the pseudorange estimate is also used. The criteria for fixing a real-valued estimate to an integer are that the uncertainty (sigma) of the estimate be less than 0.15 cycle, that the estimate be within 0.3 cycles or 3-sigma of an integer, whichever is smaller, and that the difference of the pseudorange and phase estimate be less than 0.8 cycles. This last requirement is to guard against a spurious pseudorange estimate that might be fortuitously close to an integer. The pseudorange estimate is allowed to override the decision-function estimate if the former has an uncertainty less than 0.1 cycles and is a factor of two closer to an integer. This situation would occur if a high ionosphere degraded to phase estimate. A warning is printed if both the phase and pseudorange estimates are apparently good but close to different integers.

The uncertainties obtained for the biases in the wide-lane solution are scaled by the nrms (unlike the uncertainties estimated in the complete solutions), so the ability of the decision function to fix the biases is reduced if the ionospheric constraint is too tight. In the example shown, the nrms is 2.66, a reasonable value for moderate ionospheric conditions. On the other hand, if the constraint is too loose, the wide-lane uncertainties will also go up because the estimator will be unable to separate the wide-lane and ionospheric parameters. For receivers that have no P-code range, the widelane ambiguities can assume half-wavelength values, making separation more difficult. The uncertainties from the pseudo-range solution are not influenced by the level of ionospheric error and should be reliable if the pseudorange observations are sufficiently precise (when averaged over the session) and not corrupted by multipath.
If the widelane ambiguities have been resolved in _autcln_ (LC_AUTCLN), then steps 2) and 3) are skipped, and the q-file contains only a list of the assigned ambiguities and whether or not they were resolved ("fixed", F) or remain as free parameters (R).

Next follows a lengthy summary (truncated in this documentation) of the estimation of the biases from the ionosphere-constrained L1 and L2 observations. In this solution, the station and orbital parameters have been fixed at their values from an LC, biases-free solution which solve has performed but does not write to the Q-file until later. First in the summary are the narrow-lane (L1) biases (designated B1L1), which should theoretically be integers but may not be close to integers in this solution due to ionospheric errors. Following these are the wide-lane (L2–L1) biases (designated B1L21), which because of their larger wavelengths are more likely to be close to integers even in the presence of ionospheric errors. (The B1 in the designation refers to "biases from session 1".) For brevity, we show below only the values for the 19-km baseline between Loma Verde and San Fernando (SAFE) and the 32-km baseline between Castro Peak and San Fernando.

<table>
<thead>
<tr>
<th>Label (units)</th>
<th>L1,L2 est.</th>
<th>Uncertainty</th>
<th>PR est.</th>
<th>Uncertainty</th>
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<td>196*B1L1 LOVE-SAFE 6-3</td>
<td>31.933</td>
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<td></td>
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<td>151.945</td>
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<td>0.029</td>
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</tr>
<tr>
<td>199*B1L1 LOVE-SAFE 6-11</td>
<td>-6.996</td>
<td>0.029</td>
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</tr>
<tr>
<td>200*B1L1 LOVE-SAFE 6-12</td>
<td>31.905</td>
<td>0.044</td>
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<tr>
<td>201*B1L1 LOVE-SAFE 6-13</td>
<td>0.006</td>
<td>0.031</td>
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<tr>
<td>202*B1L1 CATO-SAFE 6-3</td>
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<tr>
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<tr>
<td>231*B1L21LOVE-SAFE 6-3</td>
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<tr>
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<td>234*B1L21LOVE-SAFE 6-11</td>
<td>3.005</td>
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<td>235*B1L21LOVE-SAFE 6-12</td>
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<td>-6.095</td>
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<td>0.045</td>
<td>-0.428</td>
<td>0.174</td>
</tr>
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Fix No. 234 bias from 3.01 to 3.0
Fix No. 233 bias from -5.01 to -5.0
Fix No. 242 bias from -0.01 to 0.0
Fix No. 240 bias from 0.99 to 1.0
Fix No. 236 bias from 0.01 to 0.0
Fix No. 245 bias from 6.02 to 6.0
Fix No. 248 bias from 0.01 to 0.0
Fix No. 247 bias from 4.99 to 5.0
Fix No. 232 bias from -34.01 to -34.0
Fix No. 238 bias from -16.00 to -16.0
Fix No. 239 bias from -0.97 to -1.0
Fix No. 235 bias from -5.02 to -5.0
Fix No. 237 bias from -0.96 to -1.0
Fix No. 243 bias from 6.02 to 6.0
Fix No. 246 bias from -1.95 to -2.0
Fix No. 244 bias from 16.05 to 16.0
Fix No. 241 bias from -0.92 to -1.0

--- bias uncertainties scaled by n rms !

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In the example shown, *solve* resolved all of the wide-lane ambiguities for LOVE–SAFE (Nos. 231–236) and CATO–SAFE (Nos. 237–242) using the decision function with the ionosphere-constrained phase estimate. In four cases the phase and pseudorange estimates are inconsistent; in each of those the phase estimate was closer to an integer and hence took precedent. The uncertainties in the pseudorange estimates would have been a factor of two smaller had we used 30-s rather than 120-s sampling.

Next in the Q-file is a summary of both the narrow-lane and wide-lane biases after the resolution of as many as possible of the wide-lanes. The narrow-lane bias estimates are slightly changed, and have smaller uncertainties, but will be close to integers in the separate L1 and L2 solution only if ionospheric effects are small (as is in fact the case for this experiment). The main purpose of this summary is to highlight the wide-lane biases that have been fixed at integers and those for regional baselines that remain unresolved. Using this summary and the preceding one, you should evaluate whether or not it may be possible to resolve the remaining (regional) wide-lane ambiguities by changing the ionospheric constraint or editing the data. You can use *cview* to inspect the residuals for the station–satellite combinations in question to see whether, for example, the departure from an integer is due to an excursion in only part of the pass—in the phase estimate due to the ionosphere or in the pseudo-range estimate due to multipath—in which case you could unweight the offending data. Note that the pseudorange estimate is made using the full one-way span of data for each station and satellite so that multipath corruption of the wide-lane combination may not be visible if you display only double differences in *cview*. (The use of one-way, rather than doubly differenced pseudorange was instituted to handle the high pseudorange noise of early P-code receivers. Future versions of *solve* will provide the option of using doubly differenced pseudorange to reduce the influence of receiver range biases and to make the phase and pseudoranges for each double-difference ambiguity parameter consistent.)

**summary of wide-lane biases after fixing**

<table>
<thead>
<tr>
<th>Label (units)</th>
<th>L1,L2 est.</th>
<th>Uncertainty</th>
<th>PR est.</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>196*B1L1 LOVE-SAFE 6-3</td>
<td>31.940</td>
<td>0.026</td>
<td></td>
<td></td>
</tr>
<tr>
<td>197*B1L1 LOVE-SAFE 6-8</td>
<td>151.942</td>
<td>0.033</td>
<td></td>
<td></td>
</tr>
<tr>
<td>198*B1L1 LOVE-SAFE 6-9</td>
<td>31.979</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>199*B1L1 LOVE-SAFE 6-11</td>
<td>-6.993</td>
<td>0.021</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200*B1L1 LOVE-SAFE 6-12</td>
<td>31.899</td>
<td>0.031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>201*B1L1 LOVE-SAFE 6-13</td>
<td>0.012</td>
<td>0.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>202*B1L1 CATO-SAFE 6-3</td>
<td>11.944</td>
<td>0.027</td>
<td></td>
<td></td>
</tr>
<tr>
<td>203*B1L1 CATO-SAFE 6-8</td>
<td>66.803</td>
<td>0.035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>204*B1L1 CATO-SAFE 6-9</td>
<td>11.998</td>
<td>0.021</td>
<td></td>
<td></td>
</tr>
<tr>
<td>205*B1L1 CATO-SAFE 6-11</td>
<td>-4.202</td>
<td>0.022</td>
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</tr>
<tr>
<td>206*B1L1 CATO-SAFE 6-12</td>
<td>11.973</td>
<td>0.032</td>
<td></td>
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<tr>
<td>207*B1L1 CATO-SAFE 6-13</td>
<td>-0.135</td>
<td>0.023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>289 B1L2 LOVE-SAFE 6-9</td>
<td>-1.0</td>
<td>0.127</td>
<td></td>
<td></td>
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<tr>
<td>290 B1L2 LOVE-SAFE 6-10</td>
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<td>0.163</td>
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</tr>
<tr>
<td>291 B1L2 LOVE-SAFE 6-11</td>
<td>3.0</td>
<td>0.130</td>
<td></td>
<td></td>
</tr>
<tr>
<td>292 B1L2 LOVE-SAFE 6-12</td>
<td>-5.0</td>
<td>0.151</td>
<td></td>
<td></td>
</tr>
<tr>
<td>293 B1L2 LOVE-SAFE 6-13</td>
<td>-6.095</td>
<td>0.123</td>
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<td></td>
</tr>
<tr>
<td>294 B1L2 LOVE-SAFE 6-3</td>
<td>-0.704</td>
<td>0.188</td>
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<td></td>
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<tr>
<td>295 B1L2 LOVE-SAFE 6-4</td>
<td>-16.0</td>
<td>0.238</td>
<td></td>
<td></td>
</tr>
<tr>
<td>296 B1L2 LOVE-SAFE 6-5</td>
<td>-1.316</td>
<td>0.174</td>
<td></td>
<td></td>
</tr>
<tr>
<td>297 B1L2 LOVE-SAFE 6-6</td>
<td>0.698</td>
<td>0.182</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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After determining as many as possible of the wide-lane ambiguities, solve fixes these at integer values and performs an LC (ionsphere-free) solution for all of the geodetic parameters and the narrow-lane bias parameters. This solution is identified by the keyword summary preceding it:

```
USER   SOLN   DIFF   PHASE   CONSTRAINTS   BIASES   PARAMETERS   H-FILE
KEYS:   DEFLT   FULL   DBLE   LC   NOION   ATM   FREE   STN   ORB   ZEN   NOCLK   GCR
```

Then follows a list of the original X-files and the C-files created by the run, and the data statistics:

```
Bepheris and survey data files          (qventa.278      1998/ 5/13   9: 9:18)
TVENT7.278     XCATO7.278     CCATO7.278
XLOVE7.278     CLOVE7.278
XMOJA7.278     CMOJA7.278
XPVER7.278     CPVER7.278
XSAFE7.278     CSAFE7.278
WXSF7.278      CWXSF7.278
XYKNF7.278     CYKNF7.278
MERGE File: mventa.278
Double-difference observations:   2335
Epoch numbers    1 to  225  Interval:   120 s   decimation:   1
Start time:   87  10   5  14   37   59.080
Total parameters:   265   live parameters:   208
Prefit nrms:  0.11483E+03    Postfit nrms: 0.29527E+00
-- Uncertainties not scaled by nrms
Channels used:      1     2     3     4     5     6     7
                      568   568   311   753   765   338   937
Correlation coefficients greater than 0.999900: None
```

The predicted postfit nrms for this solution was 0.29, about the level expected for the assigned \textit{a priori} measurement error and the typical performance of the TI4100 receiver. (If the data from each baseline were used independently, then you could use this nrms value, along with the assigned measurement error [nominally 10 mm in L1, implying 64 mm, or 0.3 cycles in LC] to compute the average rms of the residuals; e.g., \(0.29 \times 0.3 = 0.09\) cycles [18 mm] in this case. \textit{Autcln} in postfit mode computes the rms values on a station-by-station basis—see Section 4.2.)

Next follows a listing of all the estimated parameters with their adjustments and uncertainties from the bias-free solution. The station coordinates have the form

```
Label (units)   a priori   Adjust (m)   Formal Fract   Postfit
1*CATO GEOC LAT (dms)   N33:54:26.75455   -0.0050   0.0127 -0.4 N33:54:26.75429
2*CATO LONG (dms)      W118:47:08.75979   0.0078   0.0266   0.3 W118:47:08.75948
3*CATO RADIUS (km)      6372.284510600   0.0225   0.0434   0.5 6372.28453315
```

The parameter adjustments and formal uncertainties are given in units of meters. Fract is the adjustment as a fraction of the formal error. Scanning these values in the solution is useful to spot anomalous adjustments and also tells you whether you need to iterate in order to achieve adjustments unaffected by non-linearities in the partial derivatives (see Section 4.2). The uncertainties are the formal errors of the least squares fit based on the assigned data weighting. They have not been scaled by the \textit{a posteriori} variance of unit
weight (the nnrm s) since (temporal) correlations among phase observations usually renders this value unduly optimistic. The uncertainties of the coordinates of station CATO (Castro) with respect to the nearest fixed station (Palos Verdes, 50 km away, in this example) are of order 1-4 cm, acceptable values for a single-session solution with a relatively weak fiducial network (Palos Verdes – Yellowknife – Westford). We should expect from this result that a multi-day solution with phase ambiguities resolved would produce uncertainties of 1 cm or less.

Next are given the adjustments to the atmospheric zenith delays for each station, either a constant over the session or the tabular points of a piecewise linear function. In this example, we are estimating 4 tabular points over the 7.5-hr session, so that the tabular points are 2.5 hr apart. The adjustments in this case are less than 3 cm and less than the uncertainties of 8–12 cm. The O-file includes with the zenith delay estimates the time of each tabular point so that they may be easily plotted.

```
22*CATO ATMOS- 1 1 2.2123446029 -0.0286 0.0820 -0.3 2.18376533
23*CATO ATMOS- 2 1 2.2123446029 -0.0275 0.0817 -0.3 2.18482288
24*CATO ATMOS- 3 1 2.2123446029 -0.0256 0.0815 -0.3 2.18675445
25*CATO ATMOS- 4 1 2.2123446029 -0.0042 0.1150 0.0 2.20815916
```

Also listed are the north-south and east-west atmospheric gradients for each station. The units of these are such that they represent the difference between the north-looking and south-looking (or east- and west-) atmospheric delays at 10 degrees elevation angle (see Section 7.4).

```
50*CATO N/S ATMOS GRAD 0.0000000000 0.0019 0.0268 0.1 0.00185385
...
57*CATO E/W ATMOS GRAD 0.0000000000 0.0043 0.0275 0.2 0.00425886
```

In this case the gradients are small compared to their uncertainties and did not need to be estimated.

In the main parameter list, as in the G-file, the orbital elements are given in terms of the Cartesian initial conditions in km and km/s. The adjustments and uncertainties, however, are given in m and m/s for ease of interpretation:

```
85*ORBIT X    km   PN03-13976.9094676840 3.5308 39.6752 0.1 -13976.90593688
86*ORBIT Y    km   PN03 22548.1011499110 9.8227 13.3860 0.7 22548.11097262
87*ORBIT Z    km   PN03 3693.2210527633 -6.6175 41.2866 -0.2 3693.21443523
88*ORBIT Xdot km/s PN03 -1.1970220165 -0.0005 0.0073 -0.1 -1.19702249
89*ORBIT Ydot km/s PN03 -1.3320686827 0.0018 0.0060 0.3 -1.33206685
90*ORBIT Zdot km/s PN03 3.3985770848 -0.0001 0.0020 -0.1 3.39857696
91*RAD PRES DIRECT PN03 1.0000000000 0.0000 0.0000 0.0 1.00000000
92*Y AXIS BIAS PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
93*B AXIS BIAS PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
94*COS DIRECT PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
95*SIN DIRECT PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
96*COS Y BIAS PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
97*SIN Y BIAS PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
98*COS B BIAS PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
99*SIN B BIAS PN03 0.0000000000 0.0000 0.0000 0.0 0.00000000
```

In this example, the initial position for PRN 3 adjusted (from the broadcast orbit) by about 10 m and has an uncertainty of about 50 m. Since Cartesian initial conditions are difficult to interpret, particularly for multi-day arcs, a summary of orbital uncertainties in terms of Keplerian elements is given at the bottom of the Q-file:

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Post-fit Keplerian orbital errors in parts in $10^{-7}$

<table>
<thead>
<tr>
<th>PRN</th>
<th>a</th>
<th>e</th>
<th>I</th>
<th>Node</th>
<th>Perigee</th>
<th>M Anom.</th>
<th>w+M</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>7.492</td>
<td>2.385</td>
<td>5.302</td>
<td>4.516</td>
<td>771.625</td>
<td>786.808</td>
<td>18.819</td>
</tr>
<tr>
<td>9</td>
<td>4.748</td>
<td>2.657</td>
<td>2.657</td>
<td>4.325</td>
<td>200.566</td>
<td>205.830</td>
<td>6.432</td>
</tr>
<tr>
<td>11</td>
<td>4.050</td>
<td>1.567</td>
<td>4.521</td>
<td>6.120</td>
<td>161.344</td>
<td>157.834</td>
<td>6.005</td>
</tr>
</tbody>
</table>

This summary shows that the semi-major axes, $a$, (representing the orbital period, in accordance with Kepler's third law) is determined with an uncertainties of 1–2 ppm, not unreasonable for the analysis of a single (~5 hr) pass, less than half an orbital period. The orientations of the orbital plane, given by the inclination, $I$, and the longitudes of the ascending node, are all determined to about 1 ppm. The next two elements, the argument of perigee and mean anomaly are intrinsically poorly defined for a near-circular orbit; hence, the more meaningful measure of the along-track uncertainty is their sum, indicated here by $w + M$ (since $w$ is the usual symbol for argument of perigee). This component is almost always the least well determined, so the uncertainty in $w + M$ will match closely the largest uncertainty in the Cartesian initial conditions; here the uncertainties are 0.6–2.5 ppm or 15–65 m of position at the GPS orbital radius (26,000 km).

Below the orbital parameters are Earth orientation parameters (EOP)—pole position and UT1 and their rates of change. The units are arc-seconds and arc-second per day. Since we have used data from a weak global network, these parameters have all been constrained tightly to their a priori values, obtained in this case from IERS Bulletin B. With a large global network, all of these can be estimated accurately from GPS observations except for UT1, which is perfectly correlated with the ascending nodes of the satellites.

The last group of parameters are the biases, of which we show only the L1 estimates for the two baselines discussed above and for which the widelane biases were resolved.

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After the summary of parameter estimates solve lists the components of each baseline for the biases-free solution:

Baseline vector (m): CATO(Site 1) to SAFE(Site 5)
X 22126.3867 Y(E) 5021.4762 Z 22600.1150 L 32024.3253
+ - 0.0279 + - 0.0351 + - 0.0238 + - 0.0122 (meters)
correlations (x-y,x-z,y-z) = 0.20228 -0.68451 -0.72699
N 27155.5488 E 16974.1265 U 112.2888 L 32024.3253
+ - 0.0099 + - 0.0267 + - 0.0420 + - 0.0122 (Meters)
correlations (N-E,N-U,E-U) = -0.51360 -0.12804 0.01121

Baseline vector (m): LOVE(Site 2) to SAFE(Site 5)
X 299.0178 Y(E) -12367.2768 Z -14970.5286 L 19420.4962
+ - 0.0238 + - 0.0313 + - 0.0210 + - 0.0133 (meters)
correlations (x-y,x-z,y-z) = 0.16977 -0.67687 -0.75822
N -18401.3186 E 6195.4832 U 403.8989 L 19420.4962
+ - 0.0076 + - 0.0235 + - 0.0371 + - 0.0133 (Meters)
correlations (N-E,N-U,E-U) = -0.60197 -0.13845 0.06462

The baseline vectors are given both in a geocentric reference frame (XYZ) and in local coordinates (north, east, up) tangent to the reference ellipsoid (changed from spherical with Release 9.92) at the first station of each pair. The sense of the vector is (second station – first station). This presentation of uncertainties is particularly helpful in evaluating the baseline uncertainties for closely spaced stations, neither of which was held fixed in the solution, since in this case the estimates of their coordinates will be highly correlated.

From these estimates, solve then attempts to resolve the narrow-lane ambiguities using first the decision-function criteria for rounding:

Narrow-lane bias-fixing criteria: deviation : 0.15 sigma : 0.15
decision func. : 1000.0 ratio : 10.0
maximum distance : 500.0

Fix No. 199 bias from -7.01 to -7.0
Fix No. 198 bias from 32.02 to 32.0
Fix No. 201 bias from -0.04 to 0.0
Fix No. 197 bias from 151.97 to 152.0
Fix No. 204 bias from 11.92 to 12.0
Fix No. 205 bias from -4.07 to -4.0

In this case, only six of the 12 narrow-lane ambiguities on the two selected baselines were resolved using the decision-function algorithm. The primary reason for this poor performance is the relatively large uncertainties due to the weak fiducial network and large orbital uncertainties. For the ambiguities not resolved by the decision function, solve evaluates the chi-square ratio for a series of solutions generated with different values of the ambiguity parameters, tested five at a time beginning with those with the lowest uncertainties.

(chi2/chi20 - 1.)*sqrt(df): 0.00 5.82 7.20 7.30 7.32 8.37 9.21 9.76 10.72 11.42

Parameter biases:

<table>
<thead>
<tr>
<th></th>
<th>196</th>
<th>200</th>
<th>203</th>
<th>207</th>
<th>210</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32.0</td>
<td>32.0</td>
<td>67.0</td>
<td>0.0</td>
<td>-26.0</td>
</tr>
<tr>
<td>200</td>
<td>32.0</td>
<td>32.0</td>
<td>67.0</td>
<td>0.0</td>
<td>-26.0</td>
</tr>
<tr>
<td>203</td>
<td>67.0</td>
<td>67.0</td>
<td>67.0</td>
<td>0.0</td>
<td>-26.0</td>
</tr>
<tr>
<td>207</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>-26.0</td>
</tr>
<tr>
<td>210</td>
<td>-26.0</td>
<td>-26.0</td>
<td>-26.0</td>
<td>-26.0</td>
<td>-26.0</td>
</tr>
</tbody>
</table>

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In this set of test solutions, none of the bias parameters has the same value for all combinations producing a χ² ratio less than the specified input value (10.0); hence, no additional ambiguities are resolved.

The last section of the Q-file gives the estimates of all of the geodetic parameters from an LC solution in which the resolved wide-lane and narrow-lane bias parameters are held fixed at integer values. Again we list only the estimates for our two sample baselines:

You'll note that resolving ambiguities for these two baselines improved the uncertainties in the horizontal components by up to a factor of two. An important check on whether the phase ambiguities have been resolved correctly may be obtained by comparing the biases-free and biases-fixed estimates of the baseline vectors. In this example the biases-free and biases-fixed estimates from the two solutions agree for all components within the (larger) biases-free uncertainties.

After solve has completed the biases-fixed solution, it repeats both the biases-free and biases-fixed solutions with very loose constraints on all of the parameters in order to obtain an unbiased set of adjustments and covariance matrix for input to GLOBK. These two solutions are saved in the H-file. The details of the loosely constrained solution are...
written to the screen or log file but not saved in the Q-file. The Q-file does record, however, the station, zenith-delay, and orbital constraints used and the normalized rms for the biases-free and biases-fixed solutions:

Loose constraints. All solutions and covariance matrix are stored in H-file.

A priori coordinate errors in kilometers

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATO</td>
<td>0.10000</td>
<td>0.10000</td>
<td>0.10000</td>
</tr>
<tr>
<td>LOVE</td>
<td>0.10000</td>
<td>0.10000</td>
<td>0.10000</td>
</tr>
<tr>
<td>MOJA</td>
<td>0.10000</td>
<td>0.10000</td>
<td>0.10000</td>
</tr>
<tr>
<td>PVER</td>
<td>0.10000</td>
<td>0.10000</td>
<td>0.10000</td>
</tr>
<tr>
<td>SAFE</td>
<td>0.10000</td>
<td>0.10000</td>
<td>0.10000</td>
</tr>
<tr>
<td>WSFD</td>
<td>0.10000</td>
<td>0.10000</td>
<td>0.10000</td>
</tr>
<tr>
<td>YKNF</td>
<td>0.10000</td>
<td>0.10000</td>
<td>0.10000</td>
</tr>
</tbody>
</table>

Keplerian a priori orbital errors (dimensionless except semi-major axis (km))

<table>
<thead>
<tr>
<th>PRN</th>
<th>Semiaxis</th>
<th>Eccen.</th>
<th>Incl.</th>
<th>Asc.node</th>
<th>Perigee</th>
<th>M.anom.</th>
<th>rad1</th>
<th>rad2</th>
<th>..</th>
<th>rad9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2600</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
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<td>1.0E-05</td>
<td>1.0E+01</td>
<td>1.0E+01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.2600</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
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<td>1.0E-05</td>
<td>1.0E+01</td>
<td>1.0E+01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.2600</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
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<td>1.0E-05</td>
<td>1.0E+01</td>
<td>1.0E+01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.2600</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E+01</td>
<td>1.0E+01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.2600</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E+01</td>
<td>1.0E+01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.2600</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E+01</td>
<td>1.0E+01</td>
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<td></td>
</tr>
<tr>
<td>7</td>
<td>0.2600</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E-05</td>
<td>1.0E+01</td>
<td>1.0E+01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A priori zenith-delay errors in meters

<table>
<thead>
<tr>
<th>Station</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATO</td>
<td>0.500</td>
<td>0.005</td>
<td>100.000</td>
</tr>
<tr>
<td>LOVE</td>
<td>0.500</td>
<td>0.005</td>
<td>100.000</td>
</tr>
<tr>
<td>MOJA</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
</tr>
<tr>
<td>PVER</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
</tr>
<tr>
<td>SAFE</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
</tr>
<tr>
<td>WSFD</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
</tr>
<tr>
<td>YKNF</td>
<td>0.500</td>
<td>0.020</td>
<td>100.000</td>
</tr>
</tbody>
</table>

A priori pole position errors in arcs and arcs/day

<table>
<thead>
<tr>
<th>Xp</th>
<th>Xp_rate</th>
<th>Yp</th>
<th>Yp_rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.000</td>
<td>0.300</td>
<td>3.000</td>
<td>0.300</td>
</tr>
</tbody>
</table>

A priori earth rotation errors in sec and sec/day

<table>
<thead>
<tr>
<th>ut1</th>
<th>ut1_rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.000</td>
<td>0.300</td>
</tr>
</tbody>
</table>

A priori atmospheric gradient error in meters at 10 degrees elevation angle

<table>
<thead>
<tr>
<th>Station</th>
<th>North-South</th>
<th>East-West</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATO</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>LOVE</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>MOJA</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>PVER</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>SAFE</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>WSFD</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
<tr>
<td>YKNF</td>
<td>0.01000</td>
<td>0.01000</td>
</tr>
</tbody>
</table>

Total parameters: 265 live parameters: 207
Prefit nrms: 0.11480E+03 Postfit nrms: 0.29258E+00

Total parameters: 265 live parameters: 202
Prefit nrms: 0.11467E+03 Postfit nrms: 0.29274E+00

Normal stop in SOLVE
4. Data Editing

4.1 Introduction

Continuously tracked, doubly differenced carrier phase observations provide an extraordinarily precise data set for estimating GPS orbital parameters and relative site positions; but the strength of the data can be realized only if it is edited properly to be free of cycle slips within each tracking session. Sometimes this is impossible, and we are forced to introduce additional "bias" (offset) parameters that effectively break the phase data into shorter and thus weaker segments. The goal of the analyst (and/or the analysis software) is to remove cycle slips while introducing as few additional parameters as possible. Too many additional bias parameters weakens the solution, but residual cycle slips not absorbed by bias parameters produce erroneous estimates of the important geodetic parameters. To put the problem in perspective, recall that the most common slip in the ionosphere-free linear combination (LC), corresponding to one-cycle slips in L1 and L2, is 0.52 cycles, or 10 cm in equivalent pathlength. Since our usual goal is few-millimeter estimates of station positions, a single undetected slip can be (but not always is) quite serious.

Strictly speaking, we require only that all cycle slips be fixed (or covered by bias parameters) in the doubly differenced phases since those are the data used by solve in its estimation. As a practical matter, however, the editing process is much simpler if cycle slips can be identified and repaired in the data from a single station and satellite. This "one-way" observable is dominated by variations in the station and satellite oscillators ("clocks"), which must be removed in the editing process. Analysis programs use two approaches to accomplish this task. With modern receivers the pseudoranges at both the L1 and L2 frequencies can be combined with the phases to produce a "wide-lane" observable that is free of both oscillator and ionospheric effects (see, e.g., Blewitt [1990]). This approach breaks down when the pseudoranges are noisy (from multipath or a poorly functioning receiver) and for equal slips in the L1 and L2 phases, which show no break in the wide-lane. A second approach, used in conjunction with the widelane, determines the source and size of a cycle slip by comparing a number of double difference combinations.

With the large number of satellites and stations now used in most surveys, automatic editing is essential for the sanity of the analyst. Fortunately, autcln, the automatic editor developed by Tom Herring, has reached a level of maturity that it can handle both regional and global networks with only occasional manual intervention. In its postfit mode it can remove clock effects and provide reliable statistics for the performance of each station. The key to efficient processing is learning to use the outputs of solve, autcln, and the scanning routines to determine quickly if a problem exists, and then to use the interactive editor, cview, together with autcln to perform an effective fix. In the next three sections we describe the most important features of these programs and how to run them. Then in Section 4.5, we discuss efficient strategies for editing.
4.2 Automatic editing using autcln

*autcln* uses the residuals written to the C-file by *model*, performs automatic editing, and writes an output C-file with outliers removed, cycle-slips repaired, and extra bias flags inserted for slips that cannot be reliably repaired. A new feature in *autcln* 3.0 estimates station and satellite oscillator variations ("phase clocks") and allows reading of an M-file updated by *solve* so that editing can be performed on (one-way) predicted postfit residuals (see the formula in Section 4.4). *autcln* is invoked with four command-line arguments:

\[
\text{autcln [command-file] [out C-file series] [D-file] [input C-file series]}
\]

or

\[
\text{[list of C-files]}
\]

The first argument gives the *autcln* command-file name. The command file can be omitted by substituting '' for the file name, and *autcln* will use the default values for all parameters. For a GAMIT batch run, *fixdrv* invokes the script sh_autedit which will always create a command file of the name *autcln.cmd.prefit*, even if there is no "base" command file present, and optionally a command file of the name *autcln.cmd.postfit*. The second command-line argument is a single character used to determine the name(s) of the output C-files. If an alphanumeric character is given (e.g., a), then the output C-file names will be the same as the input but with this character substituted for the 6th character of the input series (usually the last digit of the year or a letter). Two special characters are used: . to keep the same 6th character as the input files, overwriting the input files; + to create new files with the 6th character incremented (i.e., \[yr\] => a, a => b). If no character is given (i.e., '' used), then no updated C-files will be written. The input C-files are specified either by a D-file name followed by a character indicating the series (6th character of name), or by a complete list of the C-files to be used. *fixdrv* creates one of two forms of the *autcln* command-line:

\[
\text{autcln autcln.cmd.prefit . dvent7.278 7}
\]

if the input C-files are to be deleted (overwritten and then incremented using the *mvcf* script), or

\[
\text{autcln autcln.cmd.prefit + dvent7.278 7}
\]

if the old C-files are to be retained.

The following is a sample *autcln.cmd* file, listing the options most often invoked. This example is kept current in *pub/gps/updates/templates* in the GAMIT/GLOBK ftp directory.

* Command file for AUTCLN version 3.125 to be used for global and regional data
* Default values are listed with comment flag (non-blank first character)
* Last edited by tah/rwk/scm 000928
* Don't use any GAMIT edits

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use_gamit  no

* Remove more bias flags by allowing a base satellite if multiple slips
  allow_one_bg  yes

* Set minimum elevation for editing and output: 15 10 better for older receivers
* also sets minimum SNR
  site_param all 10 10 0 0

* Set the ionospheric tolerances so you don't throw out too much data.
* These are the current defaults and will work under both low and high
* ionospheric conditions with well-behaved receivers. For poorly tracking
* receivers and low ionosphere, you can improve the editing using
  * 240 4 0.3 0.8.
*  ion_jump all   30  6 2 5

* Criteria for detecting slips (initial bias flags). Defaults shown.
* First three are for WL, irrelevant for codeless L2 receivers
* Second three (LC) might be set tighter (e.g. 4 0.2 0.5) to catch
* partial-cycle jumps with poorly performing receivers.
* With poor coordinates, set the last two numbers to 2 5 (or 5 10)
* but use the defaults for POST or, with noisy data, skip the postfit
* edit until a second pass with good coordinates allows tight detection of jumps.
  * dd_fit_tol 5 2 10   3 0.35 0.8

* The following three commands control the repair of cycle slips and subsequent
* removed of bias flags. The default values are conservative in the sense
* that they retain the most data. They are optimal for global networks but
* will work ok also for regional networks. However, for better ambiguity
* resolution in regional networks, different values are optimal.
* Set the tolerances used in trimming the one-way data to remove small
* segments between bias flags. The following are defaults:
  * trim_oneway  120  8 0.1  24
  * For regional networks use
    trim_oneway  1000 10  0.2  50
  * The first two parameters are the minimum times in seconds and minimum
  * epochs for attempting to remove a bias flag; the last two are the minimum
  * fraction of total span and minimum number of epochs allowed after last bias
  * flag. To strengthen ambiguity resolution for regional data, increase the
  * last two parameters. For fewer bias flags in 24-hr data increase the first
  * two parameters.
  *
  * Number of data used to repair cycle slips. Defaults are ok for all data but
  * all values could be reduced for data sampled less often than 30s.
  * dd_return_site  100  50 10 10
  *
  * DD criteria for removing bias flags: chi-sq ratio  chi-sq min  max gap  gap scale
  * For global networks use
    * remove_bias 10 3 1800 5
  * For regional networks use
    remove_bias 10 3 3600 5
  * For fewer flags but more risk over small gaps, decrease the first value (see
  * autcln.out). For fewer flags and more risk over large gaps, increase the

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* third and decrease the fourth,

* Maximum number of bias flags per SV before deleting all the data.
  * Default infinite (not checked).
    
    max_scan_edit 30

* To enhance numerical stability in SOLVE (but be careful in interpreting
* one-way residuals)
    
    apply_phs_clk 1

* Set the summary filename to agree with the command file produced by FIXDRV
  
  summary autcln.prefit.sum

* Commands to be used if post-fit editing invoked in the sestbl.
  POST summary autcln.post.sum
  POST apply_phs_clk 30
  POST use_postfit
  POST postfit_edit 10 4.0
  POST pf_remove_bf
  POST remove_bias 10 3 3600 2
  POST phs_res_root DPH

* Explicit edits added by sh_autedit or the analyst
  x edit_site_sv algo 0 1 2800
  x edit_site_sv all 23 1 400
  x edit_site_sv trom 15 451 460

The first command (use_gamit no) tells autcln to ignore any loss-of-lock indicators inserted by the receivers. Selecting this option is a change from past practice, made necessary by the large number of bogus slips flagged by some receivers.

The second command (allow_one_bg) deals with the case where all channels of a receiver slip at nearly the same time, preventing autcln from patching unambiguously in the one-way observations. By specifying yes to this command, you allow autcln to select one channel (satellite) as 'base', patch it roughly in one-ways, and then patch all other channels with respect to it. Since this option applies only to multiple-satellite slips, not multiple-station slips, allowing the patch will not create problems if the data are later combined in a different network configuration. The default for this command is no, but yes will usually provide better editing. Occasionally, however, autcln will make a mistake in using this mode (yes) when the slips are at slightly different epochs.

The next command sets the minimum elevation angles for autcln to examine (first value) and retain (second value) the data. If the min_elevation command is used after the site_params command, all stations will be given the cut-off elevation angle specified in the min_elevation command. It also specifies the minimum signal-to-noise ratio (SNR) for L1 (third value) and L2 (fourth values) in order for the data to be used. Additional
commands, with all replaced by the station code, can be added to raise the cutoff for poorly functioning receivers or lower it for modern receivers in cases where you want to examine very low elevation data.

The next three commands control the removal of bad data. The ion_jump criteria are applied to the undifferenced ("one-way") LG observations in attempting to detect noise from bad receiver performance. The thresholds must be set high enough so that LG noise from high ionospheric fluctuations is not confused with receiver noise. The default values (shown) are set high enough that the ionosphere does not trigger rejection even for polar and equatorial stations near solar maximum, and thus they provide only a loose filter for bad data. If you need a tighter filter to detect problems with older receivers tracking in mid-latitude regions, you may reset the the ion_jump parameters to [station] 240 4 0.3 0.8.

The dd_fit_tol command controls the detection of cycle slips in the doubly differenced LC phase and widelane (WL) observables. It may have to be changed if you have poor a priori coordinates, causing autcln to interpret systematic point-to-point differences as cycle slips) or if you have the a large number of small cycle slips that can occur with codeless receivers. The first three parameters ( 5 2 10 ) apply to the widelane (WL) observable and are thus relevant only for P-code receivers; the second three ( 3 0.35 0.8 ) apply to the doubly differenced LC observable. They specify, respectively, the ratio of an allowed jump to the rms of the segment of data being examined, the minimum value of a jump that will be flagged, and the maximum value above which all jumps will be flagged. The tolerance of the maximum jump allowed without incurring a bias flag will fall between the minimum and maximum specified, with the intermediate values set by the ratio times the local rms. Thus the default values for LC allow for a maximum jump between 0.35 and 0.8 cycles. Values this high imply that the receiver is not likely to allow one-cycle slips in L1 and L2 (leading to 0.5 in LC). If you find from cview or your scan output that autcln is failing to detect some cycle slips, you should reset the LC values to 4 0.2 0.5. If cview indicates a large slope, suggesting bad a priori coordinates, you should loosen the last three values to 3 5 10 , in the initial (prefit) autcln run, restoring them to the defaults for the postfit run (see Strategies for Editing, Section 45).

The trim_oneway command is used to remove small segments of data that may encumber the repair of cycle slips or the resolution of the overall phase ambiguity. The first two values ( 120 8 ) are the minimum time in seconds and the minimum number of epochs between bias flags. If you find segments (using cview) for which a single gap of, for example, 5 or 10 minutes would result in a more reliable cycle slip repair than would multiple smaller gaps, then you should increase these values. The second two values ( 0.1 24 ) are the minimum fraction of the total span and the minimum number of epochs allowed after the last bias flag. Since solve attempts to resolve the ambiguity using only the last segment of data, removing even a fairly long but noisy segment of data at the end may result in lower parameter uncertainties by allowing resolution of additional ambiguities.
The next group of entries control the repairing of cycle slips and subsequent removal of bias flags. They provide your primary control for the final stage of editing. The `dd_return_size` command sets the number of data used on each side in the repair; the default values (100 50 10) imply segments of 50 minutes, 25 minutes, and 5 minutes for one-way WL and doubly differenced LC and LG, respectively, for data sampled at 30s intervals. For 120s sampling you probably want to reduce these values by factors of 2 to 4. The `remove_bias` command sets the actual criteria used to remove a bias flag. The algorithm uses a comparison of the chi-square for the data segment (set by `dd_return_size`) for the "best" choice of integer with the chi-square for the next best choice. The first value (10) gives the threshold ratio and the second (3) a minimum value used to make the comparison more robust (see the description of the command in Section 5.6). Increasing the first value provides a more conservative edit (fewer bias flags removed), and decreasing it a more aggressive one. The last two values control how large gaps are treated. The third (3600 seconds) sets the maximum gap for which a bias flag will be removed; the fourth (5.0) is a "gap factor" that scales the computed chi-square such that it becomes harder to remove a bias flag for large gaps (see the exact definition in Section 5.6). In Section 5.6 we describe how you can use the `autcln` output to determine why a bias flag was inconveniently or improperly left or removed and how you can tune the `remove_bias` values to change the action.

The `max_scan_edit` command sets limit on the number of bias flags added to the data for a particular station and satellite before `autcln` decides it would be better off deleting all of the data from that combination.

The `apply_phs_clk` command invokes estimation of satellite and station oscillator variations epoch by epoch. Its primary use in `autcln` is in 'postfit' mode (see below), in which the adjustments from `solve` are used to flatten the residuals on which `autcln` works to repair cycle slips. The phase-clock estimation is performed iteratively, with the argument of the command indicating how many iterations may be performed. A dozen or more iterations may be necessary to get a good estimate, but if you are not invoking postfit editing, you should use `apply_phs_clk` with a single iteration, which will serve to remove large jumps the in data that often create numerical problems in `solve`. Keep in mind, however, that when you use `apply_phs_clk` with only one iteration, errors in the clock estimates will produce artifacts (fractional-cycle jumps) in the one-way (undifferenced) phase residuals in `cview`. These cancel in double differences and of course are no more a problem than the much greater clock noise present when you do not remove part of the clock terms at all—it's just that in the latter case the one-way residuals are so large (> 100 cycles) that you don't expect to use them for editing. (Note that the default number of iterations for `apply_phs_clk` is 30, appropriate for post-fit editing, so the 1 is required is you want to save computation time in the pre-fit mode.)

Finally in this section we have an explicit entry for the `autcln` summary file (discussed below). This assures that the pre-fit and post-fit summaries will be saved with different file names.
As discussed in Section 5.2, we now recommend using the postfit feature of *autcln* even though this will increase computation time by 30 to 80% and the postfit *autcln* will occasionally fail with bad data. The situations most likely to be helped are the recovery of low-elevation data for estimating atmospheric parameters and the need to detect and remove data affected by systematic, low-amplitude errors resulting from poorly modeled satellite yaw, multipathing, or severe short-period tropospheric water vapor. Equally important, however, is the ability to examine one-way residuals (in the *autcln.sum* file and with *cview*) generated by *apply_phs_clk* and *use_postfit* to study the performance of stations at all levels of quality and to isolate a problem station or satellite when the pre-fit edit has failed to produce satisfactory results. There are two new controls in postfit mode. The command *postfit_edit* allows removal of data based on its deviation from the mean of the series, rather than just point to point changes. The first argument indicates at what iteration you want *autcln* to start this process, the second the sigma criterion to apply, and the third the maximum residual (in cycles) for which a data point can be restored if it was previously removed because it was close to a bias flag. The defaults are to start editing at the 10th iteration, to use a 4-sigma criterion, and not to restore any previously deleted data. The command *pf_remove_bf* allows *autcln* to remove bias flags in one-way residuals after editing. It is reasonable to forego the threshold editing (to avoid lopping the tops off large oscillations) but still invoke postfit bias-flag removal.

The final set of commands in the example, *edit_site_sv*, allow you to control the results by asking *autcln* explicitly to delete (unweight) certain segments of data that you have identified by *cview* to be problematic or have determined from other information (station or satellite logs) should be ignored. The first argument is the station 4-character code, or *all*; the second is the satellite PRN number, with 0 signifying all satellites; the third and fourth are the range of epochs over which data should be unweighted. The shell command *sh_autedit* written into the batch file by *fixdrv* creates additional *edit_site_sv* commands for *autcln.cmd.pre* and *autcln.cmd.post* in response to *sestbl* entries controlling the use of data during and after satellite eclipses.

Other entries in the *autcln.cmd* file are described in Section 5.6. Note in particular the commands which allow you to use flags inserted by *cview* (*use_cview_edit*), control the tolerance for clock resets (*clk_reset_tol*), specify station-specific editing (*site_params*), and remove extra bias flags at the beginning of a station-satellite data segment (*remove_first_bia*).

*autcln* produces two output files which are quite useful for diagnosing problems. Usually you will need to examine only the summary file, *autcln.sum*. The first two tables provide a compact indication of whether one or more stations or satellites are anomalous. The first is a summary of the clock behavior:

```
Clock and Range noise statistics at iteration 3

<table>
<thead>
<tr>
<th>Site/PRN</th>
<th>Allan SD@100  #</th>
<th>Range rms  #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sec (ppb)</td>
<td>(mm)</td>
</tr>
<tr>
<td>BRLD</td>
<td>19.761493 2832</td>
<td>596.9 16210 TRM</td>
</tr>
<tr>
<td>KAIN</td>
<td>19.931665 2879</td>
<td>675.1 15939 TRM</td>
</tr>
<tr>
<td>KIT3</td>
<td>.527232 2879</td>
<td>729.9 16307 TRB</td>
</tr>
</tbody>
</table>
```

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The Allen standard deviation at 100s is given (in parts per billion) for each station and satellite. Station clock values in excess of 50 ppb (5 parts in 10\(^8\)) indicate variations larger than those expected for well-tuned crystal oscillators in any of the commonly used receivers. Atomic oscillators (Rubidium, Cesium, or Hydrogen-maser) should show values below 1 ppb. A bad clock does not necessarily mean bad phase data but increases the chances of cycle slips and degrades the ability of `autclin` to perform a proper edit. The fourth column gives the rms of range noise in millimeters for each station. For P-code receivers under non-AS conditions, these values should be under a meter; under AS, some will increase to 1000–2000 mm. Values larger than this usually mean lots of bad range data or bad prefit residuals (station coordinate errors > 10 m). The 3rd and 5th columns of the list are simply the number (#) of observations used in the calculation.

Following the clock summary is a listing of the number of bias flags added during the initial double-difference scan:

```
DDScan bias flags added report for pass 1
SITE PN01 02 05 06 07 09 14 15 16 22 23 24 25 26 27 28 29 31
BRLD 6 2 10 8 14 10 6 4 12 7 0 2 2 0 0
KAIN 0 0 0 0 0 0 1 1 0 0 0 0 0 1 0 0
KIT3 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0
KUM6 0 2 0 2 0 0 0 0 0 2 0 0 0 0 0 0
KUMB 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
LHAS 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
```

In this example station BRLD is performing poorly relative to the others but may not have fatal errors. Many bias flags added can mean either bad prefit residuals or bad phase data. Too many flags for a satellite at more than one station usually represents the effect of an unmodeled acceleration of the satellite (e.g., unmodeled thrusting).

If you have selected postfit editing in `autclin`, the next four tables give the actual postfit phase statistics for each station and satellite after correcting the residuals for adjustments in the parameters (using the M-file from the first `solve` solution) and estimating station and satellite clocks epoch-by-epoch from the phases. The most useful of the tables is the first, containing the rms scatter of the one-way residuals:

```
ONE-WAY POSTFIT RESIDUAL STATISTICS: Pass 20

RMS by site and satellite (mm): Pass 20
SITE IT Site All 01 02 03 04 05 06 07 09 10 14 15 16 17 18 19 21 22 ...31
RMS 20 IISC 5.9 6 5 7 6 6 5 5 6 4 6 8 6 5 6 6 6 5 ... 6
RMS 20 KIT3 4.9 4 4 5 5 6 4 5 5 5 4 6 5 4 5 4 5 4 ... 5
RMS 20 LAAS 4.6 4 4 5 4 7 5 3 6 3 6 5 6 3 5 4 4 4 ... 5
RMS 20 NAGA 6.0 5 6 6 8 6 5 5 6 6 6 7 6 6 6 5 7 ... 5
RMS 20 NAMC 3.5 3 3 4 3 0 0 3 4 0 4 4 4 3 4 3 4 4 ... 4
RMS 20 SHAO 3.9 4 4 3 3 4 5 4 4 4 5 4 4 4 4 4 4 ... 4
RMS 20 TAIW 4.2 4 4 4 3 5 5 4 4 4 4 4 4 4 4 4 4 ... 4
RMS 20 TSKB 3.9 4 4 3 4 5 3 3 3 3 3 4 4 4 4 4 4 ... 3
RMS 20 USUD 3.7 4 5 4 3 3 4 3 3 3 3 4 4 4 4 4 4 ... 4
```

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From this table you can see at a glance if there is a station or satellite whose residuals are significantly higher than the others. Values between 3 and 5 mm for "clean" stations, and 6 and 10 mm for stations with larger than average multipath are typical. Values larger than this suggest a problem that may affect your solution. Since the calculation of one-way residuals requires explicit estimation of the station clock, it is possible that this calculation in autcln will fail even though you have obtained a good solution in solve using double differences. In this case, the values in the table will be large, most likely overflowing their field (*****). The cause is almost always bad ranges near the beginning of a satellite's pass, when autcln needs these to obtain an initial estimate of the phase clocks. You can identify the culprit station by grep'ing on 'JMP BIAS' in the autcln.out file:

```
JMP BIAS flag added at 1770 Site BRLD PRN 22          90744182.40     1000.0
... Updating at 1771 site BRLD PRN 04 cycles by 113430205.0 88387170.0 Pass 1 ...
JMP BIAS flag added at 1771 Site BRLD PRN 06          75620154.59     1000.0
JMP BIAS flag added at 1771 Site BRLD PRN 22          75620154.59     1000.0
```

There will always be some messages of this type in the file, and most of the time autcln has handled the clock jump correctly. However, if you see a string of these messages together, associated with several satellites or stations and with very large values, this is a good indication that autcln has miscalculated the clock at an epoch just prior to the ones shown. You can identify the problem by displaying the wide lanes in cview, and fix it by adding explicit edits to autcln.cmd using the `edit_site_sv` command. The other three tables associated with postfit editing are described in Section 5.6.

In addition to the rms (RMS) statistics, there are also tables of the mean (AVG) and 25-point-averaged rms (AMS) values, and the rms as a function of elevation angle. The AMS table also includes the ratio of the 25-point average rms to the single-point rms (RMS) and is useful for determining whether the scatter is dominated by random, short-term noise or long-period variations. In the case of random variations, the ratio should be 5.0; typical values are between 1.5 and 2.0; values near 1.0 indicate a stronger-than-usual dominance of long-period variations.

```
RMS of 25-point averages by site and satellite (mm): Pass 20

| Site | All | Ratio | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|------|-----|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| AMS  | 20  | IIIS  | 3.3| 1.77| 4  | 2  | 3  | 3  | 5  | 4  | 4  | 4  | 4  | 4  | 5  | 3  | 4  | 2  | 5  | 2  | 3  | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
| AMS  | 20  | KIT3  | 2.8| 1.70| 2  | 3  | 2  | 4  | 5  | 2  | 4  | 2  | 4  | 3  | 3  | 3  | 2  | 2  | 3  | 2  | 3  | 2  | 3  | 2  | 3  | 2  | 3  | 2  | 3  | 2  |
| AMS  | 20  | LHAS  | 2.6| 1.76| 2  | 2  | 3  | 2  | 4  | 1  | 2  | 2  | 4  | 3  | 3  | 1  | 3  | 2  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
| AMS  | 20  | NAGA  | 4.3| 1.39| 3  | 5  | 4  | 7  | 2  | 4  | 3  | 4  | 4  | 3  | 4  | 5  | 4  | 5  | 5  | 5  | 3  | 5  | 3  | 5  | 3  | 5  | 3  | 5  | 3  | 5  |
| AMS  | 20  | NAMC  | 2.0| 1.74| 1  | 2  | 2  | 2  | 0  | 0  | 2  | 0  | 1  | 2  | 2  | 2  | 2  | 2  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
| AMS  | 20  | SHAO  | 2.3| 1.67| 3  | 2  | 2  | 2  | 2  | 3  | 2  | 3  | 3  | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
| AMS  | 20  | TAIW  | 2.6| 1.59| 2  | 3  | 3  | 2  | 3  | 2  | 2  | 2  | 2  | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
| AMS  | 20  | TSKB  | 2.2| 1.74| 2  | 3  | 3  | 2  | 2  | 2  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
| AMS  | 20  | USUD  | 2.2| 1.70| 2  | 3  | 2  | 2  | 2  | 3  | 2  | 1  | 2  | 2  | 2  | 1  | 1  | 1  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
```

The table of rms as a function of elevation angle will also always show that the scatter is higher at low elevations, but since almost all error sources (orbital errors as well as
multopath and tropospheric effects) show this pattern, you should view the phase residual plots (DPHS) and make careful comparisons between stations and between successive days before drawing conclusions. The values in this table are used by script sh_sigelv to produce elevation-dependent weightings (N-file) for solve.

\[ \text{Elevation angle dependent RMS statistics} \]
\[ \text{MODEL: } \text{RMS}^2 = A^2 + \frac{B^2}{\sin(\text{elv})^2} \]

| SITE  | A    | B    | 0-05 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | ... | 85-90 |
|-------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|     |       |
| ATELV | 4.3  | 1.8  | 0.0  | 0.0  | 8.6   | 8.1   | 7.8   | 7.0   | 5.8   | 5.3   | 4.5   | 4.2   | ... | 4.3   |
| ATELV | 3.5  | 1.7  | 0.0  | 0.0  | 7.9   | 7.2   | 6.5   | 4.9   | 5.4   | 4.6   | 4.1   | 3.8   | ... | 3.2   |
| ATELV | 2.9  | 1.7  | 0.0  | 0.0  | 7.4   | 7.8   | 6.5   | 4.7   | 4.7   | 3.7   | 3.6   | 3.3   | ... | 0.0   |
| ATELV | 7.8  | 0.0  | 0.0  | 0.0  | 9.4   | 7.2   | 5.9   | 4.9   | 4.5   | 3.9   | 3.8   | 3.8   | ... | 4.2   |
| ATELV | 2.3  | 1.2  | 0.0  | 0.0  | 5.4   | 5.5   | 4.7   | 4.0   | 3.4   | 3.3   | 3.0   | 2.7   | ... | 1.3   |
| ATELV | 2.5  | 1.2  | 0.0  | 0.0  | 5.9   | 5.1   | 4.3   | 4.4   | 3.9   | 3.7   | 2.7   | 2.9   | ... | 2.4   |
| ATELV | 3.4  | 1.2  | 0.0  | 0.0  | 5.7   | 6.6   | 5.4   | 4.6   | 3.9   | 3.7   | 3.6   | 3.7   | ... | 4.6   |
| ATELV | 2.7  | 1.4  | 0.0  | 0.0  | 6.5   | 6.3   | 4.6   | 3.7   | 3.4   | 3.1   | 2.9   | 2.9   | ... | 4.0   |
| ATELV | 2.4  | 1.4  | 0.0  | 0.0  | 6.6   | 5.6   | 4.2   | 3.9   | 3.2   | 3.2   | 3.2   | 2.9   | ... | 3.5   |

A good edit of the data should not only produce a small rms scatter but also leave few extra bias flags in gaps or associated with repaired cycle slips. The DATA AMOUNTS table of autcln.sum reports this information for both pre- and post-fit runs:

<table>
<thead>
<tr>
<th>SITE</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
<th>PRN</th>
<th>Good</th>
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<th>Gap</th>
<th>BF</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORT</td>
<td>PN01</td>
<td>657</td>
<td>0</td>
<td>0</td>
<td>PN02</td>
<td>699</td>
<td>4</td>
<td>0</td>
<td>PN03</td>
<td>649</td>
<td>0</td>
<td>0</td>
<td>PN04</td>
<td>649</td>
<td>0</td>
<td>0</td>
<td>PN05</td>
<td>649</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PN06</td>
<td>945</td>
<td>0</td>
<td>0</td>
<td>PN07</td>
<td>133</td>
<td>7</td>
<td>0</td>
<td>PN08</td>
<td>648</td>
<td>0</td>
<td>0</td>
<td>PN09</td>
<td>477</td>
<td>0</td>
<td>1</td>
<td>PN10</td>
<td>813</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PN15</td>
<td>444</td>
<td>1</td>
<td>0</td>
<td>PN16</td>
<td>1119</td>
<td>2</td>
<td>2</td>
<td>PN17</td>
<td>813</td>
<td>0</td>
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<td>PN18</td>
<td>782</td>
<td>0</td>
<td>0</td>
<td>PN19</td>
<td>782</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PN19</td>
<td>1047</td>
<td>0</td>
<td>0</td>
<td>PN20</td>
<td>470</td>
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<td>2</td>
<td>PN21</td>
<td>962</td>
<td>0</td>
<td>0</td>
<td>PN22</td>
<td>1125</td>
<td>0</td>
<td>0</td>
<td>PN23</td>
<td>1125</td>
<td>0</td>
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<td>0</td>
<td>PN24</td>
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<td>1032</td>
<td>0</td>
<td>0</td>
<td>PN26</td>
<td>1132</td>
<td>0</td>
<td>0</td>
<td>PN27</td>
<td>1132</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

For each one-way sequence, the table shows the number of good data in the one-way sequence (Good), the number of data deleted in gaps between closely spaced bias flags (Gap), and the number of remaining bias flags that might be resolved (BF) (i.e., the number of bias flags separated by less than twice the maximum size over which a flag would be removed). A number greater than a few dozen in the Gap column and/or greater than 3 in the BF column usually means bad pre-fit residuals or noisy data.

If all of the data from a station have been deleted by autcln, the reason can usually be assessed from the editing report:

<table>
<thead>
<tr>
<th>SITE</th>
<th>MnCLN</th>
<th>MnOUT</th>
<th>SNR</th>
<th>LSNR</th>
<th>GF03</th>
<th>RCLK</th>
<th>GF02</th>
<th>BEND</th>
<th>BCLS</th>
<th>NFED</th>
<th>GF-1</th>
<th>GF04</th>
<th>DDSC</th>
<th>PFED</th>
<th>GFUN</th>
<th>BDL2</th>
<th>NODD</th>
<th>ELEV</th>
<th>EDIT</th>
<th>MMRG</th>
<th>ELCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>(deg)</td>
<td>(deg)</td>
<td>L1</td>
<td>L2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OBSV</td>
<td>10.00</td>
<td>10.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3640</td>
<td>83</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RCUT</td>
<td>15.00</td>
<td>15.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UCL1</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>2</td>
<td>589</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

In this case the data for station OBSV were removed due to double difference scanning errors (DDSC). This usually means that there are large slopes in the double difference residuals, most likely due to bad apriori coordinates. The AUTCN output file (autcln.out) can be scanned to see how large these scanning jumps were, and if they are not too large

28 September 2006
DD_FIT_TOL can be increased to allow the data through. sh_svdiff can also be used to improve the a priori coordinates.

The summary for RCUT suggests that autcln never saw the data at all, as you can confirm by looking at the top of the file for the number of data used in the range clock estimates. The most common reasons for this to occur are no valid L2 range/phase data even though the RINEX header said these data were available (check the RINEX header and data file), or all the range data are so bad (pre-scan range errors) that none of them were accepted in the solution. The autcln tolerances can be reset to allow very bad range data to get through the cleaning, but these range data are used to compute the clock epoch corrections in model, so if the range data are corrupted (AVCLK errors in model) then the epoch of the phase measurement is not computed correctly. Double difference phase residuals can still look smooth (but systematic) in this case but the position determination will probably not be good (i.e., several centimeters of error). Ideally, we want the epoch of phase measurement known to 1 micro-seconds which corresponds to 300 meters of range error. Allowing ranges error too much larger than this can corrupt the position estimates.

The data for UCL1 were deleted due to the postfit residuals being too large (PFED column). A check of the autcln messages in the GAMIT.status file shows that when the station was removed, the RMS was 2.7 meters:

```
STATUS :991127:0714:11.0 AUTCLN/main: +Phase clock and bias estimation pass 14
STATUS :991127:0714:11.0 AUTCLN/pf_check_rms: Removing UCL1 Postfit RMS 2766.1 mm too large. Num 4920 Limit 190.3 mm
```

(The autcln output file can be grep'd for '^RMS .. ' to get the RMS of all stations as a function of iteration.) Sometime these large residuals are due to the prefit GAMIT run being bad (i.e., large nrm), which corrupts the residuals in the postfit run. If the sestbl. contains AUTCLN Postfit = R, then the postfit solution will be run twice if the pre-fit GAMIT solution is bad. Check the P-file for AVCLK errors, and then possibly the I- and K-files to pinpoint the time and cause, and the Q-file for the sizes of the adjustments. In the case shown here, the prefit autcln run detected many DD scan errors, so most likely the a priori coordinates for the site are bad.

The other tables in the autcln.sum file and the use of the autcln.out file for tracing problems are discussed in Chapter 5.

If you have the setenv variable of your .login file referencing the stdrel/help directory, you can take advantage of an extensive on-line help file for autcln. To view the current parameter defaults, type autcln defaults.

### 4.3 Scanning the residuals to identify slips

With the postfit editing capability of autcln, it is seldom necessary to perform a separate scan of the phase residuals to identify problematic data. Several programs and scripts are
available, however. All take as input the M-file from a quick or full solution and operate on the predicted postfit LC doubly differenced residuals. The most commonly used program, an optional part of the batch sequence, is `scandd`. You can run it directly by typing the program name and the M-file from the `solve` solution:

```
scandd mventa.278
```

Omitting the M-file will put `scandd` into an interactive mode, allowing you to select only certain stations, scan pre-fit (rather than post-fit) residuals, or scan a set of C-files with different 6th character.

`scandd` calculates the LC root-mean square (rms) of each double-difference series and searches for jumps in the doubly differenced LC residuals. It also identifies all possible cycle slips and compiles a list of corrections that can be used directly as input to `cview`. `scandd` produces three output files, each with a slightly different summary of the doubly differenced residuals. The file most analysts find easiest to use in identifying potential cycle slips is called `vscan.out`, which lists the largest LC "jumps" for each double-difference series. A distinction is made between jumps that are associated with bias flags ("flagged"), which do not corrupt a "full" or "regular" `solve` solution, and those that have not had extra bias flags assigned ("unflagged"). You can obtain a sorted version of this file by running the shell script `sortv` to sort the file `vscan.out` by epoch and produce two additional files, one listing the largest slip for every double difference combination, the other (more useful for large networks) listing only the 80 worst slips. Shown below is the output of the second of these files, named `vxxxx1.ddd.worst`, where the experiment name (`xxxxx`), type of solution (1), and day number (`ddd`) are taken from the M-file name.

```
80 worst jumps

<table>
<thead>
<tr>
<th>CHAN1</th>
<th>CHAN2</th>
<th>SIT1</th>
<th>SIT2</th>
<th>NDATA</th>
<th>RMS</th>
<th>EPOCH (F)</th>
<th>FLAGGED</th>
<th>EPOCH (U)</th>
<th>UNFLAGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>496</td>
<td>0.27</td>
<td>712</td>
<td>-1.02</td>
<td>713</td>
<td>-1.41</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>7</td>
<td>9</td>
<td>441</td>
<td>0.45</td>
<td>712</td>
<td>+1.23</td>
<td>713</td>
<td>+1.40</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>517</td>
<td>0.26</td>
<td>712</td>
<td>-1.21</td>
<td>713</td>
<td>-1.40</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>529</td>
<td>0.40</td>
<td>712</td>
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<td>713</td>
<td>+1.38</td>
</tr>
<tr>
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<td>4</td>
<td>7</td>
<td>10</td>
<td>531</td>
<td>0.40</td>
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<td>+1.38</td>
<td>713</td>
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<td>1</td>
<td>7</td>
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<td>712</td>
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<td>713</td>
<td>-1.34</td>
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<td>7</td>
<td>530</td>
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<td>-1.32</td>
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<td>7</td>
<td>532</td>
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<td>-1.27</td>
</tr>
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<td>7</td>
<td>9</td>
<td>165</td>
<td>0.20</td>
<td>423</td>
<td>-1.29</td>
<td>360</td>
<td>-0.40</td>
</tr>
</tbody>
</table>

... 68 lines deleted ...

3     | 4     | 7    | 10   | 392   | 0.12 | 503       | -0.19    | 366       | -0.27   |
```

This file can be used as a guide to interactive editing using `cview` since the epoch of the largest jump, and the double-difference combination affected, are shown. In the list shown above, for example, the repeated appearance of the same computed unflagged (u) LC jump at epoch 713 indicates that a cycle slip occurred at site 7 in either channel 2 or 4. If renamed to `cview.list`, it can also be read into `cview` and used to skip directly to the potential cycle slips in the list.
A second summary of potential slips is file scan.dd. It differs from vscan.out in listing all of the potential slips (not just the largest in each series) and suggesting the number of L1 and L2 cycles to be added or subtracted to fix them. It also includes an indicator for bias flags on each of the channels. By including all flagged and unflagged slips, however, scan.dd provides a larger and more complicated file than one usually needs after running autcln. To use scan.dd it is usually best to sort it by epoch by running program sorter, which will ask you to select for inclusion slips associated with series with rms values above a given value:

% sorter

CHOOSE A LOWER BOUND TO SORT SCAN.RMS (e.g. 0.8) : 0.1

An rms below 0.1 cycle usually indicates that there are no slips in the series. You may also exclude from the sorted list a satellite and/or station:

ENTER SAT AND SITE TO EXCLUDE (e.g. 3 0 or CR to skip) :

An abbreviated example of the output file, dd.srt, is shown below. The column headers are not printed by the program but have been added here for clarity.

<table>
<thead>
<tr>
<th>Predicted slip</th>
<th>Epoch</th>
<th>LC full rms</th>
<th>Chan 1</th>
<th>Chan 2</th>
<th>Site 1</th>
<th>Site 2</th>
<th>L1</th>
<th>L2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 199</td>
<td>0.05</td>
<td>4 2 8 1</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 199</td>
<td>0.05</td>
<td>4 2 9 1</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 199</td>
<td>0.06</td>
<td>4 2 5 1</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 199</td>
<td>0.06</td>
<td>4 2 6 1</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 199</td>
<td>0.06</td>
<td>4 2 10 1</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 199</td>
<td>0.07</td>
<td>4 2 3 1</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>127 476</td>
<td>0.13</td>
<td>6 5 14 6</td>
<td>0.00</td>
<td>-1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>128 477</td>
<td>0.12</td>
<td>6 5 14 5</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>129 477</td>
<td>0.13</td>
<td>6 5 14 9</td>
<td>-1.00</td>
<td>-2.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>130 477</td>
<td>0.15</td>
<td>6 5 14 4</td>
<td>-1.00</td>
<td>-2.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this example, the repeated appearance of the same computed L1 jump at epoch 199 indicates that a cycle slip occurred at site 1 in either channel 4 or 2. The combinations shown for epochs 476 and 477 paint a less clear picture, but probably indicate multiple slips—at both epochs and/or more than one satellite or station.

The third output of scandd is file scan.rms, which gives for each series the rms value calculated three different ways: 1) "full" (as in vscan.out and scan.dd), in which a jump in the phase is estimated and removed whenever there is an explicit bias flag inserted by autcln or cvview; 2) "quick" in which a jump parameter is removed for all gaps; and 3) "total", in which jump parameters are estimated—i.e, the rms value will include all jumps in the phase. This file is most helpful in identifying stations with receiver problems or satellites experiencing unmodeled translations (from, e.g., non-gravitational forces) or rotations (mis-modeled yaw during eclipse or "noon turn"). Like the scan.dd file, scan.rms file is sorted by program sorter, producing three output files:

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rms.qui - LC-RMS for quick solution (any gap/flag starts a new rms)
rms.ful - LC-RMS for full solution (any flag starts a new rms)
rms.tot - LC-RMS of the entire series (as in CVIEW).

An abbreviated example of the file rms.ful is shown below, where the rms information (for "quick", "full", and "total") has been sorted in order of decreasing size of the "full" rms:

<table>
<thead>
<tr>
<th>Quick</th>
<th>Full</th>
<th>Total</th>
<th>No obs.</th>
<th>Chan 1</th>
<th>Chan 2</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>21</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>0.17</td>
<td>0.17</td>
<td>27</td>
<td>7</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>....</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>0.10</td>
<td>0.11</td>
<td>0.40</td>
<td>52</td>
<td>7</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>67</td>
<td>0.10</td>
<td>0.11</td>
<td>0.11</td>
<td>39</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>68</td>
<td>0.10</td>
<td>0.11</td>
<td>0.11</td>
<td>34</td>
<td>6</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

In this example, the smaller quick than full rms for series 2 indicates that there is an unflagged gap that may still have a slip. The large (0.40 cycle) total rms for series 66 indicates that there is a flagged jump (probably at a gap) which could not be patched by autcln. With a largest full rms of 0.18 cycles, this solution is probably free of slips or unmodeled effects.

A way of determining better whether the presence of cycle slips or bad modeling at a particular station or satellite is causing the high rms values for certain series is to run SHOWRMS. The input is one of the sorted rms lists (from sorter), and the output is a normalized distribution of the contribution of each station/satellite pair to the overall rms of the predicted postfit residuals:

```
% showrms
```

Enter 1 for rms.qui 2 for rms.ful 3 for rms.tot
2
RMS DISTRIBUTION (total rms = 1000) example: 234 = 23.4%

<table>
<thead>
<tr>
<th>stn</th>
<th>sum</th>
<th>--------------------------------------------------------------</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: 227: 33 44 3 47 47 14 36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2: 132: 22 25 7 18 22 11 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3: 139: 29 14 14 11 0 36 33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4: 125: 22 22 7 18 25 11 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:  80: 18 11 0 11 14 7 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:  88:  0 18 7 14 22 11 14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7: 205:  0 55 18 33 36 11 51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

sum --> 125 191 58 154 169 102 198
chn --> 1 2 3 4 5 6 7

Enter 1 fix, 2 new, 0 quit, otherwise help
2

Selecting 2 ('new') allows you to see the redistributed rms contributions after a station or satellite is removed. Selecting 1 ('fix') is similar but doesn't redistribute the contributions—that is, they no longer add up to 100%. In this example, four of the highest contributions are from station 1 (channels 1,2,4, and 5), so we may want to see what happens to the distribution if we remove station 1 from the computation:

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Enter channel #s to be removed (- for all sites)
0
Enter site #s to be removed (- for all channels)
-1

RMS DISTRIBUTION (total rms = 1000) example: 234 = 23.4%

<table>
<thead>
<tr>
<th>stn</th>
<th>sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>0:</td>
</tr>
<tr>
<td>2:</td>
<td>88:</td>
</tr>
<tr>
<td>3:</td>
<td>102:</td>
</tr>
<tr>
<td>4:</td>
<td>88:</td>
</tr>
<tr>
<td>5:</td>
<td>44:</td>
</tr>
<tr>
<td>6:</td>
<td>58:</td>
</tr>
<tr>
<td>7:</td>
<td>161:</td>
</tr>
</tbody>
</table>

sum --> 58 102 51 58 73 73 125
chn --> 1 2 3 4 5 6 7

Now channels 2 and 7 from station 7 stand out as the largest contributors to the overall rms. The results of SHOWRMS should not by themselves lead you to remove a satellite or station from the solution since a higher rms value for a particular satellite or station may just indicate a longer span of observations. The summary can, however, be used effectively as a guide for inspecting the residuals using cview.

4.4 Interactive editing using cview

Program module cview is the primary interactive tool of the analysis software. It allows the analyst to display to the screen almost every imaginable combination of phase and pseudo-range residuals, as well as clock behavior and the sky tracks of the satellites. For editing, it has a number of features which allow rapid and effective repairing of cycle slips, insertion and removal of additional bias parameters, and the unweighting of questionable data. cview also accepts as input RINEX or X-files, allowing inspection of raw data when you suspect a receiver problem or want an early look at the ionosphere (LG) or widelane (WL) observables, neither of which depend on modeling the geometry. Any analyst new to GAMIT should take the time to become proficient at using cview. In our 15 years of experience we have seen no data set which can be completely understood without some examination of the residuals.

By giving you a choice of the C-files to be viewed and (optionally) a particular set of parameter adjustments to be removed, cview allows you to examine the results of different stages of the processing. In the most common case (at least before the advent of post-fit editing by autcln), you will want to examine the doubly differences residuals as they are predicted to be after parameter adjustments in the final solve. cview obtains these residuals by correcting the (pre-fit) residuals on the C-files using the partial derivatives and the parameter adjustments written by solve on the M-file, according to the following formula

\[ r'_i = r_i + \sum_{j=1,m} (\Delta p_j \cdot \partial c_i/\partial p_j) \]
where \( r_i \) is the prefit O – C ("observed – computed") at epoch \( i \)
\[
\Delta p_j \text{ is the adjustment to parameter } p_j
\]
\[
\frac{\partial c_i}{\partial p_j} \text{ is the partial derivative of the observation with respect to } p_j
\]
and \( m \) is the number of adjusted parameters

To invoke \textit{cview} in this mode, type

\[
\text{cview m[expf]a.ddd}
\]

If you have used \textit{autcln} in its post-fit mode, you have a choice of two sets of residuals to examine. With the “a” M-file, you will get the doubly differences residuals from the final \textit{solve} solution, just as before. In this case the one-way residuals made available by \textit{autcln}’s corrections to phase clocks will be “nearly” flat but will in fact not represent the actual post-fit residuals because the corrections for parameters adjustments have been taken from the final \textit{solve} M-file whereas in correcting clocks \textit{autcln} used parameter adjustments from the previous (“\textit{autcln pre-}”) \textit{solve} solution, recorded on the M-file now named with “p” as the sixth character (see the batch-file sequence in Section 5.3). To best evaluate the one-way residuals, you should give \textit{cview} the name of this earlier M-file. Since this M-file will contain the names of versions of the C-files (the “b” versions with a 1-ITER run, whereas the final “a” M-file has the “d” versions), you will need to have saved these earlier C-files or substitute the later ones (which are equivalent for this purpose). This can be accomplished easily by using additional optional command-line arguments when invoking \textit{cview}:

\[
\text{cview m[expf]a.ddd.autcln ddd d}
\]

The last argument (\texttt{d}) corresponds to the version of the C-files that are currently present in your day directory. The day number is also included because it was added as a second command-line argument to earlier versions of \textit{cview} for use with multi-session processing (in which a single M-file may have C-files from more than one day). Invoking \textit{cview} in this mode is usually the best way to examine the data if you have used \textit{autcln} in post-fit mode since you can see problems directly in the one-way residuals without having to infer from the double differences the station and satellite at fault. The doubly differenced residuals, however, will not be those from the final \textit{solve}—though they will usually be very close—so if there is a question about systematic signatures, you may have to invoke \textit{cview} a second time with the usual “a” M-file. This is usually unnecessary.

There is one additional mode for \textit{cview} that is sometimes useful; namely viewing the (doubly differenced) residuals as they are passed to \textit{autcln} from \textit{model} or to \textit{solve} from \textit{autcln}. The first case is interesting if \textit{autcln} has performed poorly for one or more stations or satellites and you want to determine why (e.g. poor \textit{a priori} coordinates leading to large pre-fit residuals and deletion by \textit{autcln} of most or all of the data). The second is interesting if the solution \textit{nrms} and \textit{scandd} output suggest mismodeling of a satellite (e.g., from a “burn”) and you want to see the effect before \textit{solve} has “smeared” it into the residuals of other satellites in the least squares adjustment. To view pre-fits, as

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well as to select a sub-set of C-files, you must invoke `cview` with no arguments on the command line. In this case, the program will prompt you for the name(s) of an M-file or C-file(s). Responding with the M-file name results in a display of all the C-files, giving you the opportunity to select a subset of the files and/or to change the sixth character of the C-file names listed to as to read in a different set. Then `cview` will then ask if you want to view post-fit residuals. Responding `n` ("no") will give you the prefit residuals.

Regardless of how many command-line argument you use, `cview` will ask if you wish to read in one of the lists of rms values and cycle slips generated by `scandd`, `sorter`, or `sortv`. An affirmative answer gives you the opportunity to go move quickly to the problematic double-difference combinations using the LIST command in `cview`, as described below. Almost always you will want to choose `rms.ful`, the output of `sorter` order in decreasing rms. The filenames `vscan.out` and `scan.out.worst` are not currently included among the choices listed by `cview`, but the file format can still be read—the user need only rename these files to `cview.list`.

As each C-file is read, header information is displayed, including parameters indicating the data types present. Once all the C-files are read, `cview` will display the first of several interactive menus used in plotting:

```
L1  L2  LC  LG  WL  NO POLY  TIME SERIES  STACK[ ]  MOVIE[ ]  STOP
SEEK  PLOT  LIST  1-WAY  2 PRN06  3 PRN08  1 BLHL  2 VNDN  FILE  SEEK-FORW
```

For most of the boxes on the screen there is a stack of allowable commands, which can be selected by clicking on the box with the mouse. The left button moves you backward in the stack, the right button moves you forward, and the center button selects the pre-programmed default shown in the illustration above. The first four boxes in the top panel select up to five observables to be plotted. The default is plots of the L1, L2, LC, LG phase residuals and the wide-lane combination of phase and pseudo-range. Many analysts prefer to use the fifth plot not for wide-lane by to show the time span of each one-way combination contributing to the double difference. This give you the best opportunity to infer quickly the likely station and satellite responsible for a gap, extra bias parameter, or large residuals stemming for low-elevation data. The complete list of allowable data types is given below in the order they appear in the menu stack:

```
AZ  azimuth from station to satellite (degrees, clockwise from north)
EL  elevation angle (degrees)
..  nothing plotted
L1  L1 phase
LG  geometry-free linear combination phase (L2 - g*L1)
LC  ionosphere-free linear combination phase (2.546 L1 - 1.984 L2)
L2  L2 phase
```

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The sixth box in the top panel selects the order of polynomial to be removed from the plot, or the order of derivative to be taken. For example, to plot the rate of change of double differences (akin to "triple differences") you would select DERIV 1 (the units are cycles per second), and to plot the derivative with a first-order polynomial removed, select D1 + P 1. The most useful selections are P 1 and P 2, in connection with the SPAN command described below, allowing you to remove a first or second order polynomial from a short segment of data. The next box selects TIME SERIES, SKY PLOT, or SPECTRUM, defining the type of axes to be drawn for the plot. The next two boxes, STACK and MOVIE, allow you to stack a series of plots on the same screen and/or to cause them to be displayed automatically in sequence without intervention as explained below. The brackets [] indicate that these two boxes are toggles, not stacks; clicking with any mouse button in the brackets introduces an asterisk [*] and turns on the feature. The final box STOPS the cvew display and returns you to the control menu in the operating system window, at which point you can resume the display (and editing) or exit the program. Returning to the operating system menu without exiting the program is useful if you need to check files or available disk space, for example.

The bottom menu panel contains the satellite(s) and station(s) being displayed. The default is the first double-difference combination (as shown here), but you may display one-way or single-difference combinations by making the second box of one or both pairs blank. Clicking on the fourth box (1-WAY) plots the one-way observable for the satellite and site shown in the first box of each pair. As for the upper panel, the selection is changed by clicking on the box to rotate forward (right mouse button) or backwards (left button) in the stack. The first three boxes on the left contain the commands allowing you to move from one screen to another. To change to a particular combination of satellites and stations, rotate (either backward or forward) to the selections in the right four boxes and click on PLOT.

To select the next available double difference, click (with any mouse button) on SEEK. The default is to "seek-forward", in increasing order of satellites and stations, but you can reverse the process (e.g. to return to a problematic combination) by clicking on the last box to change SEEK-FORw to SEEK-BACK and then using SEEK. To move through the scandd list you have read in, select SEEK-LIST and then SEEK. Clicking on LIST with the left or right buttons will display in the bottom right corner of the screen the last or next combination, respectively, but will not plot it.

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Finally, a hard copy of the screen plot may be obtained by clicking on **FILE** to write a file and then using the shell script `sh_cview_panel`.

Time series are displayed with the mean removed and the value indicated to the left of the vertical axis as $Y: 0 \text{ [mean value]}$. Also shown is the rms ("s") of the series about the mean. The time (X-) axis is marked in hours and minutes (hh:mm) but without resetting to zero if the series goes over midnight. Unless **SHOW MARGINAL** has been selected, the display will include only those observations weighted in the solution. Continuous observations (no gap) are indicated by lines connecting each point. The epoch number of any point can be displayed by clicking on the point. The presence of an extra bias parameter is indicated by vertical bars, with "semaphores" attached to indicate (in single or double differences) which satellite(s) and station(s) have the bias flags; e.g.

```
       /  \
       |    station 1 satellite 1     |    station 2 satellites 1 and 2
       |    \       /                  \\
```

Stations are indicated by semaphores to the left (station 1) or right (station 2) (*memory tool*: stations are separated *horizontally* on the Earth); satellites by semaphores at the bottom (satellite 1) or top (satellite 2) (satellites rise or set *vertically*).

When one or more time series are plotted on the screen, the top and bottom menu panels change to display the following:

```
SLIP [ ] MOVE PATCH FIND SAVE UNWT REWT BIAS (-/?/+ UNDO ELIM
SAVE ABORT SPAN[* ALI[ ] <<T>> >>T<< MARG[ ] HIDE[ ] << >>
```

The boxes in the bottom panel (except for the first two) control the display of the plots. The most useful command is **SPAN**. Toggled on it automatically expands and contracts the horizontal axis to fit the time series being displayed. Toggled on after selecting a range of points on the screen (by simply clicking on any of the displayed plots), it adjusts the horizontal scale to fit the span selected. Toggled on after selecting a single point, it expands the scale and moves the selected point to the center of the screen. **ALL** returns the horizontal scale to the complete interval of the session. The next two boxes (**<<T>>** and **>>T<<**) directly expand or contract the time axis. The final two boxes (**<<** and **>>**) move the origin to the left or right, expanding the time scale if appropriate. For short (e.g., 225-point) series, the same effect can be accomplished with any one of several different selections of these six boxes. The seventh box is a toggle between showing **MARGINAL** (unweighted) points and hiding them. Toggled on [*], unweighted points are displayed as open circles or, if they were unweighted because they were below the elevation cutoff, as open squares. At present *cview* does not distinguish between slightly and grossly bad residuals, so that with marginals displayed the vertical scale is often distorted, masking variations in weighted points. The **HIDE** box is a toggle between hiding or not the bias flags that occur in one-way observations that fall in gaps in the

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double-difference combination being displayed (solve will remember the flags and insert an extra bias parameter in the solution; we term these "pushed" biases.) ABORT quits the plot with no changes to the series; SAVE quits and saves any editing that has been done to that series.

Most repairing of cycle slips is accomplished with the PATCH and MOVE selections of the top panel. For either box, you must first select a single point in the series you wish to have moved to connect smoothly with the immediately preceding segment. You do this by placing the cursor on the point and clicking with the left button on the mouse. (The use of the middle and right buttons will invoke more powerful features, described below.) Then, clicking on PATCH will cause the program to calculate automatically the number of cycles needed to repair the slip and to move selected point and all points beyond it. If you have clicked on and L1 or L2 plot, PATCH will move the points in that plot only by the number of integer cycles that best connects the phase. If you have clicked on LC, LG, or WL the program will calculate the number of L1 and L2 cycles necessary to best fit two combinations (with an appropriate weighting based on their respective scatters) and will display in the lower right corner the statistical confidence level of the fit. Clicking on LC, invokes use of LC and LG; clicking on LG invokes use of WL (!) and assumes the change in LG = 0.; clicking on WL invokes use of WL and LG. The PATCH algorithm is discussed further below in the context of editing strategies. MOVE works only on L1 and L2 and allows you to adjust these series by integer or half-integer cycles using additional menu boxes that will appear:

<table>
<thead>
<tr>
<th>0.25</th>
<th>0.5</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>50</th>
<th>100</th>
<th>500</th>
<th>1000</th>
<th>Add 0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>CANCEL M</td>
<td>PERFORM R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each of the boxes of the top panel, clicking on the left mouse button will decrement (subtract from), and clicking on the right button will increment (add to), the value shown by the unit for that box. Clicking on the middle button will choose the unit value. The value selected will appear in the upper right corner of the screen (shown here as 0.). Then clicking PERFORM or the right mouse button with the cursor in the plot area will execute the move; clicking CANCEL or the middle mouse button will cancel the selection. The value of 0.5 is primarily for L2 with squaring-type receiver channels where a one-cycle slip in the original signal corresponds to a half-cycle in the displayed phase. (The value of 0.25 [or 0.5 with full-wavelength signals] should be used sparingly and is included only to check for 180° phase shifts, usually temporary, of the signal in some receivers.) MOVE is primarily useful to test for phase repairs when the visual impression implies a different number of cycles than the number calculated by PATCH. Most of the time PATCH alone will do the trick.

The BIAS box allows you to add (right mouse button), remove (left mouse button), or locate (center mouse button) extra bias parameters at epochs with questionable cycle slips. It can be used with a single epoch or a range of epochs (the latter being useful primarily in removing bias flags). ELIM will eliminate bias flags in all one-way data in series displayed unless a narrower span is defined by brackets. FIND will attempt to assist you
in locating the (one-way) satellite and station combination associated with a cycle slip or extra bias parameter following a gap by changing the display to put as the first satellite and station the one in which the gap occurred. Clicking on SAVE or ABORT, followed by PLOT or SEEK will restore the original sequence. (Be careful here, though, because you may end up using intervening commands that erase cview's memory of the last combination. It's a good idea to jot down on paper the combination on the screen before invoking FIND, so that when you're finished editing a particular epoch you can return to the right place in the search sequence.) UNWEIGHT flags data points to be omitted from the solution by solve; REWEIGHT removes the flag. All of these commands are to be executed after you have selected a point or range of points on the screen by clicking on them with the mouse.

Note that for double differences, the corrections you make are applied to the first satellite and first station displayed for the double-difference combination. The importance of being aware of this feature is discussed in the next section.

The eighth and ninth boxes allow you to reverse your immediately previous action. UNDO reverses the effects of PATCH, MOVE, WEIGHT, REWEIGHT, BIAS, and ELIM, all of the commands that actually change the data. CANCEL simply removes the selection of points you have made in anticipation of a move. The SLIP box is unused at present.

The MOVIE function is useful for viewing an entire set of residuals quickly to infer its character, locate a problem, or verify at the end of editing that everything is clean. If STACK is invoked, all of the plots will be superimposed on the screen. This is a powerful feature for discerning the nature of the residuals but it can become a mess if there are too many series. Once you start the MOVIE, you can stop it by clicking anywhere on the screen with the middle mouse button (click once only and wait for the current frame to finish being written to the screen). Following this by PLOT will show you the series that was on the screen when you stopped, allowing you to hit the panic button when you see something you don't like. If you start the MOVIE with the right button, plotting will stop at the first series with LC RMS > 1.0.

When you have exercised all of the commands and gained some experience in data editing, you can use cview in a more automatic mode, using the mouse buttons to reduce the number of hand motions required. When the cursor is in the plot area of the screen, the mouse buttons take on different functions. The left button puts brackets on the data as described above. The middle button acts as SEEK or ABORT according to command displayed at the bottom. The right button executes the sequence FIND + PATCH, with PATCH’ing being performed only if the correct satellite and station was "found"; a second click on the right button will SAVE and re-PLOT. To UNDO the PATCH’ing, use the left button.

Fixing cycle-slips in double differences is straightforward if you remember certain rules. If a particular receiver channel slips one or more cycles, a break will appear in all data combinations that include that channel. For example, a slip in the L2 phase at station 1 received from satellite 3 will appear in all double difference plots LC, LG, and WL that
include station 1 and satellite 3. *The first step is to identify the station and satellite for which the slip occurred.* One way to do this is to make use of the sorted output of *scandd* (e.g., *vscan.out.worst*), marking on the printout or in the file displayed by an editor the satellite and station common to all occurrences of the slip at a particular epoch (see Section 43). If you have run *autcln* in post-fit mode, you can identify the source(s) of the slip by viewing each of the one-ways contributing to the double difference. In the case where there is a gap or extra bias flag in only one station and satellite combination of the double difference, then the *FIND* command will identify for you the combination and move it to the (1, 1) position in the display. With this display, you can use *PATCH* (or *MOVE*) to fix the slip, and then return to the original order of the double difference combination by clicking on *SAVE* or *ABORT*. If there is no gap or several gaps, then you should check all four one-way series. Multiple slips are not uncommon since a satellite or receiver may "hiccup", affecting multiple stations or channels, respectively. In cases of very high noise in the one-ways (due to bad clocks or ionosphere), you may have to deduce the culprit channel by displaying several combinations of double differences. For example, suppose that for three stations and three satellites the following combinations had a cycle-slip at a particular epoch of observation:

\[
\begin{align*}
\text{(station 1 - station 2)} & - \text{(satellite 1 - satellite 3)} \\
\text{(station 1 - station 2)} & - \text{(satellite 2 - satellite 3)} \\
\text{(station 2 - station 3)} & - \text{(satellite 1 - satellite 3)} \\
\text{(station 2 - station 3)} & - \text{(satellite 2 - satellite 3)}
\end{align*}
\]

It is clear that the cycle-slip occurred at station 2 and satellite 3. Thus the slip should be fixed with satellite 3 and station 2 appearing first when the double difference combination is selected in the menu. In some cases the location of the cycle-slip is ambiguous. For example, if only two stations are observing, it is impossible to determine at which site a slip occurred. In this case, the slip can be fixed at either site. The only requirement is that all double-difference plots be free of cycle slips, i.e., that the cycle-slips are fixed consistently.

*Remember: All editing operations are applied only to the first satellite and station in the double difference combination, so if the tedit is made in double differences, you may have to switch the order before executing the operation (bias, unweight, reweight, patch, move)*

Once the correct satellite and station are identified as responsible for a cycle slip, the next step is to determine its size and whether it occurred in L1 or L2. If the ionospheric fluctuation between epochs is much less than a cycle (or a half-cycle with codeless tracking channels), it will be obvious in the separate plots of L1 and L2 how many cycles slipped in each channel. If the ionospheric fluctuations are large, however, only LC may be sufficiently smooth to discern the size of the slip. In the most difficult cases, it may be necessary to examine all four phase series (L1, L2, LC, and LG) to deduce the combination of L1 and L2 cycles (and/or half-cycles) responsible for the LC jump. Table
41 gives the most common residual LC and LG jumps that occur for combinations of slips in L1 and L2 for the cases of full-wavelength and half-wavelength L2. The bold-faced entries, representing LC jumps of less than one cycle, are the most dangerous since they can escape detection if the fluctuations in L1 and L2 due to the ionosphere are very large.

Using **PATCH** in *cview* allows you to avoid computing the L1 and L2 combinations explicitly. Used with LC or LG, **PATCH** will make a best estimate of the jumps by examining these two time series and apply integer corrections to L1 and L2. The statistical confidence of the estimate is displayed, allowing you to assess whether to retain or add a free-bias flag at the break. This is a useful feature even when you believe that there is no slip, in order to reinforce your subjective judgement of the confidence of the connection made by *autcln*. **PATCH** uses up to 15 points on either side of the slip (usually also a gap) in estimating its correction. Its estimate and confidence level are reliable as far as the LC and LG residuals are concerned. There are times, however, when the analyst is justified in raising the confidence level based on the appearance of L1 and L2. If LC and LG are noisy compared with L1 and L2 (which can occur if multipathing dominates ionospheric fluctuations), then using **PATCH** or **MOVE** on L1 and L2 separately is more convenient. In this case Table 41 is particularly useful.
Table 4.1  LC and LG jumps for L1 and L2 slips

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>LC</th>
<th>LG</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>-1</td>
<td>-0.56</td>
<td>-0.22</td>
</tr>
<tr>
<td>-1</td>
<td>-0.5</td>
<td>-1.55</td>
<td>0.28</td>
</tr>
<tr>
<td>-1</td>
<td>0</td>
<td>-2.55</td>
<td>0.78</td>
</tr>
<tr>
<td>-1</td>
<td>0.5</td>
<td>-3.54</td>
<td>1.28</td>
</tr>
<tr>
<td>-1</td>
<td>1</td>
<td>-4.53</td>
<td>1.78</td>
</tr>
<tr>
<td>0</td>
<td>-1</td>
<td>1.98</td>
<td>-1.00</td>
</tr>
<tr>
<td>0</td>
<td>0.5</td>
<td>0.99</td>
<td>-0.50</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>-1.98</td>
<td>1.00</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>4.53</td>
<td>-1.78</td>
</tr>
<tr>
<td>1</td>
<td>-0.5</td>
<td>3.54</td>
<td>-1.28</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>2.55</td>
<td>-0.78</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>1.55</td>
<td>-0.28</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.56</td>
<td>0.22</td>
</tr>
</tbody>
</table>

All combinations $\leq 1$

Positive combinations $\leq 5$ with LC < 1.0 or LG<0.1

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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<td>2.12</td>
<td>-0.06</td>
</tr>
<tr>
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<td>2</td>
<td>3</td>
<td>-0.86</td>
<td>1.44</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>-0.30</td>
<td>1.66</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>0.26</td>
<td>1.88</td>
</tr>
</tbody>
</table>

In data sets with many gaps (from, e.g., a poorly performing receiver), there may be a large number of bias flags inserted by autcln and you would like to perform the entire edit manually. In this case, you can use the BIAS function to remove all bias flags which are in the first satellite and station displayed or the ELIM function to remove bias flags in all satellites and stations associated with the series. If a data set has many small gaps but few actual cycle slips, it is sometimes easier to remove all the bias flags before starting and then add back the ones you need. This strategy is facilitated by program rmbias, which is run from a batch file (rmbias.bat). To create this batch file run the script mk.rmbias, responding to the prompt with the 6th character of the input C-files. The script will then create in rmbias.bat an rmbias command for each C-file in your directory with that 6th character. The output C-files will always have 6th character "x". You can rename them using the scripts mvcf or copyc. If you are using autcln, there should never be a large number of bias flags remaining and you should have no need for rmbias.

After you have completed all editing for the session, click on STOP and answer positively the query to write out corrected C-files. The names of the new C-files are created by incrementing the sixth character of the old C-file names. Whenever you select STOP while editing, cview will give you the opportunity to continue editing and/or to save the edited C-files by issuing the following prompt:
You may:
1. Write new C-files, incrementing series letter
2. Write new C-files, incrementing series letter and deleting old C-files
3. Overwrite input C-files
4. Not write any C-files
5. Not write any C-files but save vcview.out

Only 1 and 4 will let you continue editing

Pick a number

With modern data sets, for which any editing is can usually be accomplished by adding `edit_sv_site` commands to `autcln`, you will have used `cview` only for diagnosing problems and you may select 4 or 5 to avoid writing out the C-files. If you have performed edits, particularly cycle-slip repair, which you wish to keep, then you should select 1, 2, or 3. The simplest course is to overwrite the input C-files, but if you have spent a long time editing and don’t want to chance a (rare) system problem, then 1 is the safest option. In this case you may need to rename the C-files (change 6th character) to match what `solve` is expecting (from the M-file) using the script `mvcf` after finishing with `cview`. If you select options 1 or 4, you will get the prompt

Do you wish to continue editing (Y/N)

A "yes" (Y) reply will return you to the editing screen, after performing an interim save of the C-files if you have chosen option 1. A "no" (N) reply will exit the `cview`, either directly if you have selected option 4, or after writing out the C-files if you have selected option 1. When you are engaged in a long editing sessions, it is prudent to STOP editing periodically to save the C-files. (Neither the hardware we have used nor the software we have written is immune to unexpected crashes.)

Option 5 at the end of editing will write out a file (`vcview.out`) of all the edits you have made in the session. Running the (interactive) program `autedt` or (better) the shell script `sh_cvedt` extracts from `vcview.out` the information about which data you have unweighted and appends to the `autcln.cmd` file the appropriate `edit_site_sv` commands for `autcln`.

4.5 Strategies for editing

When used in its postfit mode, `autcln` will usually produce a near-optimal editing of the data from almost any survey, including those performed in the 1980s and 1990s with first or second generation receivers. For these older surveys, or modern ones spanning only a few hours and including only two or three stations, it is efficient to view all of the data with `cview` to satisfy yourself that `autcln` has recovered all of the useful data and not left any unnecessary bias flags. If you find problems, you may elect to perform the edit manually, especially with small data sets, but most of the time you can induce `autcln` to
do the right thing by changing its input parameters and/or pre-deleting (with the `edit_site_sv` command) short spans of noisy data. This approach has two advantages over manual editing: 1) it transfers the burden of editing from the (expensive, slow, and fallible) analyst to the (cheap, fast, and slightly less fallible) cpu; 2) the `autcln.cmd` file now maintains the record of all edits, so that you can reprocess the data, from RINEX files if necessary, as modeling and editing algorithms improve.

The preferred strategy for networks with more than two or three stations is to first examine the outputs of `solve` (q-file) and `autcln` (`autcln.post.sum` and the sky-plots of phase residuals [DPHS] produced with `sh_gamit`) to determine if there were any problems with the run. If so, then you can use the outputs of `scandd` (sorted versions of `vscan.out` and `scan.rms`) with `cview` to identify the station or satellite and cause of the problem and add controls to `autcln.cmd` to fix it. Since `scandd` is fairly time-consuming to run, it's usually most efficient to omit it from the standard batch solution and repeat the run if you suspect problems.

The most obvious indicator of a bad solution is the `nrms` value in the Q-file. As discussed in Section 3.4, values above 0.3 usually signify a problem, and for many surveys you should expect most values to be near 0.2. If you are processing several days of a survey at one time, grep'ing on `nrms` for all of the q-files will give you an indication of problem days. If the `nrms` is abnormally high, you should then look at the `scan.rms` output of `scandd` (or `rms.ful` after running `sorter`) to see if a single satellite or station is causing a problem. If you find values greater than about 0.2 cycles, you should examine the residuals visually with `cview` to understand the cause of the problem.

Even without a high `nrms`, you should examine the `autcln.sum` file to ascertain whether there are problems with a station or satellite. If a receiver or clock is malfunctioning, or if you have a bad a priori coordinate for the station, `autcln` may have deleted large quantities of data or added an excessive number of bias flags. The first three tables in the summary file will tell you quickly if there is a major problem. With postfit editing, the table of one-way phase residuals will characterize precisely the preformance of each station and satellite. With either postfit or prefit editing, you should also make sure that in the `DATA AMOUNTS` listing there are small numbers in the `Gap` (data deleted in gaps) and `BF` (bias flags remaining) columns and that the number of data retained (Good column) are comparable to those for other stations. If you find anomalies, the other tables in the file and `cview` can help you determine the source of the problem. If you have run `autcln` in post-fit mode, there will a summary of the rms of the residuals for each station and satellite, allowing quick identification of outliers. (See the explanation for these tables in sections 4.2 and 5.6 and the on-line help for `autcln`.)

If you suspect problems at a station from its postfit `rms`, you should run `sortv` on the `vscan.out` file from `scandd`. Usually, looking at `vxxxxa.ddd.worst` will tell you if there are any potential slips. It would be unusual for there to be more than one or two of these (if any) after `autcln` unless there is a station with a malfunctioning receiver.

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The most common problem with autcln is losing all of the data from a station because poor receiver performance or a priori coordinates leads to insertion of too many bias flags. Loading the (doubly differenced) unedited, prefit residuals (i.e., the “year” C-files) into cview will tell you immediately which of these two situations is the case. (If you find no data displayed for the problem station even with the unedited C-files, find a double difference combination that does display data, toggle on the SHOW MARGINAL button and return to the problem combination. Selecting small spans will usually reveal the behavior of the LC phase at the few-cycle level). If the slope of the LC residuals is small (less than one cycle over 30s) but the residuals are noisy, then you need to judge whether some of the data could be useful if the editing were done carefully, by tightening the dd_fit_tol parameters or adding edit_site_sv commands to remove segments of data. If the slope of the residuals is large, then you have a bad model. If all long baselines have large slopes, and the magnitude is proportional to baseline length, the problem is orbits. If only a few stations have large slopes, then the problem is coordinates. The solution is either to find and fix a blunder in the L-file values or, if the epoch-to-epoch differences are less than 10 cycles, loosen the last three dd_fit_tol parameters (to, e.g., 3 5 10). A particularly difficult situation arises when you have both noisy data and poor a priori coordinates. Loosening of the dd_fit_tol parameters for the prefit autcln can leave the adjusted coordinates still so bad (5 m or more) that the postfit autcln will fail because the residuals are too large. In this case a reasonable strategy is to run the session first with post-fit autcln turned off and the default (3 0.35 0.8) LC phase tolerances to get a solution with basically good data and a few cycle slips, leading to coordinates no worse than 1 m. Then, with these coordinates as input, run the usual prefit and postfit autcln solution with tighter (4 0.2 0.5) dd_fit_tol values.

For regional networks, there is one additional and very important editing consideration if you plan to attempt ambiguity resolution in the analysis. The present version of solve assigns the (one allowed) explicit ambiguity parameter to the last segment of the double-difference series; that is, the data after the last extra bias parameter (shown by a bar in cview). This is because the extra bias parameters are all estimated implicitly. In order to maximize the probability that the ambiguity for a series will be resolved, you want to have the last segment as long as possible. This means that for stations in a regional network you should not leave an extra bias parameter in the latter part of an otherwise continuous series, but rather unweight the data at the end containing these extra biases. The last entry in the trim_oneway_tol command for autcln gives you some control over this, but it’s still possible to have a too-short segment at the end of a double difference sequence. For widely spaced fiducial stations where there is no chance to resolve ambiguities, leaving an extra bias parameter associated with a few points at the end is of little consequence. The important thing in this case is to avoid breaking up with bias flags long segments of data, wherever the segments are located in the observing span.

Once you have identified any editing problems with the solution, you should make take corrective action and then rerun the solution from the appropriate step. If the problem is bad data from station or satellite you can begin with autcln, after removing the bad data from consideration using the edit_site_sv command in the (base) autcln.cmd file (taking advantage of cview’s ability to generate these entries automatically for short segments.

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removed using the **UNWT** command—see the last paragraph of Section 4.4). If the problem is a bad a priori station coordinate, you should begin with **model** after updating the L- or T-file. If you suspect a bad orbit, you can first repeat the **solve** run with the satellite excluded (**exclude**: **PN04**, e.g., in the **Session Options**) to test your hypothesis, and then add **edit_site_sv** entries to the **autcln.cmd** file to provide a permanent record and assure exclusion in future runs. Occasionally the appearance of bad data can be traced back to a problem with the information in the RINEX file (e.g., named incorrectly) or the auxiliary files of GAMIT (**UT1.**, **pole.**, **station.info**).
5. Running the Modules Individually

5.1 Introduction

Each module can be run individually using the batch files created by *fixdrv*, edited if necessary to change input controls. To run the modules from a batch file, use the operating system option for the redirection of standard input devices. This option allows the user to redirect the input from a batch file rather than from the keyboard. For example, to run *model* from batch input file *bvent7.002*, type

```
model < bvent7.002
```

and the program will take responses from the input file. This is the basis of the batch mode of processing. An examination of the primary and secondary input files output by *fixdrv* will make these concepts clearer (Section 3.3).

5.2 Running *arc*

The function of *arc* is to create a T-file of tabulated ephemerides of the satellite coordinates and the partial derivatives of these coordinates with respect to initial conditions and the other adjustable parameters (just the three non-gravitational force parameters in the current version). Below is a sample batch file from the example network discussed in Chapter 3:

File *bvent7.001* (arc)

```
PRN 3
PRN 6
PRN 9
PRN 11
PRN 12
PRN 13
END
IGS92 SPHRC 900.0 75.0 GPST INERTIAL B1950
arcout.002
gvent7.002

87 23 21 37 23.00000
87 9 16 37 23.00000
Y
tvent7.002
```

The first five lines list the "names" of the satellites to be integrated (*arc* expects names of the form *PRN nn* or *NAVSTAR nn*), terminated by **END**. The next line specifies the models
The preferred gravitational model is IGS92, invoking the IGS standard for GM and an 8x8 truncation of the GEM-T3 gravity field. However, most GAMIT analyses prior to release 9.25, including the GARNER orbits generated at SIO, have used MERIT standards, so if you are reintegrating a G-file for regional analysis but combining the H-files with those generated elsewhere, be careful that the gravitational models are consistent. In multiyear analysis for station positions and velocities, there is no serious problem in having used different gravitational models to generate the orbits since the adjustments of initial conditions will absorb most of the model differences.

The radiation pressure model specified in the example is a "flat-plate" or "spherical" (SPHRC) model in which adjustable parameters were defined for the Sun direction ("direct"), spacecraft y-axis ("y-bias"), and the Earth-pointing (spacecraft z) axis ("z-bias"). Only the first two of these are well determined and usually estimated. A better geometric model is defined by the Sun-pointing axis, y-axis, and a third axis orthogonal to both of these. Investigators at AIUB (Berne) [Beutler et al., 1994] have termed this third axis "x", but we designate it the "b-axis" to distinguish it from the spacecraft x-axis. This parameterization is available by specifying SRDYB, which allows three adjustable parameters, or BERNE, which allows the three constants plus once-per-rev accelerations (sine and cosine terms) along each of these three axes, for a total of 9 parameters. Beutler et al. [1994] (and the AIUB standard processing) incorporate into these formulations the ROCK4 model described by Fliegel et al.[1992], modified to lump the "X" and "Z" forces into a single "direct" force (M. Rothacher, personal communication, 1994). Tests carried out at MIT thus far have shown no improvement (in fact, a slight degradation) using the ROCK4 model, so we do not include it in BERNE or SRDYB. A second difference between the GAMIT and Bernese formulations is that we include shadowing only in the constant, direct solar term, whereas Berne includes it for all 9 terms. Two additional parameterizations are available: SRDYZ uses the same adjustable parameters as SPHRC but includes the original formulation of the ROCK4 model, with the additional forces applied along the X and Z axes. Finally, SRXYZ uses adjustable parameters and ROCK4 forces along the spacecraft x, y, and z axes. The details of these formulations may be found in the code and documentation of subroutine ertorb.f in the /arc directory.

The next two entries on the same line are for the T-file tabular interval and integration step-size, both given in seconds. The nominal values are 900 (15 minutes) and 75 seconds, respectively. The tabular interval must be an even multiple of the integration step-size. The final three entries give the time type (GPST or UTC) desired for the T-file (GPST is now default), and the reference frame, which in the current version must be 1950.0 inertial.

The next two lines give the filenames of the arc printed output and the input G-file containing the initial conditions and initial values of the non-gravitational force parameters. There is then a blank line (for historical reasons), followed by the start and stop times of the integration, given as (2-digit) year, day-of-year, hours, minutes, seconds. The times given are the times between which interpolation can occur; the actual
values on the T-file will extend five epochs beyond the limits given. The last two lines of
the arc input contain a single control (Y or N) indicating whether the variational equations
(partial derivatives with respect to initial conditions and parameters) are to be integrated,
and the name of the output T-file.

The arc print output file (arcout.ddd) summarizes the input controls and also records
the times when each satellite is being eclipsed by the Earth. This information is useful in
evaluating the level of stochastic variation (Markov parameters) to be allowed with
multisession T-files in GLOBK. A sample output file is given below but with the
summary for only one satellite included:

Output archive file: arcout.278
Input ICs file: ggpst7.278

9.16 of 94/07/26 14:40:00 (SunOS)

Standard spherical radiation pressure model used

Epoch of ICs, read from: ggpst7.278
Yr Mn Dy Hr Min Sec JD Sec of Day (GPST)
87 10 5 18 22 59. 2447074 66179.00000000

Input start time for observations:
Yr Mn Dy Hr Min Sec JD Sec of Day (GPST)
87 10 5 13 7 59. 2447074 47279.00000000

Input stop time for observations:
Yr Mn Dy Hr Min Sec JD Sec of Day (GPST)
87 10 5 23 37 59. 2447074 85079.00000000

TDT-GPST at IC epoch = 51.1840 sec

********************************* PRN 9 *********************************

From svnav.dat: PRN 9 SV 6 Blk I Mass (kg) 462.600

Satellite and ICs: PRN 9
-0.256749494345660D+05  0.415313921343370D+04  0.565073203730440D+04
-0.104843035787760D+01 -0.158739652566680D+01 -0.336546540194340D+01
0.100000000000000D+01  0.000000000000000D+00  0.000000000000000D+00

Sat   Se mimjr Ax Eccen'ty   Perigee      Inclin'n    Ascen.Node   Mn Anomaly
___KM.___             DDD MM SS.S  DDD MM SS.S  DDD MM SS.S  DDD MM SS.S
PRN 9  26560.651   0.012882   66 23 29.5   63 59 40.5  356 53 45.0   98 29 17.0

PRN 9 Radiation pressure, Y-Bias, Z-Bias:  0.100000D+01  0.000000D+00  0.000000D+00

IERS92/IGS Standards for model constants

Times written to T-file header (GPST)
IC epoch:  87 10 5 18 22 59.000000
Start :  1987 10 5 11 22 59.000000
Stop :  1987 10 5 23 37 59.000000
No. epochs:  57
Tabular interval:  900.0 Integration interval:  75.0000

Start eclipse:  2447074.56631  0.161  87 278  10 5 13 35 PRN 9
Eclipsing:  2447074.54027  0.010  87 278  10 5 12 57 PRN 9
Eclipsing:  2447074.53940  0.912  87 278  10 5 12 56 PRN 9
End eclipse:  2447074.53853  1.000  87 278  10 5 12 55 PRN 9

Start eclipse:  2447075.03940  0.432  87 279  10 6 0 56 PRN 9

Output yaw file: yvent7.278

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The identification of the satellite as Block I, Block II, Block IIA, Block IIR, or Block III is relevant to select the nominal direct acceleration in the radiation-pressure models. These are further modified by the nominal mass of the satellite, read from file svnav.dat. This nominal direct acceleration also becomes the unit for the (smaller) estimated accelerations along the x-, y-, z-, and b-axes.

For the eclipse summary, the first line printed (Start eclipse) gives the first integration epoch for which the shadow factor (LAMBDA; 1.0 = full sunlight) is less than 1.0; this is followed by all epochs for which the factor is less than 1.0 (only one in this case) and the first epoch for which the factor is again 1.0 (End eclipse).

During the integration arc will combine the eclipse information with the history of spacecraft yaw biases given in svnav.dat to create a session-specific Y-file of predicted spacecraft attitude for the span covered by the T-file. An example of a Y-file a span in late 1995 is shown below:

<table>
<thead>
<tr>
<th>PRN</th>
<th>YAW_RATE</th>
<th>BIAS</th>
<th>YR</th>
<th>MO</th>
<th>DA</th>
<th>HR</th>
<th>MN</th>
<th>ECLIPSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>NOMINAL yaw rates</td>
<td>- explanation of file in read_yaw.f</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.128</td>
<td>P</td>
<td>95</td>
<td>10</td>
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<tr>
<td>9</td>
<td>0.128</td>
<td>P</td>
<td>95</td>
<td>10</td>
<td>30</td>
<td>21</td>
<td>36</td>
<td>E -134.4 9.7</td>
</tr>
<tr>
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<td>P</td>
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<td>10</td>
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<tr>
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<td>36</td>
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</tr>
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<td>0.199</td>
<td>U</td>
<td>95</td>
<td>10</td>
<td>30</td>
<td>9</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>0.097</td>
<td>P</td>
<td>95</td>
<td>10</td>
<td>30</td>
<td>9</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

Examples are given for satellites with positively-biased (P), negatively-biased (N), and unbiased (U) yaw, and for satellites with no eclipses (PRNs 1, 2, 12, and 31) and two eclipses and a noon maneuver during the span (PRN 9). The extra values given for the second eclipse of PRN 9 are the yaw and beta angles at the start of the eclipse; these are not written into the original Y-file by arc but rather added by model during processing. For an explanation of the history and importance of yaw modeling see Bar-Sever [1996].
5.3 Running model

The function of \textit{model} is to create a C-file containing the observation residuals (O-Cs) and partial derivatives to be used in \textit{solve} to estimate adjustments to parameters. Below is a sample batch file from the example network discussed in Chapter 3:

\begin{verbatim}
File bvent7.002 (model)
S                   Static Mode
pcato7.278          Print file
ivent7.278          Station clock polynomial (I-) file
lvent7.278          Coordinates (L) file
xcato7.278          Input X or C-file
ccato7.278          output C-file
N                   Delete input C-file?
tvent7.278          T-file
I                   Inertial frame
W-file
Z-file
jvent7.278          Satellite clock polynomial (J-) file
0 7 7               Geodetic datum / Tide model / SF Earth rotation
0.0  NONE           elevation angle cutoff (now ignored in MODEL) / antenna model
3 yventt.278        Clock model / Yaw file
1013.25 20.0 50.0   pressure, temp, humidity
SAAS SAAS NMFH NMFW met models (dryzen wetzen drymap wetmap)
\end{verbatim}

The first line indicates the type of experiment—static (S), kinematic (K), or dynamic (D)—and is used to guide \textit{model} in the reading of the X-file. There is an additional key-letter input possible ('O') if the X-file is 'old-style', written prior to October, 1991, and doesn't itself have an identifier for the type of experiment. The "hooks" for kinematic and dynamic processing have been put in \textit{model} (and most of the other modules), but these features are not yet operational.

Line 2 gives the name of the print (P) file that records the file-header and model information for the run. The P-file name is normally the same as the X-file name except for the first character, but any name can be used for test purposes.

Line 3 gives the name of the receiver-clock (I) file, which should have been created by \textit{fixdrv}. The I-file name is normally the same as the D-file name except for the first character, but again is arbitrary.

Line 4 gives the name of the site-coordinate (L) file. The L-file name is normally the same as the D-file name except for the first character, but again is arbitrary.

Line 5 gives the name of the input X- or C-file. \textit{model} will use the first character to determine the file type. The next line gives the output C-file name. This is followed by an input ('Y' or 'N') indicating whether the input C-file should be deleted at the end of the \textit{model} run. If the the input data file is an X-file, \textit{model} will not delete it regardless of the entry on the seventh line.
Line 8 gives the name of the satellite ephemeris (T) file. The T-file name is arbitrary except for the first character. For single-day T-files, use of the last digit of the year and the day of year are convenient.

Line 9 indicates whether the *model* computations are to be performed in an earth-fixed ('E') or inertial ('I') coordinate system. At present, only inertial frame computations are supported by *arc* and *model*.

Line 10 gives the name of the W-file containing time-variable meteorological data. If blank, there is no input W-file.

Line 11 gives the name of the output Z-file containing atmospheric data used at each epoch.

Line 12 gives the name of the satellite clock (J) file. The name is arbitrary but is usually the same as the D-file except for the first letter. The J-file should have been created from an E-file using *makej*. With Selective Availability invoked, a large J-file, computed using observations at a site with an atomic frequency standard, may be necessary.

Line 13 has three integers designating the geodetic datum and the models to be used for solid-earth and ocean tides and short-period (diurnal and semidiurnal) oscillations of UT1 and pole. The current version of GAMIT works properly only in spherical (internally Cartesian) coordinates, so '0' should always be specified for the datum. The integer controlling the tide model is binary coded—the first (1) bit for the default frequency-independent model for solid-earth tides, the second (2) bit for a frequency-dependent model for the K1 solid-earth tide, the third (4) bit for the pole tide, and the fourth (8) bit for ocean tides. The default (7) is to apply the first three models. Previous versions of GAMIT did not use the pole tide, but GLOBK will detect this and add it when combining h-files. Application of ocean tides requires an additional input table (*otide*) and is still being tested.

Line 14 was formerly used for the elevation cutoff angle, but this can no longer be controlled in *model*; hence the zero entry. The other entry on this line is a keyword indicating the model to be used for antenna phase-center variations. The default is *NONE*, but a table (*antmod.dat*) may be used to provide an elevation-dependent (*ELEV*) or elevation-and-azimuth-dependent (*AZEL*) model. See Appendix 7 for the current state-of-knowledge of the mean and time-variable locations of the L1 and L2 phase centers for commonly used GPS antenna.

Line 15 has two unrelated entries. The first (integer) specifies the way in which the receiver clock is determined. A value of 1 indicates no correction is to be calculated—the time-tag on the X- (or C-) file is accepted as correct; this option is used for a receiver that keeps its clock synchronized with GPS time. A value of 2 indicates that the first or second order polynomial estimated from pseudoranges in *fixdrv* and stored in the I-file is used to model the clock throughout the session; this option is valid for clocks that...
maintain continuity and have a stability of better than 1 part in $10^8$ over the session, such as the TI4100 or any receiver attached to an atomic frequency standard. A value of 3 forces a clock estimate from pseudoranges at each epoch; this is the most general option and can be used under all circumstances except when the clock is synchronized but the pseudoranges are corrupted, as was the case with early MiniMac data. The second entry is the name of the satellite yaw file to be read to determine the spacecraft attitude.

The last two lines allow you to select the default (fixed) values for surface meteorological data and the models to be used in computing the atmospheric delays. The default models are shown; see Chapter 7 for a more detailed discussion.

A summary of the *model* run is contained in the P-file. It records, successively in divided sections, 1) the version and files used, 2) the X-file header information, 3) T-file header information, and 4) the information actually used by *model* and recorded on the output C-file header. In reading a P-file, be careful not to confuse X-file header values (for, e.g. antenna height or station coordinates) with the values read at run-time and used by *model*. At the end of the P-file are warnings issued by *model* regarding the calculation of receiver-clock corrections. See `/gg/gamit/example` for sample p-files (e.g. `pcato7.278`).
5.4 Running cfmrq

The purpose of cfmrq is to create an M-file to control the combination of C-files and selection of adjustable parameters to be input to the estimation module solve. solve rewrites the M-file, adding adjustments to the parameters; this updated M-file is then read by cview to calculate predicted postfit residuals. A sample input batch file follows:

```
BATCH
  cato                4 letter site code
  love                4 letter site code
  moja                4 letter site code
  pver                4 letter site code
  safe                4 letter site code
  wsfd                4 letter site code
  yknf                4 letter site code

  3  6  8  9 11 12 13     Total PRN Numbers
  ccatod.278          C-file
  cloved.278          C-file
  cmojad.278          C-file
  cpverd.278          C-file
  csafed.278          C-file
  cwsfdd.278          C-file
  cyknfd.278          C-file
  mventa.278          M-file

  Y                   coordinate partials? This should be hard wired
  Y                   atmospheric partials? This should be hard wired
  4  4  4  4  4  4     Number zenith delay parameters
  Y                   orbital partials?
  Y                   SV antenna offset partials?
  Y                   gradient parameters estimated? (Y/N)
  1  1  1  1  1  1  1   Number of gradient parameters - Session 1
```

The structure of the batch file is rather archaic, with many entries present for historical rather than logical reasons. The first line of the input file specifies batch mode for cfmrq; interactive mode is no longer supported. This is followed by a list of the 4-letter site codes for the run, a blank line, and a list of the satellites appearing on the C-file. Next is a list of the C-files to be included, terminated by 'END'. The next line, a string of 'E's, one for each station, specifies that explicit, rather than implicit biases are to be used. Next is the M-file name, which must match the name given in the solve batch file. The 'Y' ('yes') for coordinate partials may be changed to 'N' if sites coordinates are not to be included in the solve parameter menu (for 'ORBIT' mode in solve). The 'Y' for atmospheric or gradient partials should not be changed. The number of zenith-delay parameters or gradient parameters to be used may be changed, but must match the values in the solve batch file and must be the same for all sites. The 'Y's for orbit and satellite antenna offset partials may be changed to 'N' if no orbital parameters are to be adjusted and you do not wish to have them appear in the solve menu.
5.5 Running solve

The principal inputs to solve are the C-files and an M-file. The phase data, the O-C's, and the partial derivatives are read from the C-files; the parameter menu and pointers are read from the M-file. The adjusted values are output to the M-file in order to compute the post-fit residuals in cview, and adjusted station, orbital, and (optionally) clock parameters are written to new L-, G-, and I-files, respectively, for use in subsequent processing.

solve was originally designed to be interactive in order to facilitate manual intervention in resolving phase ambiguities. With the increasing size of GPS networks, interactive use is less tractable, and this feature is no longer supported. With solve version 9.33 we have radically changed the input batch file to replace commands designed originally for interactive operation with commands more easily understood and edited by the user. The batch file generated by fixdrv for the 'full' (not 'quick') solution for the sample network discussed in Chapter 3 is shown below with comment lines added to document additional controls.

```
* << key-word-controlled batch file format >>
* symbol ":" must exist in command lines as separator
* any non-blank character at first column means comment line
* empty after ":" means comment line too

*------------- Part 1 -- Files and Global Controls
operation mode: batch
Q-file name: qventa.278
H-file mode: 0
datum code: 0
M-file name: mventa.278
quick solution choice: full
biases: explicit
phase difference options: double difference
combination mode: LC_HELP
    bias search approach: decision function
    search path: narrow lane
    search criteria: 0.15 0.15 1000.00 10.00
start and end epochs: 1 225 1
set cutoff_elevation:
    cutoff: all_sites 15.0
error model:
    stn_error: all_sites uniform 10.0
    sat_error: all_sats 0.0

*------------- Part 2 -- Parameters
set parameters:
estimate: all_sites all_parameters
fix: all_sites clock
# fix: all_sites zenith
fix: all_sites grad
estimate: all_sats all_parameters
fix: all_sats clock radiation
fix: global all_parameters

exit set:
```

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------------ Part 3 -- A priori Constraints

set apriori constraints:
  tight_apr_coord:  cato  100.000 100.000 100.000
  tight_apr_coord:  love  100.000 100.000 100.000
  tight_apr_coord:  moja  100.000 100.000 100.000
  tight_apr_coord:  pver   0.010   0.010   0.010
  tight_apr_coord:  safe  100.000 100.000 100.000
  tight_apr_coord:  wsfd   0.010   0.010   0.010
  tight_apr_coord:  yknf   0.010   0.010   0.010
  loose_apr_coord:  all_  100. 100. 100.

zenith delays: all_sites  4 PWL
  tight_apr_zenith:  cato  0.500  0.005  100.0
  loose_apr_zenith:  cato  0.500  0.005  100.0
  tight_apr_zenith:  love  0.500  0.005  100.0
  loose_apr_zenith:  love  0.500  0.005  100.0
  tight_apr_zenith:  moja  0.500  0.020  100.0
  loose_apr_zenith:  moja  0.500  0.020  100.0
  tight_apr_zenith:  pver  0.500  0.020  100.0
  loose_apr_zenith:  pver  0.500  0.020  100.0
  tight_apr_zenith:  safe  0.500  0.020  100.0
  loose_apr_zenith:  safe  0.500  0.020  100.0
  tight_apr_zenith:  wsfd  0.500  0.020  100.0
  loose_apr_zenith:  wsfd  0.500  0.020  100.0
  tight_apr_zenith:  yknf  0.500  0.020  100.0
  loose_apr_zenith:  yknf  0.500  0.020  100.0
  tight_apr_grad:  cato  0.030  0.030
  loose_apr_grad:  cato  0.030  0.030
  tight_apr_grad:  love  0.030  0.030
  loose_apr_grad:  love  0.030  0.030
  tight_apr_grad:  moja  0.030  0.030
  loose_apr_grad:  moja  0.030  0.030
  tight_apr_grad:  pver  0.030  0.030
  loose_apr_grad:  pver  0.030  0.030
  tight_apr_grad:  safe  0.030  0.030
  loose_apr_grad:  safe  0.030  0.030
  tight_apr_grad:  wsfd  0.030  0.030
  loose_apr_grad:  wsfd  0.030  0.030
  tight_apr_grad:  yknf  0.030  0.030
  loose_apr_grad:  yknf  0.030  0.030
  tight_apr_orbit:  PN03 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  tight_apr_orbit:  PN06 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  tight_apr_orbit:  PN08 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  tight_apr_orbit:  PN09 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  tight_apr_orbit:  PN11 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  tight_apr_orbit:  PN12 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  tight_apr_orbit:  PN13 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04 1.0E+04
  loose_apr_orbit:  all_  10. 10. 10. 10. 10. 1000. 1000. 1000.

exit set:
*

------------- Part 4 -- Session Options

set session_1 options:
  include: all_sites all_sats
  error model:
    stn_error: all_site elevation
    sat_error: all_sats 0.0
    noise file name: nventc.278

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With the new batch file, almost all of the `solve` options and constraints can be changed simply by editing the command lines. In Part 1, for example, you can rerun `solve` with a different observable or ambiguity-resolution options, for example by changing combination mode, bias search approach, and search criteria. The combination mode keywords are the same as in the `sestbl` for Choice of observable as explained in Section 3.2. The only ambiguity resolution schemes that have been exercised with recent data are the range-priority algorithm selected by Combination mode = `LC_RANGE` and tuning of the deviation and sigma of the search criteria, as discussed in Section 3.5. However, other approaches, including simple rounding and use of an expectation function, are coded and could be invoked by users interested in further research in this area (see Blewitt [1989], Dong and Bock [1989], and `solve` subroutine `bisopt.f`) The algorithm and parameters for the widelane resolution are specified in the batch file under Session Options since these depend on instrumentation and ionospheric activity.

Editing the batch file is particular convenient for running quickly different subsets of the data. To change the span or sampling, edit the `start and end epochs` line, in which the first value is the start epoch, the second the end epoch, and the third the decimation factor. To the low-elevation cutoff, edit the numerical value and/or add additional lines:

```
cutoff:  all_sites 15.0
cutoff:  cato 20.0
```
The **error model** keywords and values are analogous to those in the `sestbl` (Section 3.2), in which you can choose uniform, baseline-length-dependent (**baseline**), or elevation-angle-dependent (**elevation**) weights for any or all stations, and/or different weights for individual satellites. For example,

```
error model:
  stn_error: all_sites uniform 10.0
  stn_error: cato elevation 4.3 7.0
  sat_error: all_sats 0.0
  sat_error: PN09 20.
```

To fix a parameter, add its name to the list in Part 2; i.e.,

```
  fix: all_sites clock cato long
```

to fix the longitude of site 'CATO' (Castro Peak). In Part 3 are given the a priori constraints for sites, orbital parameters, and zenith-delays for both the tight (user-specified, in `sestbl`) and loose (default, for GLOBK) solutions. The units for all of these inputs are meters for position and meters/second for velocity. Note that for zenith delays, it is best to use the same constraints for the loose solution as for the tight, since GLOBK does not estimate these parameters.

To unweight stations or satellites in the solution, use the exclude command in Part 4; e.g.,

```
exclude: cato pver pn03
```

Part 5 specifies mainly the output files for the run. You can change the names of any of these if you want, e.g., to make multiple runs with the same data.

When **solve** runs it writes output both to standard output (screen or the `.log` file) and to the Q-file. The screen output is almost the same as the Q-file but includes also a record of every 50 epochs as the program is running plus indication of when additional (implicit) bias parameters are inserted as the data are read and the normal equations formed. An explanation of the Q-file is given in Chapter 3.
5.6 Running autcln

`autcln` operates on one or more C-files to flag and/or patch cycle slips and unweight questionable data, using all combinations of the available phase and pseudorange data. The program is executed using a single runstring:

```
autcln <command file> <out cf series> [....list of cfiles...] OR
      [dfile name] <in cf series>
```

where `<command file>` is an optional command file (commands are given in the ctagsob.hlp file). If no command file is given (default file generation) then " should be used as a place holder in the runstring. If `defaults` is given as the command file then the defaults will be printed. The program will not act on the rest of the runstring.

`<out cf series>` is a single character to denote the new cfile series to be written out. If no character given (i.e., ' ' used) then no updated cfiles will be written. Special characters that can be used are:

- . -- Overwrite the input C-files
- + -- Increment the C-file series letter, converting numeric series values to a.

`[....list of cfiles...]` is the list of cfiles to be cleaned or

`[dfile name]` is the name of a D-file with the list of C- (or X-) files

`<in cf series>` when the df ile form is used this optional argument can be used to change the input cfile series from that in the D-file.

A sample `autcln` command file is given in Chapter 4 and copied below (but see also the template in gg/tables).

**autcln Command File**

```
remove_bias_cond 10.0 3.0 1800.0
allow_one_bg yes
use Gamit_elev yes
use_cview_edit yes
remove_first_bia yes
dd_return_size 100 25 5 10.
* Site dependent ion parameters
  ion_jump fair 120 6 2 5
  ion_jump kour 120 6 2 5
  ion_jump yell 120 6 2 5
  ion_jump darw 120 6 2 5
  ion_jump mcmu 120 6 2 5
  ion_jump trom 120 6 2 5
```

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A non-blank character in the first column denotes a comment. All commands are case insensitive. A complete list, copied nearly verbatim from the on-line help file (kf/help/autcln.hlp) is given below:

`end` Last command issued. An end-of-file (EOF) will have the same effect.

`use_postfit <mfile name>`

Used to invoke postfit editing. The argument may be all or part of the name of the m-file updated with adjustments by `solve`. If no argument is given then the name is assumed to be `m[dfnm]a.ddd` where `[dfnm]` are the four characters from the D-file name given in the `autcln` runstring. If one character is given this is assumed to be the series name (i.e., a, b..). If less than seven characters are given these are used as the beginning of the name of the M-file; if 7 or more, they are assumed to be the complete M-file name. If the M-file cannot be opened, then a warning message is printed and prefit residuals will be used. The M-file does not need to contain all of the stations being used by `autcln`. Note: Care should be taken that the M-file goes with the current C-files (i.e., that `model` has not been re-run using different parameter values since the M-file was created).

`apply_phs_clk [MAX Iter] [Non-int] [Converged %] [Over shoot]`

This command will invoke a new feature in which will generate one-way phase residuals which should have all the clock effects from the ground sites and satellites removed. The process is done iteratively with the arguments allowing the user some control. `MAX Iter` is the maximum number of iterations (default 30). `Non-int` is the number of iterations before a non-integer bias parameter will be used in estimating the clock offset (default 3). `Converged %` gives the percent change in the rms of the one-way residuals between iterations that will be taken to mean the solution has converged (default 0.1 %). `Over shoot` can be used to speed convergence. At each iteration, the mean offsets of the one-way residuals are computed and removed. The overshoot is a multiplier used so that more than the mean is removed during each iteration. The default is 1.5, and values greater than 2 seem to cause solutions to diverge. All of the arguments are optional with the default being used for any values not passed. Invoking this option will normally double the `autcln` runtime. The solution will not be affected unless there are pathological clocks that cause numerical problems in `solve`, in which case `apply_phase_clk` will usually fix the problem. With this option on, the RMS scatters of the one-way residuals are computed and added to the summary file. These can be useful when attempting to diagnose problems. Caution: The one-way residuals will look flat in `cview` only when the same M-file is used in `autcln`.

`postfit_edit [Start Iter] [Nsigma] [Max Restore] [Max rms]`

This commands allows editing of phase residuals using an n-sigma criterion. `Apply_phs_clk` is invoked when this option is used. `Start Iter` denotes the iteration number in `apply_phs_clk` before editing starts. Several iterations should be made before editing. The default is 9. `Nsigma` is the multiplier threshold in sigma
units for deleting data. The sigma used is the RMS scatter of the LC phase data from each site. The default is 4.0. LC residuals that are less than $N_{\text{sigma}}$ and have been flagged due to close bias flags can be restored provided they are less than $\text{max\_restore}$ (default 0.5 cycles). If a station's RMS is greater than $\text{Max\ rms}$, its data will be completely removed from the solution (default 0.5 cycles).

\texttt{rng\_jump\_tol [n-allan\ sd] [min\ jump\ (\mu sec)]}

This command specifies the size of a discontinuity in the range O-C that will be considered a clock jump. The first value [n-allan sd] is the multiplier of the clock stability given by the Allan standard deviation and the second value (min jump (usec)) is the minimum, in microseconds, that will be considered a jump in microseconds; i.e., both numbers must be exceeded for a clock jump to be flagged. The default values are 100.0 and 0.95, but to better detect bad ranges that cause problems with postfit editing, values of 20. and 0.1 may be preferred.

\texttt{clk\_reset\_tol [jump\ difference\ (\mu sec)]}

Tolerance for jump to be taken as a millisecond reset in the clock (\mu sec). A typical value is 10 \mu sec, but it may need to be increased if apriori clock polynomial (from \texttt{fixdrv}) does not match the data well (for example due to bad apriori station coordinates or satellite orbits). The default is set to 100 \mu sec to account for low quality crystal clocks in many receivers.

\texttt{rng\_resid\_tol [n-sigma] [min\ error\ (m)] [max\ error\ (m)]}

Tolerance for bad range residuals. Range residuals are computed after satellite and station clocks are estimated. They are equivalent to doubly differenced range residuals and are affected by poor station coordinates and satellite orbits. The maximum value before a point will be deleted is n-sigma times the rms of the range residuals, but the value tolerance value cannot be less than $\text{min\ error}$ nor more than $\text{max\ error}$, both in meters. The defaults are 10. 190. 380 and should not be overridden unless many BAD Pre-RNG data for messages appear.

\texttt{ion\_jump\_tol [Reciever\ code/ALL] [max\ gap\ (sec)] [Multiplier]}\n\hspace{1cm} [Min\ dIon\ (cyc)] [Max\ dIon\ (cyl)]

Lets user set the tolerances for detection cycles slips in the ionospheric delay (LG). The maximum jump allowed is set by minimum of the [Max dIon] and the maximum of the [multiplier] by the last change in the ion delay and the [Min dIon (cyc)]. That is, the tolerance will fall somewhere between Min dIon and Max dIon with the intermediate values set by the Multiplier by the change in the previous two data points. The test will be done for all data points separated by [max gap] or less and all contiguous data. The default values are 30. 6. 2.0 5.0, which work well with modern receivers even in polar and equatorial regions. With older receivers and a quiet ionosphere, the first three values should be 240. 4. 0.8 to provide more sensitive detection of cycle slips.

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rng_noise [Receiver code/ALL] [noise (mm)]

Lets user specify the apriori values for the standard deviation of the range measurements by site (initial values only). They will be updated during the autocln run and the updated values reported in the clock and range statistics in the output and summary file.

max_rclk_iterations [max iterations]

Maximum number of range clock iterations. The solution for the estimate of the satellite and station clocks is iterated to determine the statistics of the range noise and clock Allan standard deviations. The iteration stops either at [max iterations] or until the convergence criteria are met.

rel_clk_weight [weight]

Weight to be given to the clock noise model based on previous iteration's estimate of the Allan standard deviations of the clocks relative to data noise while estimating the clocks. Typical value is to down weight the clock statistics by a factor of 10 relative to the data.

rng_clk_root [range clock root of file names]

Lead part of the name to be given to the range clock solution output. If no root is given then the range clock solution will not be output. For example crng will produce output files named crng.PIN1 and crng.PRN_21. A cplot command file will also be generated called <root>.plt

phs_clk_root [phase clock root of file names]

Lead part of the name to be given to the phase clock solution output. If no root is given then the phase clock solution will not be output. See rng_clk_root.

phs_res_root [phase residual root of file names]

Lead part of the name to be given to the one-way phase residual (to the prefit model) output. If no root is given then the phase will not be output. See rng_clk_root and residual_site.

sng_diff_root [single difference file root]

Lead part of the name for single difference between stations files. (These may be used with the program mon_data to processing single difference kinematic data). The single differences are between first site and subsequent sites. The residual_site list is used select which sites to write to single difference files, which are only generated if C-files are written out.

residual_site [List of four character codes/ALL/NONE]

Lets the user specify which sites should be output to the phase residual or single difference files.

summary_file [Name of summary file/6]
Name of a summary file. If the command is not given, the summary is written to a file named `autcln.sum`. If 6 is given as the file name then the summary is written to standard out.

```
rcv_allan_sd [site code/ALL] [Allan standard deviation (ppb@100sec)]
```

Allows the user to specify the Allan standard deviations of the clocks at each site. These are updated during `autcln` run.

```
remove_bias_cond [Chi**2 Ratio] [min chi**2] [max gap] <large gap scale>
```

Sets the constraints for removing biases. A bias flag is removed if

\[
X = \frac{C2}{(C1+\min\exp(-C1/min))} > \text{ratio}
\]

where \(C1\) is the smallest \(\text{Chi}**2\) obtained during trial fixes to integer values; \(C2\) is the next smallest; \(\min\) is \(\text{min chi}**2\) in the command; and \(\text{ratio}\) is \(\text{Chi}**2\ \text{Ratio}\) in the command. In addition, the gap must be smaller than \(\text{max gap}\). The default values of \(\text{Chi}**2\ \text{Ratio}\), \(\text{min chi}**2\), and \(\text{max gap}\) are 12., 3., and 3600. (sec), respectively. The final argument \(\text{large gap scale}\) is optional; if it is specified, then the value of \(X\) computed from the data is reduced by \(1 + \text{large gap scale}\times\text{atan(gap/min data)}\) where \(\text{gap}\) is the gap in the data and \(\text{min data}\) is the smaller of the number of data in the left and right segments about the gap. The default value of \(\text{large gap scale}\) is 5.0.

```
allow_one_bg [yes/no]
```

Deals with the case where all channels of a receiver slip at nearly the same time. By specifying \(\text{yes}\) you allow `autcln` to select one channel as a base, patch it roughly in one-ways, and the patch all other channels with respect to it.

```
use_gamit_elev [yes/no]
```

If \(\text{yes}\) is specified (default), then the cutoff angle specified in the C-file will be used in editing and outputting data, the safest approach for rerunning old data (cutoff passed from the C-file to the X-file via CTOX). With new data a better approach is to use the `min_elev` command of `autcln` and to control use of data by `solve` with the GAMIT sestbl. input.

```
use_cview_edit [yes/no]
```

Allows user to specify if the `cview` unweight flag (-1) should be used or not. If \(\text{yes}\) is specified then the `cview` unweight flag will not be overridden by `autcln`. The default is \(\text{no}\).

```
use_mm_range [yes/no]
```

Allows user to specify if MiniMac range measurements should be used. The default is not to use them (\(\text{no}\)). (If ranges are not used then MiniMac should be connected to a very good clock.)

```
ignore_gaps [yes/no]
```

Lets user specify that gaps should be ignored when forming acceptable double differences during cleaning. The default is \(\text{no}\); this option should only be used for cleaned data when the GAMIT elevation cutoff and `cview` edits are used.

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flag_gaps [yes/no]
Lets user specify if gaps in the one-way data should be flagged with a bias flag. The default is no, but is automatically set to yes when the allow_one_bg yes is given.

gap_size [cf_code/ALL] [number of epochs]
Lets user specify the number of epochs allowed in a gap so that it will not be flagged. At setting of 1 (default) will cause all gaps to be flagged. Specifying gap_size automatically turns on the flag_gaps option.

remove_ms_jump [yes/no]
Lets user decide if millisecond jumps are in the clock are removed when C-files are written. The default is to remove the jumps (yes).

remove_first_bia [yes/no]
By default autcln puts a bias flag at the beginning of each one-way sequence as part of its internal bookkeeping. This has no influence on the solve solution, but the extraneous flags will be removed before C-files are written if yes is specified for this command. The writing of single-difference files requires the initial bias, so yes should not be specified when single difference files are to be written.

edit_site_sv [Site Code] [PRN] [Start Epoch] [Stop Epoch]
Allows user to specify site/satellite combinations over specific epoch ranges to be edited and not used in determining clock behavior and double difference editing. Useful for treating bad satellite range data. ALL may be used delete all sites for a specified specified satellite; 0 may be used for the PRN number to delete all satellites over the specified epoch range.

phs_fit_tol [4 values all in cycles]
Tolerances in deciding if a cycle slip has occurred in the pre-fit clock fit to the one-way phase data. The values and their defaults are as follows:
(1) deviation of mean phase residual from range solution in pass 1 (1000.);
(2) deviation of worst phase residual from range solution in pass 1 (500.);
(3) deviation of pass 2 mean phase from pass 1 phase solution (200.);
(4) deviation of pass 2 worst phase residual from pass 1 phase solution (100.).
Values 3 and 4 are normally much less than values 1 and 2. The actual deviations being flagged can be viewed by setting status_report Pass1_slips Pass2_slips.

status_report [List of options]
Allows user to tailor the output of the program by selecting which quantities will be output in autcln.out. The options come from the following list:
CLK_JMP_PROC - possible clock jump detection
CLK_JMP_VAL   - value of clock jump when one is found
BIAS_ADDED    - BIAS flag added during one-way phase processing
PASS1_SLIPS   - Number of cycles added in Pass 1 one-way clean
PASS2_SLIPS - Number of cycles added in Pass 2 one-way clean
DD_TRIALS - List each double difference combination tried
DD_ESTIMATES - Estimates of cycle slip during the DD fix.
DD_SCAN - Details of scan flag showing sites and svs used.
ELEV_DIST - Distribution of final (weighted) data by elev
RUN_PARAMS - Dump of parameters used in run.

ALL may also be used, and then -option to turn off particular output; e.g., status_report
all -clk_jmp_proc. The status reports are sent to standard out.

dd_report [DD Report file name] [option]
Allows user to specify a file of the format readable by cview and to specify which types
of double differences should be output to this file (i.e., ALL, FIXED, NOT_FIXED). If the
file name dd.srt is used then the file can be directly read into cview to allow checking of
the cleaning results.

min_elevation [Min clean elevation (deg)] <Min output elev (deg)>
Minimum elevation to which data will be cleaned. Once this value has been set in autcln,
the data below this elevation will not be useable later without further cleaning. The
minimum output elevation is optional and is the elevation cutoff to be applied when the
C-files are written. This command is ignored if use_gamit_elev = yes.

trim_oneway_tol [min_dtl_bias] [min_good_bias] [min_dtr_end] [min_good_end]
Set the tolerances used in trimming the one-way data to remove small segments of
data (defaults in parentheses):
  min_dtl_bias - minimum time in seconds between bias flags (120 s)
  min_good_bias - minimum epochs between bias (8)
  min_dtr_end - Fraction of total duration of data allowed for a bias flag at the end
               of the one-way sequence (0.1)
  min_good_end - Number of epochs of data allowed after last bias flag (24)

dd_return_size [Max WL] [Max LC] [Max LG] <One way fix tol>
Set the number of data to be used for cycle skip repair (defaults in parentheses):
  Max WL - widelane estimates (100), applies to one-ways
  Max LC - LC (50), applies to double differences
  Max LG - LG (10), applies to one-ways or double differences
These values should be decreased if there is significant curvature in the data, which
might apply particularly to LG with a high ionosphere. They cannot be set less than 5.
One way fix tol is an optional argument that sets the maximum duration over which
one-way L1/L2 range data will be be patched using the widelane and LG.
dd_fit_tol [WL Ratio] [WL Min] [WL Max] [LC Ratio] [LC Min] [LC Max]

Set the tolerances for flagging cycle slips in wide-lane [WL] and LC double differences [LC] (defaults in parentheses):

- **Ratio** - Ratio allowed for jump compared to local rms or last change (WL 5, LC 3.)
- **Min** - Minimum value for a jump that will be flagged (cyc) (WL 2., LC 0.5)
- **Max** - Maximum value above which all jumps will be flagged (cyc) (WL 10., LC 0.8)

(The tolerance on the maximum jump allowed will fall between Min and Max with the intermediate values set by [local rms] x [ratio])

scan_site [All/None/list of site names]

Lets user specify which sites should be scanned before double difference cleaning. If unflagged slips are found during double difference cleaning this command should be used. All will set all sites to be scanned; clear will set no sites to be scanned. A minus sign before a site name will remove this site from list (e.g., -PIN1 will remove PIN1 from the scan list.)

max_scan_edit [number]

Lets user set the threshold for the number of double difference bias flags that can be added during scanning before the complete station/satellite set of one-way data is edited. (The default is not to apply this editing condition). For non-AS data the number can be set small (~10). For AS data, <50 will excessively delete old Rogue data. This control is used to automatically delete bad stations and satellites experiencing burns.

np_set [size (epochs)] [Start (epochs)]

Form normal points with phase and range data using groups of [size (epochs)] points. For 30 second data, size=15 forms 7.5 minute normal points. The value must be odd. [Start (epochs)] sets the starting epoch for forming normal points. If the value is negative then normal points will not be formed but the editing necessary to form the normal points will be applied to the data. (This feature is useful for testing the effects of the approximations inherent in the normal point formation.)

site_params [site/ALL] [Min Clean El] [Min Out El] [Min L1 SNR] [Min L2 SNR]

Allow site specific parameters to be specified:

- **[Min Clean El]** - minimum elevation angle to which data will be cleaned (degs)
- **[Min Out El]** - minimum elevation angle to be used for output of C-files (deg).
  
  [Min Out El] must be greater than or equal to [Min Clean El] (By cleaning to a lower elevation angle, more data are available for detecting and fixing cycle slips)

- **[Min L1 SNR]** - minimum SNR value to be used at L1. Setting this to 0 will allow all initially into the solution. (same as Pre 2.13 Versions of autcIn).

- **[Min L2 SNR]** - minimum SNR value to be used at L2.

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The default values for these parameters are set based on receiver type. If the `min_elevation` command is used after the `site_params` command all stations will be given the cut-off elevation angles specified in the `min_elevation` command.

`igs_clk [clock-file name] [min rms] [max rms] [List of reference clocks]`

Write out one-way clock values in the standard IGS clock format. The clock-file name is arbitrary but has only three characters, `autcln` will construct a name of the form `[name]WWW.D.clk` where `WWW` is the GPS week and day number (e.g., `mit10452.clk`). The `[min rms]` sets the upper limit for a clock to be used as a reference if no reference clock list is given; the units are cycles, and 20 is typical for a hydrogen maser. The `[max rms]` is the largest rms a station clock can have for it to be included in the output file (200 cycles will include most stations). You may optionally list stations to be used to define the reference (e.g., `ALGO WZT`). A small program `diff_igs` has been added to the `ctogobs` directory to compute differences between clock files.

`Lc_autcln [min num] [dchi ratio] [max sig] [max deviation]`

Use the Melbourne-Webena wide lane to resolve (WL) double-difference ambiguities (“biases”) and pass this information on to `solve`. This feature is used in conjunction with the ‘Choice of observable = LC_AUTCLN’ setting in the sestbl. The first argument is the minimum number of double differences used (default = 50). The second is the ratio of the best to next best deviation divided by sigma to resolve the bias (default = 10). The last two arguments are the maximum widelane sigma and deviation from an integer for resolving the bias (both defaults = 0.2). Use of –1 as an entry will retain the default value (which may change with subsequent releases).

`autcln` produces two output files, a step-by-step log of the editing process (`autcln.out`) and summary (`autcln.sum`). In order to interpret either of these, it is necessary to understand the algorithms used in the editing. Since the steps are made in sequence with results from previous steps used, errors in one stage of the processing usually cause errors in later stages. Also errors at one station or on one satellite can affect the results from other stations and satellites. There are seven major steps in the process:

1. Clock error estimates for sites and satellites based on range data. This analysis is iterated until there is convergence between iterations for the estimates of clock statistics. The maximum number of iterations can be set. Range data can be edited by the analyst if they are not consistent with data from other sites and satellites. In the default settings for autcln, bad range data are typically undeleted in the second iteration if there are lots of bad range measurements.

2. Clock error estimates for sites and satellites based on phase data. The clock errors from the range data are used as a priori values for estimates from phase data. During this analysis, large jumps in the phase data can be detected and the number of cycles of phase
needed to make the range and phase consistent is computed. Changes in the ionospheric delay estimates from phase data are also used to detect jumps in the data. When jumps are detected, bias flags are added. Bad range or bad prefit residuals can cause an excessive number of bias flags to be added at this stage. The adding of bias flags and the number of cycles removed with each bias flag are reported in the output of `autcln`. The default ionospheric jump detector parameters are too tight for polar and equatorial regions and can be changed by station in the command file.

(3) The default action next is to add bias flags to all gaps in the data. This can be changed in the command file, but is not recommended.

(4) The default action next is to scan all contiguous one-way data and to form double differences with triplets of the data to see if there are jumps in the double differences. When a jump is found, more double differences are formed to assess if the one-way data being analyzed have the jump. (This is done by switching the satellite and station to see if the jump persists.) Bad prefit residuals can cause many biases to be added at this stage. Unmodeled accelerations of the satellites can also cause many bias flags to be added at different stations.

(5) Cleaning of data using as many observables as possible. This step involves trying to assess the number of cycles of slip at each bias flag in the one-way data and whether the bias flag can be reliably removed. Small segments of data (i.e., closely spaced bias flags) are removed before any attempt is made to resolve biases. Three criteria are used to compute the number of cycles: (1) continuity of LC, (2) continuity of LG, and (3) continuity of the widelane. Different number of data are used in each of these with the widelane typically being the longest and LG the shortest. The sequence `autcln` uses is to first try to resolve the integers in one-ways if P-code L1 and L2 range data are available using the widelane and LG continuity. If this fails then double differences are used and LC continuity is also considered. The default setting in `autcln` is to not allow one-way bias flag removal because this became unreliable once AS was turned on. To patch in double differences, `autcln` finds another station and satellite combination which does not have a bias flag or gap around the time of the flag which is being evaluated. Stations and satellites are scanned in sequence until `autcln` finds a combination that can be used to remove the bias flag or runs out of stations and satellites to try. The default is to output a line for each combination tried. The last one output is the one which was used to determine the number of cycles. A common occurrence is that all satellites at a station have bias flags at or near the same time (due to a power failure for example). In these cases, there is an optional feature to "allow one bias or gap" (the `allow_one_bg` command) at this time. In this case, `autcln` first determines if bias flags can be removed if it ignores the bias flags on both satellites being used in the double difference. If the bias flag can removed, then it resolves the cycles slips on the first one-way data sequence to be tested and removes the bias flag. When later bias flags are encounted at this time for this station, they will be patched relative to the first one-way sequence where the bias flag was removed. "Force? T" appears in `autcln.out` for those bias flags removed this way. (There is no explicit bookkeeping to ensure that this happens). When data are very "broken up" with many bias flags and gaps, `autcln` can make mistakes in this procedure,
so this is normally the most unreliable part of the cleaning process. Only loss of lock on all satellites at a station is treated in this way. If all stations lose lock on a satellite at the same time then the bias flags will be not removed unless they can be patched in one-ways. While data are being used for patching, they are also checked for jumps. When a jump is found, autcln scans each of the one-way sequences, checking to see if there are cycle slips in them. Because more data are used than when the jumps were first detected, this test is more sensitive than the orginal scanning and sometimes detects jumps that had not been previously detected. In many cases, these jumps are noisy data and the added bias flag is later removed (and sometimes added back again later). Jumps detected this way can be found in the output by grep'ing on LCDD. If they are large, then autcln has become confused about where a slip is located and this can cause problems. The cleaning loop is iterated four times since data with bias flags resolved late in the cleaning loop may be used to resolve biases on data looked at earlier. There are some differences between the iterations. In the first iteration, allow_one_bg is not used. This is so that as many bias flags as possible are resolved before it is attempted. On subsequent iterations, allow_one_bg is invoked on increasingly larger gaps in the one-way sequence. It starts at about 10% on the maximum gap size over which biases will be removed, and increases by about 5% each iteration. After the first iteration, large gaps in the data are no longer considered (i.e., we will never be able to remove these bias flags).

(6) Data trimming. In this step, short sequences of data between bias flags are removed and the length of data after the last bias flag on each each one-way sequence is checked as a percentage of the total number of data on the sequence. If this percent is too small then the data are removed and the process repeated. This is done so that solve will have a long sequence of data for resolving biases. (Double differences are not checked at this point, so it is possible to get bias flags which have only a small number of data available for their determination.)

(7) Normal pointing (optional). Normal points can be formed at this point.

The tables in the autcln.sum file summarize the results of these steps:

Clock Statistics

<table>
<thead>
<tr>
<th>Site/PRN</th>
<th>Allan SD@100 sec (ppb)</th>
<th>Range rms (mm)</th>
<th>#</th>
<th>Site/PRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARAK</td>
<td>1.610128</td>
<td>1344.1</td>
<td>905</td>
<td>LEI</td>
</tr>
<tr>
<td>AYVA</td>
<td>1.635893</td>
<td>695.8</td>
<td>864</td>
<td>LEI</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERDT</td>
<td>100.000000</td>
<td>190.3</td>
<td>1199</td>
<td>TRM</td>
</tr>
<tr>
<td>MATE</td>
<td>0.010000</td>
<td>6707.6</td>
<td>2879</td>
<td>ROG</td>
</tr>
<tr>
<td>ONSA</td>
<td>0.030619</td>
<td>2179.0</td>
<td>2859</td>
<td>TRB</td>
</tr>
<tr>
<td>WETT</td>
<td>0.010000</td>
<td>2253.7</td>
<td>2879</td>
<td>ROG</td>
</tr>
<tr>
<td>PRN_01</td>
<td>0.434580</td>
<td>7729</td>
<td>1097</td>
<td>TRM</td>
</tr>
<tr>
<td>PRN_02</td>
<td>0.441315</td>
<td>18710</td>
<td>1054</td>
<td>TRB</td>
</tr>
<tr>
<td>PRN_04</td>
<td>0.438818</td>
<td>18020</td>
<td>1130</td>
<td>ROG</td>
</tr>
</tbody>
</table>

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This table gives estimates of the clock Allan standard deviation (in parts-per-billion) and range noise rm s for each receiver. These clock statistics are based on range data only. The example shown is typical for AS conditions with SA active. With AS off, the range noise for a Rogue SNR-8 or TurboRogue will approach that of the Trimble SSE (< 1 m). Values much larger than a few meters usually mean lots of bad range data or bad prefit residuals (station coordinate errors of >10 m). Very bad range data can be seen with AVCLCK errors in the model output P-file. Also autcln.out will list bad range measurements (but sometimes here the station or satellite may be incorrectly listed especially when there are a lot of bad data). If there are AVCLCK errors, then the edit_site_sv command can be used to pre-edit these values in autcln. With each clock and range statistic is also the number of data used to calculate it. For the example here, the two regional stations (ARAK and AVYA) observed for only 8 hours whereas the three IGS stations (MATE, ONSA, and WETT) observed for 24 hours.

Scanning Summary

```
DDScan bias flags added report for pass 1
SITE PN01  02  04  05  06  07  09  12  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  31
ARAK  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
AYVA  0  3  0  0  0  1  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
...
MATE  3  0  1  13  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
ONSA  3  0  0  1  0  0  1  0  0  0  3  1  0  0  0  3  6  2  0  0  0  0  2  0  8
WETT  2  2  0  0  0  2  0  0  1  1  1  0  0  0  0  0  0  0  2  0  0  0  1  0  0
```

This summary lists the number of bias flags added by site and satellite during double difference scanning of the phase data. Large values here can mean either bad prefit residuals or bad phase data. The max_scan_edit command can be used to automatically delete all data on a station/satellite combination which has too many bias flags added during double difference scanning. Many bias flags being added to a satellite at many stations usually represents the effects of an unmodelled acceleration of the satellite. Rogue SNR-8 often have many bias flags added when AS is on. (Note that in the current version of autcln the clock statistics and scanning summaries are given twice, once for each of two initial passes through the data.)

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One-way Residual Statistics

When \textit{autcln} is run in post-fit mode, the next four tables give a summary of the phase residuals for each station and satellite after correcting the data for adjustments in the parameters (using the M-file from the first solve solution) and estimating station and satellite clocks epoch-by-epoch from the phase residuals. The two tables give the rms values and the number of data used in the calculation for each station or satellite.

### RMS by site and satellite (mm): Pass 22

|   | ARAK | 01  | 02  | 04  | 05  | 06  | 07  | 09  | 12  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | ... | 31 |
|---|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RMS | 7.2  | 0   | 6   | 7   | 0   | 8   | 7   | 6   | 8   | 0   | 7   | 0   | 6   | 6   | 0   | 0   | 15  | ... | 0   |
| RMS | 6.7  | 0   | 6   | 7   | 13  | 0   | 5   | 7   | 8   | 7   | 0   | 6   | 0   | 6   | 5   | 0   | 0   | 12  | ... | 0   |
| RMS | 5.1  | 5   | 4   | 6   | 4   | 4   | 6   | 5   | 4   | 4   | 5   | 6   | 5   | 6   | 5   | 4   | 4   | 5   | ... | 5   |
| RMS | 5.5  | 5   | 6   | 6   | 5   | 5   | 6   | 3   | 4   | 5   | 5   | 6   | 5   | 6   | 5   | 6   | 5   | 7   | ... | 5   |
| RMS | 6.3  | 6   | 7   | 6   | 5   | 5   | 7   | 5   | 7   | 7   | 6   | 6   | 8   | 5   | 6   | 5   | ... | 6   |
| RMS | 6.0  | 6   | 6   | 6   | 5   | 5   | 6   | 6   | 6   | 6   | 6   | 6   | 6   | 5   | 5   | 7   | ... | 6   |

### Number of data by site and satellite: Pass 22

|   | ARAK | 01  | 02  | 04  | 05  | 06  | 07  | 09  | 12  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | ... | 31 |
|---|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NUM | 5385 | 0   | 587 | 311 | 84  | 0   | 224 | 177 | 228 | 199 | 0   | 507  | 0   | 534 | 631 | 0   | 0   | 118  | ... | 0   |
| NUM | 5224 | 0   | 552 | 306 | 48  | 0   | 195 | 139 | 195 | 220 | 0   | 509  | 0   | 535 | 631 | 0   | 0   | 142  | ... | 0   |
| NUM | 17346 | 825 | 507 | 539 | 728 | 638 | 775 | 736 | 788 | 764 | 673 | 695  | 636 | 761 | 660 | 634 | 577 | 640  | ... | 640 |
| NUM | 17276 | 820 | 734 | 846 | 668 | 619 | 782 | 346 | 609 | 697 | 631 | 834  | 817 | 717 | 682 | 744 | 676 | 651  | 733 | ... | 664 |
| NUM | 17739 | 868 | 734 | 701 | 652 | 462 | 746 | 716 | 684 | 732 | 624 | 689  | 619 | 726 | 695 | 595 | 664 | 663  | ... | 663 |

The values here (5–8 mm overall) for the five stations shown are typical for well-performing receivers in a good solution. The only rms value over 10 mm is for PRN 13 at station AYVA; the second table indicates that there were few data (48) compared to the other satellites, suggesting either that \textit{autcln} deleted a number of bad observations (which can be checked below) or that the satellite's pass was short and low on the horizon and therefore with a larger fraction of data corrupted by high multipath or atmospheric fluctuations.

The next table gives the average one-way residuals, a useful addition that may help you distinguish between systematic, long-period errors and high receiver noise or multipathing.

### Average OW residuals by site and satellite (mm): Pass 22

|   | ARAK | 01  | 02  | 04  | 05  | 06  | 07  | 09  | 12  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | ... | 31 |
|---|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| AVG | 7.2  | 0   | 1   | 0   | 0   | 0   | 0   | -1  | 0   | 0   | -1  | 0   | 0   | -1  | 0   | 0   | 0   | 0   | ... | 0   |
| AVG | 6.7  | 0   | 1   | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ... | 0   |
| AVG | 5.1  | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 1   | -1  | -1  | -1  | 0   | -1  | 1   | 0   | 0   | 0   | ... | 0   |
| AVG | 5.5  | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 1   | -1  | 0   | -1  | 0   | 0   | 0   | ... | 0   |
| AVG | 6.3  | 0   | -1  | 0   | -1  | 0   | 0   | 0   | -1  | -1  | -1  | 1   | -1  | 1   | 0   | 1   | 0   | 0   | ... | 0   |

In this case the averages are all less than about 1 mm, indicating no significant systematic residuals. The last table shows the rms values as a function of elevation angle, a potential tool for deciding whether elevation-angle-dependent weighting of the data might be useful (an analysis approach we are currently investigating).

28 September 2006
Elevation angle dependent RMS statistics. Model: \( \text{RMS}^2 = A^2 + \frac{B^2}{(\sin(\text{elv}))^2} \)

<table>
<thead>
<tr>
<th>SITE</th>
<th>A</th>
<th>B</th>
<th>0-05</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
<th>30-35</th>
<th>35-40</th>
<th>...</th>
<th>75-80</th>
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</tr>
</thead>
<tbody>
<tr>
<td>ARAK</td>
<td>5.5</td>
<td>2.1</td>
<td>0.0</td>
<td>0.0</td>
<td>8.2</td>
<td>12.6</td>
<td>10.8</td>
<td>8.2</td>
<td>6.7</td>
<td>5.4</td>
<td>...</td>
<td>5.5</td>
<td>5.0</td>
<td>8.1</td>
</tr>
<tr>
<td>AYVA</td>
<td>3.7</td>
<td>2.6</td>
<td>0.0</td>
<td>0.0</td>
<td>11.9</td>
<td>11.1</td>
<td>8.1</td>
<td>7.9</td>
<td>6.2</td>
<td>5.7</td>
<td>...</td>
<td>3.3</td>
<td>3.7</td>
<td>2.9</td>
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</tbody>
</table>

...}

<table>
<thead>
<tr>
<th>SITE</th>
<th>A</th>
<th>B</th>
<th>0-05</th>
<th>5-10</th>
<th>10-15</th>
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<th>...</th>
<th>75-80</th>
<th>80-85</th>
<th>85-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE</td>
<td>2.6</td>
<td>2.1</td>
<td>0.0</td>
<td>0.0</td>
<td>9.8</td>
<td>8.0</td>
<td>7.1</td>
<td>5.6</td>
<td>4.8</td>
<td>3.8</td>
<td>...</td>
<td>3.4</td>
<td>3.9</td>
<td>3.7</td>
</tr>
<tr>
<td>ONSA</td>
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<td>2.1</td>
<td>0.0</td>
<td>0.0</td>
<td>9.8</td>
<td>8.3</td>
<td>6.6</td>
<td>5.6</td>
<td>5.0</td>
<td>4.6</td>
<td>...</td>
<td>3.3</td>
<td>3.0</td>
<td>2.6</td>
</tr>
<tr>
<td>WETT</td>
<td>3.7</td>
<td>2.4</td>
<td>0.0</td>
<td>0.0</td>
<td>11.5</td>
<td>9.4</td>
<td>7.9</td>
<td>6.8</td>
<td>5.8</td>
<td>5.0</td>
<td>...</td>
<td>4.1</td>
<td>4.8</td>
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</table>

Data Editing and Bias Flags Remaining

<table>
<thead>
<tr>
<th>SITE</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
<th>SITE</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
<th>SITE</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARAK</td>
<td>PN01</td>
<td>587</td>
<td>0</td>
<td>0</td>
<td>PN02</td>
<td>311</td>
<td>0</td>
<td>0</td>
<td>PN05</td>
<td>84</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PN06</td>
<td>224</td>
<td>1</td>
<td>1</td>
<td>PN09</td>
<td>177</td>
<td>0</td>
<td>0</td>
<td>PN12</td>
<td>228</td>
<td>0</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>PN14</td>
<td>507</td>
<td>0</td>
<td>0</td>
<td>PN15</td>
<td>507</td>
<td>0</td>
<td>0</td>
<td>PN17</td>
<td>507</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PN18</td>
<td>631</td>
<td>1</td>
<td>0</td>
<td>PN20</td>
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<td>0</td>
<td>PN21</td>
<td>0</td>
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</table>

...}

<table>
<thead>
<tr>
<th>SITE</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
<th>SITE</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
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<th>SITE</th>
<th>PRN</th>
<th>Good</th>
<th>Gap</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE</td>
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<td>525</td>
<td>34</td>
<td>0</td>
<td>PN05</td>
<td>728</td>
<td>13</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PN06</td>
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<td>PN12</td>
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<tr>
<td></td>
<td>PN14</td>
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<td>PN17</td>
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<tr>
<td></td>
<td>PN18</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

These lists (one per station) show by satellite number of good data in the one-way sequence, the number of data deleted in gaps between closely spaced bias flags, and the number of remaining bias flags that might be resolved (i.e., number bias flags separated by less than twice the maximum size over which bias flags would be removed). Large numbers in the gap columns and/or large numbers of remaining bias flags usually mean bad prefit residuals or noisy data. Usually, the numbers in gap column increase when AS is on especially for SNR-8 receivers. More than 3 bias flags remaining usually indicates that the data is noisy and broken up into small pieces. (Bad data at one site can often lead to additional biases at other sites, so it usually the site with the most bias flags that is causing the problems.)

Elevation-angle Statistics

<table>
<thead>
<tr>
<th>SITE</th>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
<th>30-35</th>
<th>35-40</th>
<th>40-45</th>
<th>45-50</th>
<th>...</th>
<th>80-85</th>
<th>85-90</th>
<th>Min (dg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARAK</td>
<td>0</td>
<td>505</td>
<td>502</td>
<td>591</td>
<td>429</td>
<td>437</td>
<td>537</td>
<td>361</td>
<td>...</td>
<td>40</td>
<td>15.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AYVA</td>
<td>0</td>
<td>575</td>
<td>499</td>
<td>545</td>
<td>419</td>
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<td>...</td>
<td>40</td>
<td>15.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

...}

<table>
<thead>
<tr>
<th>SITE</th>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
<th>30-35</th>
<th>35-40</th>
<th>40-45</th>
<th>45-50</th>
<th>...</th>
<th>80-85</th>
<th>85-90</th>
<th>Min (dg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE</td>
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<td>1643</td>
<td>1704</td>
<td>1400</td>
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<td>54</td>
<td>15.00</td>
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<td></td>
</tr>
<tr>
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<td>1789</td>
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<td>1419</td>
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<td>79</td>
<td>15.00</td>
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<td></td>
<td></td>
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<tr>
<td>WETT</td>
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<td>1624</td>
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<td>1529</td>
<td>1468</td>
<td>1441</td>
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<td>...</td>
<td>208</td>
<td>15.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This table shows the number of good data or good normal points in elevation bins. Correctly operating receivers should have about the same number in 15-20 degree bin as in the 20-25. (The above example is for 24 hours with 15-point normal points).
Bias Flag Report

This report provides an overall summary of the number of bias flags in the clean data and why they were added.

<table>
<thead>
<tr>
<th>SITE</th>
<th># Flagged</th>
<th># Remaining</th>
<th># Edited</th>
<th># with jump</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORG</td>
<td>JMP</td>
<td>ION</td>
<td>GAP</td>
<td>DDS-DD</td>
</tr>
<tr>
<td>ARAK</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MATE</td>
<td>63</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>8</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
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<td>26</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ONSA</td>
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<td>0</td>
<td>0</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>6</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
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<td>16</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>55</td>
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<td>0</td>
<td>7</td>
</tr>
<tr>
<td>WETT</td>
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<td>0</td>
<td>11</td>
</tr>
<tr>
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<td>2</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The report is in four sections:

- **# Flagged** are the numbers of bias flags added or encountered during cleaning (Entries explained below).
- **# Remaining** are the numbers of bias flags left in the cleaned data.
- **# Edited** are the numbers of bias flags removed by deleting the data affected by the bias flag (as opposed to the bias flag removed by reliably resolving the integer number of cycles at the flag).
- **# with jump** are the numbers of bias flags which were resolved to non-zero integer values. The difference #Flagged - (#Remaining+#Edited+#with jump) gives an idea of the number of bias flags added that were not really needed. (It is not possible to tell how many real jumps were in the edited data).

When data are normal pointed the number of remaining bias flags will not necessarily be the same as the sum of the values shown in the "Data Editing and Bias Flags Remaining" report because this latter report is generated before normal points are formed, and some bias flags reported in the #Edited columns are not present if the data are deleted during the normal point formation.

Within each of these categories, the reasons for adding the bias flags are given:

- **ORG** is the number of original bias flags in the data (loss-of-lock indicator set in the rinex file). There is not much the user can do about these if they are large, other than to conclude that the receiver itself was not very happy.

- **JMP** is the number added due to large jumps between the phase and range estimates of the clocks. Large values here can indicate very bad prefit data (e.g. when site positions are 100's km in error) but most often indicate bad range data. Very bad ranges (>300 m) will generate **AVCLCK** errors in model, and smaller range errors can be detected by the reports of biases added in the one-way phase fitting. The tolerances for these fits can be increased to stop the bias flags being added, or the initial range data can be deleted. (These are often low elevation data that will not be used in the final analysis anyway.)

28 September 2006
ION is the number of bias flags added in the ionospheric jump detector. Again the tolerances can be increased so that these jumps are not detected. This jump detector is independent of both the range and prefit model quality. For equatorial and polar sites the detector tolerances should be loosened. (e.g., *ion_jump_tol yell 30 6.0 2.0 5.0*)

GAP is the number added due to gaps in the data. There is not much that the user can do about these since they result from gaps in the data. If the SNR is being used to flag data, reducing the SNR limit can make these values smaller.

DDS is the number of bias flags added due to discontinuities in the double difference data. Large values here indicate poor quality phase data or bad prefit residuals.

WLS is the number of bias flags added due to jumps in the widelane observable. The widelane jump detector should be loosened for AS data. (In the example used here all these values were zero, so the WLS column has been cut out to reduce the table width.)

DDC is the number of bias flags added during cleaning. Large values here are very bad because all the jumps in the data should have been detected before cleaning starting. Grep'ing on LCDD in autcln.out will show the magnitudes of the jumps. Most often these are just above the tolerances for detection and simply reflect the increased sensitivity of the detector used during cleaning. Large jumps usually mean that autcln has become confused as to which one-way a jump occurs on and is trying to patch it in the wrong place. Often deleting some of the data around these times is sufficient to remove the problem. Grep'ing on the epoch number (with a space on either side) shows the manipulations of all data at this epoch, including which stations and satellites were used to do the patch. This can be useful in tracing what happened during the cleaning.

Editing Report

This report shows the parameters used at each station for the editing and why data were eliminated from the analysis.

```
EDITING REPORT AND SITE PARAMS
SITEMnCLN MnOUT SNR LSNR GF03 RCLK GF02 BEND BCLS NPED GF-1 GF04 DDSC PFED GFUN BDL2 NODD ELEV EDIT MMRG ELCL Good (deg)(deg)L1 L2
ARAK 10.00 15.00 1 1 0 0 2 0 16 0 0 0 0 58 6 0 0 0 6 61 0 6 5359
AYVA 10.00 15.00 1 1 0 0 0 0 0 0 0 0 0 37 0 0 11 61 0 11 5214
... MATE 10.00 15.00 1 1 0 0 0 0 79 77 0 0 0 0 266 0 0 0 28 1605 211 0 1605 166
ONGA 10.00 15.00 1 1 0 0 0 0 249 167 0 0 0 0 260 0 0 1050 4180 216 0 4180 16388
WETT 10.00 15.00 1 1 0 0 0 0 142 17 0 0 0 0 255 0 0 11 2347 199 0 2347 16793
```

MnOUT is the minimum elevation angle to be used when writing out the C-files.

MnCLN is the minimum elevation angle used during cleaning. By including lower elevation data for cleaning, there is more chance of finding double differences. The disadvantage is that low elevation angle data can be of very poor quality for some receivers. Also we have seen cases where the low elevation angle data appears to be values generated by the model in the receiver and therefore is very smooth but inconsistent with the real data. This really confuses autcln because the data appear very good and often autcln will remove the real data because they are so much noisier than the "model" data.

28 September 2006
**SNR** L1 and L2 are the signal-to-noise ratio (snr) limits used by station. There is some inconsistency in the snr limits used by different RINEX translators especially for Rogue SNR-8 data. The values above (for KIT3 which is a TurboRogue) are for Rogues translated by JPL's SRX program. (Strictly, 4 means SNR<0 in the SRX converter, but there seem to be lots of good data with snr of 4 so we accept these data. RGRINEX running on SNR-8 data will have snr values as low as 2 and these are often good data. An snr of 1 in the RINEX standard means bad data and hence the limits should never be less than 2. 0 or blank in the RINEX file for SNR will NOT be edited by *autcln* since by definition these values mean no information is available.

The meaning of each column is the number of points (before normal pointing, but after data for normal pointing has been selected) edited for the given reason. Data points can have multiple reasons for being edited.

**LSNR** -- SNR value at either L1 or L2 below the set limit

**GF03** -- GAMIT low amplitude flag (rarely if ever set by the current *makex*).

**RCLK** -- Large difference between autcln's estimates of the station clock and the value actually used in model (not implemented currently and cut from table displayed here to reduce the table width)

**GF02** -- GAMIT bad data flag. Indicates that the receiver is not tracking; usually denoted by an L2 SNR of 2. This flag may be set by *makex* but also set by *autcln* if the L1 and L2 range values are exactly equal. (All were zero in the table displayed here so they have been cut to reduce the width.)

**BEND** -- Bias flags were too close to the end of the data.

**BCLS** -- Bias flags were too close together.

**NPED** -- Data could not be used in normal point but was OK otherwise (usually about 10% of the total amount of good data for 15-point normal points).

**GF-1** -- GAMIT marginal flag. Usually zero for raw data but is set when data are cleaned in *cview*. Reprocessing of *autcln* output C-files with *edit_site_sv* used in the command file will set this flag.

**GF04** -- GAMIT elevation cutoff flag (set in *model*).

**DDSC** -- Too many bias flags were added during double difference scanning so the whole one-way sequence was deleted.

**PFED** -- Postfit *autcln* edits (postfit_edit command).

**INTR** -- Interactive edits (not implemented and not shown in the displayed table).

**GFUN** -- GAMIT flag of unknown type (should be zero; not shown in the displayed table).

**BDL2** -- SNR edits for L2 only (i.e., L1 SNR was good).

**NODD** -- Data for which no double differences could be formed (not implemented, but should be flagged if separate *autcln* runs are to be combined).

**ELCL** -- Data edited below cleaning elevation angle.

28 September 2006
EDIT -- Data edited by edit_site_sv command

MMRB -- Data flaged with the use MiniMac range = no command.

ELEV -- Data flagged below the output elevation angle.

Good -- Number of good data remaining that will be used in the solve analysis.

At the end of the autcln.sum file is a list of the parameter values used in the run.

The information written in autcln.out can sometimes be helpful in determining how autcln handled data at a particular epoch. Given below is an explanation of the lines appearing in the file:

**DD Trials line**

```
Ep 114  S1/C1 2 13  S2/C2 1 2  dL1/2 slip 0.0  0.0 cycles  NumLR 23 18
EpLR 111 114  dchi, Chiqual 1.7 102.9  30.3
```

- **Ep** is the epoch number
- **S1/C1** is site number and channel for one way
- **S2/C2** is site number and channel for double difference. If these values are zero then there was no double difference formed.
- **dL1/2 slip** is the change in number of cycles at L1 and L2
- **NumLR** is the number of data in left and right segments (May actually be less than this if unflagged bias found.
- **EpLR** is the epoch numbers across the gap or bias flag being patched
- **dchi, Chiqual** are the lowest two chi**2** increments when integer cycles are tried, and the ratio used to see if bias flag can be used.

**Bias Flag line** (always printed)

```
Epoch 114  Site MOJ1 PRN 20  L1 from 0.0 to 0.0  L2 from 0.0 to 0.0
Reliable?  T  30.44  BFLG OneBG F  Force F
```

where the first line designates the epoch, site, satellite and cycles added in L1 and L2

- **Reliable? T** indicates that the bias flag was removed, and the value following is **Chiqual**
- **BFLG** or **GAP** says whether a bias flag or gap is being patched
- **OneBG T** or **F** gives the value of the **OneBG** flag (see commands)
- **Force** indicates whether (T) or not (F) the one-ways were forced to have the bias flag removed so that other combinations could have one bias or gap.

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6. Automatic Batch Processing

6.1 Overview

Once you understand the file structure and analysis tools of GAMIT, you can save significant time in processing large quantities of data by using the automatic processing script `sh_gamit` and the related scripts `sh_glred`. `Sh_gamit` takes you, with a single command, from raw or RINEX data over a range of days to a solution and sky plots of phase data as a record of the GAMIT analysis. `Sh_glred` uses the GAMIT results to produce time series of day-to-day repeatability and a solution (h- or SINEX) file that may be combined with those from other epochs to estimate station velocities. The only preparation required is setting up the control files, most of which are common to all analyses of a particular era, and assembling the non-IGS data in one or more directories on your system.

The first step in running the scripts is to create an experiment directory and to link or copy into it the standard control and data tables. With Release 10.1, all of the GAMIT files reside in `~gg/tables`. Executing the script `sh_setup` will invoke `links.tables` to link into the experiment `.tables` directory all of the standard data tables (see Section 4.1) and will copy into the experiment `.tables` directory the seven control and data files listed below:

- `process.defaults`: Edit to specify your computation environment, sources for internal and external data and orbit files, start time and sampling interval, and instructions for archiving the results.
- `sites.defaults`: Edit to specify which local and IGS stations are to be used and how station log data are to be handled.
- `station.info`: Make sure that this file is current (from SOPAC) for all IGS stations you will use in your analysis. If the RINEX files for your local network contain IGS-standard receiver and antenna codes and the correct height information refers to the ARP, then no further entries are required. If not, then you must manually enter the GAMIT codes and height values into the file. You can give `station.info` priority over the RINEX headers using the `xstnfo` option in `sites.defaults`.
- `apr` files: `Sh_gamit` maintains in the experiment tables directory two files of a priori coordinates. The file ending in .apr (set as aprf in `process.defaults`, `itrf00.apr` in the template) contains the Cartesian coordinates (position and velocity) of stations you wish to have unchanged throughout the processing. The L-file (.lfile.), which with Release 10.1 can contain either Cartesian position and velocity (same as .apr file) or spherical (GAMIT old-style) position, is updated after each day is processed if the adjustments exceed a specified value (0.3 m by default). When you execute `sh_setup`, you can specify whether you want `.lfile` to be spherical (-newfmt no, default) or Cartesian (-newfmt yes). If you have good coordinates for stations not in the apr file, you should append these to the file if you want them to be unchanged. For any station that does not have coordinates in `.lfile`, `sh_gamit` will attempt to calculate coordinates via a pseudorange solution, or (if set use_rxc Y in `process.defaults`) use the coordinates in the RINEX header. When GAMIT runs, these

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coordinates will be updated from the phase solution so that for successive days on which the same station is observed, the accurate coordinates will be used.

`sestbl` and `sittbl` : Edit these to set the appropriate options for your analysis. Make sure that any station for which you specify tight constraints in `sittbl` has accurate coordinates in the `apr` file (`aprf` in `process.defaults`).

`autcln.cmd` : This file will usually not require editing unless you encounter unusual data during the processing.

You may also choose to create under the experiment directory a `/rinex` directory and to copy into it all of your local RINEX files. Alternatively, you can specify in `process.defaults` the directory structures for searching for raw and RINEX files on your local and remote systems, as explained in Section 10.3. All other directories and files required by GAMIT will be created by the script.

Once you have edited appropriately the template files, you can start the processing from within the experiment directory by giving `sh_gamit` simply the 4-character code for the experiment and a range of days to process:

```
sh_gamit -expt emed -d 1999 235 236 237 238 >&! sh_gamit.log
```

The time span can also be specified using `-s <start_day> <stop_day>` to indicate a range of consecutive days, or `-r <days>` to indicate that you want to process a single day `<days>` before the current date. You may also override some of the parameters specified in `process.defaults`:

- `orbit <type>` Type of orbit (IGSP IGSR IGSF SIOP SIOR SIOF)
- `eops <name>` EOP series to be used (usno [default], bull_b)
- `sessinfo` Sampling interval, #epochs, start time (HH MM) (e.g. 30 2880 0 0)
- `copt` List of files to compress in the day directory (default x, k, autcln.out, d)
- `dopt` List of files to delete from the directory (default C-files only)
- `pres` Plot phase residuals as postscript skyplots (default no)
- `nogifs` Do not create gif files of sky plots (default is to create from postscript)
- `netext <char>` Add net--specific suffix (character) to day directory names (e.g. 035z)
- `noftp` Don’t try to ftp any data from outside your system (default is to ftp)
- `mailto` User name and machine (e.g. simon@chandler.mit.edu)

Most of the time the parameters may be omitted in favor of the values you have specified in `process.defaults` for the whole experiment. The overrides are useful, however, if you wish to test the effect of processing a day with a different orbit, EOP table, or session length, in which case you can create second directory for the same day by appending a character to its name (e.g., `-netext t`). Finally, you may launch `sh_gamit` from anywhere on
the system by specifying the full path name of the processing directory with -dir <path>. When the script runs, it will write to the screen a record of each step, which you may choose to redirect to a file (e.g., >&! sh_gamit.log). Though the current version of this log is cryptic in parts, you should be able to use it together with GAMIT.fatal file, and the source code for sh_gamit to identify the point and reason for failure should that occur. We welcome user feedback to improve the displayed information.

When processing of each day is completed, sh_gamit will send a mail message to you giving the number of stations used, the rms of the one-way phase residuals for the two best and two worst stations from the AUTCLN postfit summary file, the nrm values from the Q-file, the number of ambiguities resolved, and a list of any large adjustments to station coordinates. These statistics will let you know whether you need to examine the GAMIT output further for possible reprocessing.

A collateral benefit of the automatic processing development is that we have cleaned up many of the utility shell scripts so that they can be easily used in non-automatic or customized processing. The most useful of these are sh_make_rinex, sh_get_nav, sh_get_rinex, sh_get_orbits, sh_update_eop, sh_link_rinex, and sh_make_sky_gifs. Instructions for running each of these may be obtained by typing the name with no arguments.

In the initial release of sh_gamit (10.0), many of the control files were kept in ~/gg/templates and copied to [expt]/templates to begin processing. This scheme proved to be unnecessarily complicated and has been replaced by the scheme described above, with all the required files provided in ~gg/tables and copied to [expt]/tables to begin the processing. The directory ~gg/templates still exists and contains template files for GLOBK, duplicates of some files in ~gg/tables, and some extra documentation.

6.2 Control files

Following are annotated copies of the two control files used by sh_gamit.

process.defaults

# Do not remove any of these entries. To by-pass a function, set the # value to null: ""
#
## LOCAL DIRECTORIES
# Directory for translation of raw data (may have links to /rawfnd)
set rawpth = "/data13/simon/mitnet/raw"
# Directory path for raw archives (search all levels); e.g. /data18/simon
set rawfnd = ""
# Input files for RINEX translators
set mpth = "$procdir/mkrinex"
# RINEX files directory
set rpth = "$procdir/rinex"
# Directory path for RINEX archives (search all levels); e.g. /data18/simon
set rnxfnd = ""
# Broadcast orbit directory
set bpth = "$procdir/brdc"
# IGS files directory
set ipth = "$procdir/igs"
# G-files directory
set gpth = "$procdir/gfiles"

# GAMIT and GLOBK tables directory
set tpth = "$procdir/tables"

# Globk solution directory (required but not yet used)
set glbpth = "$procdir/soln"

# Globk binary h-file directory (required but not yet used)
set glfpth = "$procdir/glbf"

# Output gifs directory
set gifpth = "$procdir/gifs"

# Template files
set templatepth = "$procdir/tables"

# Place to store temporary control files
set cpth = "$procdir/control"

# Archive root directory (cannot be null)
set archivepth = "$procdir/archive"

## FTP INFO FOR REMOTE FILES

# Raw data archive
set rawarchive = 'chandler.mit.edu'
set rawdir = 'pub/continuous/mitnet'
set rawlogin = 'anonymous simon@chandler.mit.edu'

# Addresses for CDDIS, SOPAC, IGSCB, and USNO are given in /com/ftp_addresses

## GAMIT

# Set sampling interval, number of epochs, and start time for processing
set sint = '30'
set nepc = '2880'
set stime = '0 0'

# New variables for updating tables (see sh_upd_stnfo)
set stinf_unique = "-u"
set stinf_nosort = "-nosort"
set stinf slthgt = "2.00"

# Set "Y" to use RINEX header coordinates if not in lfile or apr file
set use_rxc = "N"

# 4-character code for broadcast orbits
set brdc = 'brdc'

# Minimum x-file size to be processed (Def. 300 blocks)
set minxf = '300'

# Set search window for RINEX files which might contain data for day
set rx_doy_plus = 1
set rx_doy_minus = 1

## RESOURCES

# Minimum raw disk space in Kbytes
set minraw = '30000'

# Minimum RINEX disk space in Kbytes
set minrinex = '30000'

# Minimum archive disk space in Kbytes
set minarchive = '20000'

# Minimum working disk space in Kbytes
set minwork = '200000'

## SYSTEM-DEPENDENT SETTINGS

# UNIX df command must be set to return the correct form
set udf = 'df -k'

# UNIX mail command
set umail = 'mailx -s'

# Mail address for the processing report
set mailto = 'simon'

# Host name for email and anonymous ftp password use
set machine = 'wegener.mit.edu'

# Ghostscript path

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sites.defaults

# File to control the use of stations in the processing
#
# Format: site  expt  keyword1  keyword2 ....
#
# where the first token is the 4- or 8-character station name (GAMIT
# uses only 4 characters, GLOBK allows only 4 unless there are earth-
# quakes or renames); the second token is the 4-character experiment
# name, and the remaining tokens, read free-format, indicate how the
# station is to be used in the processing. All stations for which
# there are RINEX files in the local directory will be used auto-
# matically in the GAMIT processing and do not need to be listed.
#
# GAMIT:
# ftprnx = sites to ftp from rinex data archives.
# ftpraw = sites to ftp from raw data archives.
# xstinfo = sites to exclude from automatic station.info updating.
# xsite = sites to exclude from processing, all days or specified days
# GLOBK:
# glrepu = sites used in the GLRED repeatability solution
# glreps = sites used for reference frame definition (stabilization) in
# GLORG for the GLRED repeatability solution
# glts = sites to plot as time series from GLRED repeatability solution
# may use the following:
# all_sites tubi xstinfo
  mate_gps tubi ftprnx xstinfo glrepu glreps
  ankr_gps tubi ftprnx xstinfo glrepu glreps glts
  kit3_gps tubi ftprnx xstinfo glrepu glreps
  nico_gps tubi ftprnx xstinfo glrepu
  sofi_gps tubi ftprnx xstinfo glrepu
  zeck_gps tubi ftprnx xstinfo glrepu
  zwen_gps tubi ftprnx xstinfo glrepu glreps
  bahr_gps tubi ftprnx xstinfo glrepu
  tela_gps tubi ftprnx xstinfo glrepu
  tubi_gps tubi ftpraw xstinfo glrepu glreps glts
  mert_gps tubi ftpraw glrepu glreps glts
  kant_gps tubi ftpraw glrepu glts
  ..ttth_gps tubi xstinfo xsite:1999_256-1999_278 glreps xsite:1999_300
  ..thht_gps tubi xstinfo xsite glreps

6.3 Using sh_gamit

Before you start, review carefully all of the entries in process.defaults. In particular, make sure that the system-dependent UNIX commands are correctly specified. The df and mail commands are set in process.defaults. A form of df must be used that produces a return of the form

Filesyst 1024-blocks Used Available Capacity Mounted on  
shida:/shida/data34 13573771 11711318  1156800  91%   /tmp_mnt/data34

Some systems also return different units with the ls -s option (e.g., kilo-bytes vs 128-word blocks, so the minimum sizes of the X-files should be checked to make sure that the
limits represent truly small files. A POSIX-compliant version of awk must be specified with a link in your path (e.g., in /gamit/bin). (An alias in your .cshrc file will not work with the sh_gamit scripts.)

The most complex feature of sh_gamit is the procedure by which raw and RINEX files are gathered for each day of a survey. The simplest situation is when you have all of the data on your local system in RINEX form and placed into the /rinex directory under the experiment directory before you start. In this case, you should leave blank all of the variables associated with collecting additional data: /raw, /rawfnd, /rnxfnd in process.defaults and the ftpraw and ftpnx tokens of sites.defaults. If you need to acquire global RINEX files from an IGS data center, you may specify the stations using ftpnx in sites.defaults. Sh_gamit will invoke sh_get_rinex for the CDDIS, SOPAC, and UNAVCO archives and ftp to your /rinex directory all stations specified that are available. A more complicated situation arises when you have a mixture of raw and RINEX data, which may be archived in multiple directories on your system or at a remote data center. The /rawfnd and /rnxfnd variables of process.defaults specify a path to multiple-level raw and RINEX directories which will be searched for any data files available for the day being processed. In this case, sh_gamit will create links within the experiment /raw and /rinex directories to the files in the /rawfnd and /rnxfnd paths. Any case-folding or renaming necessary to create standard file names for raw files will be done for the links in /raw, leaving the original names in /rawfnd unchanged. Whatever the mix of raw and RINEX files available, sh_gamit will compare the lists of X-, RINEX, and raw files available, and perform translations only when the product file is not available. If you wish to force retranslation of raw to RINEX, you must remove the product files before you start. X-files are remade whenever there is a change in session information (-sessinfo in the command line, or a change in the session.info file) or when you specify --remake X

If you expect sh_gamit to generate station.info entries from the RINEX header information, you should review the antenna and receiver names used in all of the headers before you start (e.g., by grep'ing on the RINEX files for 'REC #' and 'ANT #'). If any non-standard names have been used, make sure that a unique string representing these names appears in /tables/guess_rcvant.dat. If you know that all of your receivers and/or antennas are of the same type, you can force their use by specifying them as ant default and rcv default in this file. Antenna heights can also be problematic. In the RINEX standard, the height is supposed to be a vertical height to antenna reference point, but often a slant height is actually given in the file. If the latter is the case, then stinf_slthgt in process.defaults can be set to a height above which the height will be assumed to a slant height to the outside edge of the ground plane. (Setting stinf_slthgt to 0 or a large number will make all heights interpreted as direct height measurements.) Running from raw data can be problematic because the antenna type is not usually stored in the raw files and must be supplied by the user. The UNAVCO TEQC program is used for converting to RINEX. The sh_make_rinex script assumes an antenna type and adopts a generic (not IGS standard) name based on the receiver type: Trimble --> TRIMBLE_4000SST, TurboRogue-->AOAD/M_T, Ashtech --> ASH701933_M. If the wrong

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height is used in the GAMIT processing, but the antenna type is correct, then the station.info file can be updated and program hfupd used to correct the binary H-file without the need to rerun GAMIT. Note that sites that are listed in sites.defaults with the xstinfo ("exclude station.info update") entry should have station.info entries. This entry should be used for all IGS stations since the station.info file in ~/gg/tables has the information for these stations corrected specified whereas their RINEX headers, particularly for older data, may be incorrect. If sh_gamit cannot determine the receiver or antenna type from an existing station.info or from the RINEX headers, it will terminate with one of several messages that make this clear (see GAMIT.fatal or the screen or log-file output of the script).

If you are processing a session which does not cover a single UTC day, there can be problems in automatically updating the entries in station.info. If there have been changes in antenna height during the session, then you will need to create the station.info entries manually. Otherwise, the processing should go smoothly as long as you instruct the script to look for RINEX files on all of the days covered by the session using the \texttt{rx_doy_minus} and \texttt{rx_doy_plus} entries in process.defaults. Since the date in a RINEX file is supposed to reflect the time of the first measurement, for single-day processing, the \texttt{rx_doy_plus} entry should be 0 (since no data from the next day should be needed). For RINEX files which cross the day boundary, \texttt{rx_doy_minus} = 1 should capture these data correctly. If RINEX files are longer than 24-hours then \texttt{rx_doy_minus} may be to set larger to ensure that all data are processed. (This feature currently does not work across year boundaries.)

A common mode of failure for sh_gamit is having a station or all of its data removed from the solution. If the station does not appear at all, the problem is usually a missing RINEX or incomplete RINEX file. If the station appears but has no data, then the data have most likely been removed by AUTCLN. The most common reason for the removal is that too many bias flags were added (\texttt{dpsc} column of the editing report of the AUTCLN summary file), either because of poor a priori coordinates or poor receiver performance.

If a priori coordinates for a station are not available in the L-file (or apr file) from previous processing, sh_gamit will by default invoke the sh_rx2apr script to perform a pseudorange solution. Coordinates good to 10-20 m can usually be obtained from the data at the station of interest (better if SA is off), but the preferred approach is to perform the solution differentially, using also a RINEX file from an IGS station with known coordinates. To make sure this happens, you should specify ftpprnx in sites.default and have present in the /rinex directory or available via ftp from an IGS data archive the RINEX files for each day from one or more IGS stations. To by-pass sh_rx2apr and use the coordinates from the RINEX header, set \texttt{use_rxc = Y} in processdefaults. This option should be used only if you know that the header values are always present and accurate.

Sh_gamit can also fail if it is unable to ftp required global RINEX files or orbital information from an IGS archive (usually SOPAC or CDDIS). The GAMIT.fatal message
will usually make clear what file is missing. In this case, check the ftp connection manually and restart the processing.

When you rerun a day after a previous failure, you need to exercise some care to avoid repeating the failure. The easiest solution is to remove the day directory completely and to remove any bad entries in the L-file and station.info in the /tables directory. If you do not remove the day directory, then note the following protocols: (a) Any existing X-file in a directory will be used again and the script assumes that there is a valid station.info entry for this file (if not, the process will fail). (b) Any existing RINEX file linked in the day directory will be assumed to exist. If the link is now empty because you have renamed or removed the file in the remote directory, this may not be detected correctly on all systems. (c) A previously added station.info entry will be used (and not replaced) if it applies to the day being processed. (d) Coordinates in the L-file will be used if they exist (so if the entry has been corrupted it should be removed).

Sh_gamit will handle sessions spanning UTC day boundaries so long as you keep in mind the requirements for external RINEX and orbit files for both days. Currently the script will ftp RINEX files only for the start day specified in the calling arguments, so if you do not have already on your system the external RINEX files for the following day, you should ftp it in advance of running the day. (If you are processing a sequence of days and do these in backward time order, you'll automatically get the RINEX files you need.) For regional analysis, orbits can be handled by fitting a single arc to the sp3 files from the two days using sh_sp3fit; the g-file epoch will be noon on the first day (even if this is outside the span of the session), so the file-naming for the session remains consistent. The command sequence for processing a 12-hour session beginning at 1800h on day 234 of 1997 might look like the following:

```
   cd .igs
   sh_get_orbits  –yr 1997  –doy 234  –ndays 2  –multiday
   cd ../rinex
   sh_get_rinex  –yr 1997  –doy 234  –ndays 2  –sites albh drao
   sh_gamit  –expt pcnw  –d 1993 234  –rx_doy_plus 1  –sessinfo 30 1440 18 00 > &! sh_gamit.log
```

You can check the consistency of the orbits by examining the output file sp3fit_igsf7234.rms.

### 6.4 Using sh_glred

This script provides an efficient way to generate time series from a combination of regional and global data. The input is a specified set of regional and/or global networks, a total span of days to be processed, and the number of days to be combined in each solution. The script then collects all the available ascii h-files, generates binary h-files using htoglb, combines all of these for each day or group of days, runs glred and glorg to produce a solution for each group, and generates repeatability plots. The search areas for h-files may include GAMIT day directories, any number of other local directory trees,
and the SOPAC archive. Sh_glred is executed from the experiment-level directory, but runs in a solution directory below it, specified by glbpth in process.defaults. By changing this name you can generate multiple parallel solution directories. Although sh_glred can generate the command files (globk_comb.cmd and glorg_comb.cmd) if they are not present, we recommend that you create them manually by copying the versions in gg/templates into the solution directory and editing them for your task. The most common changes are for the apriori files and for the stations to be used in the solution and for the stations and constraints to be used in defining the reference frame.

Sh_glred is not designed to generate repeatabilities from daily binary h-files that have already been combined or to estimate velocities from h-files spanning several years. Templates for using glred and globk for these tasks, however, may be found in the /templates directory; see run_repeat, run_combine, run_velocity, globk_rep.cmd, globk_comb.cmd, globk_vel.cmd, glorg_vel.cmd.

Once you have edited appropriately the template files, you can start the processing from within the experiment directory:

```
sh_glred -s <yr1 doy1 yr2 doy2> -expt <expt> -net <networks> -local
-netext <char> -yext <year> -ncomb <num> -stnfo <station.info> -cmd
-opt <A F H L U G E K C R>
```

where -s is used to specify the start (yr1 doy1) and stop (yr2 doy2) year and day-of-year for the processing, -expt is the 4-character experiment name for the H-files in local day directories (ddd[char]) , and -net indicates the SOPAC H-files to be included. The options for SOPAC are ALL (default), or some combination of the solutions in the archive: global (igs1 igs2 igs3), California (bard net1 net2 ...net7), Basin and Range (ban1 ban2 ebr1), northwest North America(akda pan1), and western Eurasia(eura emed). If -local is specified, the script will process only days within the span for which local data are available; otherwise, it will process all days within the span for which it can find SOPAC H-files. The days to be processed can also be specified explicitly using -d yr doy1 doy2 doy3..., or with -r days to indicate that processing should commence a certain number of days (days) before the current date and continue until there are no more local or SOPAC files to include.

The local directories are searched by default with the day-of-year, but can be restricted by specifying a network suffix (e.g., 03Sr) with -netext or a year prefix (e.g., 1997_) with -yext. The optional argument -ncomb is used to specify the number of days to include in each combination. The default is 1 day, but you can also use the script to produce weekly or monthly averages of local or global files. The argument (-stnfo) is the name of the station.info or SINEX file to be read by program hfupd; the default is ../tables/station.info.

The following processing tasks are available, listed in the order in which they are performed:

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Remove old h*.gl? files from the glfpth directory prior to starting.

Ftp global h-files from the SOPAC archive, search names given by <networks>.

Run htoglb on all ascii files present or linked within glfpth (usually prodir/glbf).

Link locally archived ascii H-files (all h[net|expt]?_yyddd) for inclusion in the combination.

Link locally archived binary H-files (all hyymmdd????_[net|expt].gl?) for inclusion in the combination. Searches are from hfnd down, where hfnd is by default prodir/glbf but may be specified as multiple paths in process.defaults.

Link locally generated combined binary H-files (*.GLX)

Run hfupd on binary h-files (not yet tested).

Run glred for combination or repeatabilities.

Run ensum and sh baseline for plots.

At the end compress the ascii H-files, remove any links, and copy the ascii and binary H-files to glbpth/ascii_yyyy and glbpth/bin_yyyy, respectively, where glbpth is specified by process.defaults [default glbf]

Do all options.

The stations to be used in each part of the processing are specified by tokens in sites.defaults, as shown in Section 10.2. Stations included in the glred combination are accompanying by token glrepu, those used to define the reference frame in glorg by glreps, and those for which time-series plots are to be generated by glts. The default for glred and plots is to use all stations. For glorg stabilization, there is a default list of IGS stations built into the script, but for regional networks, you probably want to specify explicitly the stations to be used.

The script uses command files named globk_comb.cmd and glorg_comb.cmd, which it looks for in the solution (not /templates) directory. If these files do not exist, they will be created with the appropriate commands to do a loose combination with glred and a glorg stabilization. If you wish to alter any of the globk or glorg commands, for example to constrain orbits in a regional solution, change the default EOP constraints, or omit the glorg solution, you can run sh_glred initially with only the -cmd option to create the command files for editing.

To avoid overwriting useful h-files or using obsolete ones, it is important to keep in mind the precedence rules of the script. For local data (sh_gamit day directories), specifying the H option will force htoglb to be rerun for all directories within the time span indicated, whether or not a binary file exists in the searched directories (nominally glbf and glbf/bin_yyyy). Omitting H will cause no new binary files to be created, so it is not possible to retranslate only a selected group of ascii H-files. This is not an important limitation, however, because htoglb runs quickly. For remote data (locally linked or ftp'd from SOPAC), setting H will also force htoglb to be rerun on any ascii H-files present or linked (by LA) in the H-file (glbf) directory, but you can safely set F since the script will not re-ftp any remote (ascii) H-files that are present.
Output H-files from the combination are named HYYMDD_[expt][netext].GLX and written in to the solution directory. The script creates a separate .gdl file for each day with a similar name, each pointing to the combined GLX H-file in the solution directory. When ensum is run, it will create SUM. and VAL. files by concatenating all .org files present, so you can run sh_glred separately for different time spans and create plots that combine the spans.

Examples

Combine regional files from sh_gamit with global files from SOPAC, one day at a time and generate repeatability plots:

```
sh_glred -s 1999 235 1999 250 -net igs1 igs2 igs3 -netext r -expt emed -opt F H G E C
```

Regenerate repeatability plots from existing binary h-files (e.g with different stabilization):

```
sh_glred -s 1999 235 1999 250 -net igs1 igs2 igs3 -netext r -expt emed -opt G E
```

Rerun one day and then repeat the plots:

```
sh_glred -d 1999 241 -net igs1 igs2 igs3 -netext r -expt emed -opt H E
sh_glred -s 1999 235 1999 250 -netext r -expt emed -opt E
```

Combine existing regional and global binary h-files into monthly averages:

```
sh_glred -d 1999 235 2000 120 -ncomb 30 -net igs1 igs2 igs3 -expt emed -opt G LB
```
7 Atmospheric Delay Models

7.1 Description of the atmospheric delay

As the GPS signal travels from the satellite to the receiver, it propagates through the atmosphere of the earth, where it is retarded and its path changed from a straight line to a curved one. If we take the simplified mathematical model for the observable to be one in which the signal is assumed to be propagating in a straight line and at the speed of light in vacuum, then the "atmospheric delay" is defined to be the difference between the true electrical path length and this assumed straight-line length. Using this definition, the atmospheric delay is a term to be added to the simplified model.

The atmospheric delay in the zenith (i.e., vertical) direction varies from about 6 to 8 nanoseconds (190 to 240 cm, or 10-12 cycles of phase at L1-band) depending on meteorological conditions and site location. The atmospheric delay increases with decreasing elevation angle approximately with the cosecant of the elevation angle, so that the atmospheric delay at an elevation angle of 20 degrees may be from 30-36 cycles of L1 phase.

The atmospheric delay is usually broken down into two components. The first component is due to the mixture of all constituents, but it is assumed that the mean molar mass of these constituents is equal to the mean molar mass of only the "dry" (all except water vapor) constituents. Assuming that the atmosphere is in hydrostatic equilibrium, the "zenith delay" due to these components is very well modeled (standard deviation of approximately 0.5 mm) using the surface pressure, which represents the total weight of the atmosphere. This component of the atmospheric propagation delay is usually termed the "dry" or "hydrostatic" delay, and accounts for nearly all (90-100%) of the atmospheric propagation delay.

The second component of the atmospheric delay is due to water vapor, and includes a correction for the "dry mean molar mass" assumption used to derive the dry delay (see above). This component of the atmospheric propagation delay is called the "wet delay" and is equal to zero if there is no water vapor present anywhere along the path of the signal. However, there usually is water vapor present along the path of the signal and it is poorly predicted using measurements of conditions at the site alone. This difficulty is caused by the "unmixed" condition of atmospheric water vapor, which means that the water vapor is present in "blobs" throughout the troposphere. Because of this condition, models for the wet delay are notoriously inaccurate and can have RMS errors of several cm (zenith), out of a total (zenith) wet delay of 0-40 cm. Hence, we almost always estimate the wet zenith delay from the observations.

GAMIT includes the ability to estimate a zenith delay and a gradient for each station, modeled in both cases by a piecewise-linear function over the span of the observations. The following sections describe the a priori models used for the hydrostatic and water vapor delay, and the parameterization and output tables used for the estimation. Section
7.5 describes a new utility for extracting estimates of precipitable water from GAMIT processing.

7.2 Algorithms for the atmospheric delay

The atmospheric propagation delay is implemented in the following manner:

\[ \text{ATDEL(EL)} = \text{DRYZEN} \times \text{DRYMAP(EL)} + \text{WETZEN} \times \text{WETMAP(EL)} \]

where \( \text{EL} \) is the elevation angle of the satellite, \( \text{DRYZEN} \) is the dry zenith delay, \( \text{WETZEN} \) is the wet zenith delay, \( \text{DRYMAP} \) is the "mapping function" for the dry delay (see below) and \( \text{WETMAP} \) is the mapping function for the wet delay. A mapping function is a mathematical model for the elevation dependence of the respective delays. The mapping functions (for both the dry and the wet terms) are approximately equal to the cosecant of elevation, but there are significant deviations from this "cosecant law" due both to the curvature of the earth and the curvature of the path of the GPS signal propagating through the atmosphere.

Many expressions for the four terms \( \text{DRYZEN}, \text{DRYMAP}, \text{WETZEN}, \) and \( \text{WETMAP} \) appear in the scientific literature. For microwave observations there is little controversy about the expressions for the dry zenith delay; the default model (\( \text{SAAS} \)) described by Saastamoinen [1972]. Since the wet zenith delay is estimated from the GPS observations, the expression used for the a priori value is not critical. What is important, however, is the use of a correct mapping function for both the hydrostatic and wet delay, and an \textit{a priori} value for the hydrostatic delay that is accurate enough that when we estimate corrections to zenith delay using the wet mapping function, we are adjusting primarily errors in set delay. These models and a priori values are prescribed by 8 entries in the \textit{sestbl}:

<table>
<thead>
<tr>
<th>Met obs source</th>
<th>Hierarchical list: RNX ufite GPT/STP [humid value]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>to match 10.2, use STP 50; new default is GTP 50</td>
</tr>
<tr>
<td>Dmap</td>
<td>Hydrostatic mapping function GMFH (default) NMFH / VMF1</td>
</tr>
<tr>
<td>WMap</td>
<td>Wet mapping function GMFW (default) / NMFW / VMF1</td>
</tr>
<tr>
<td>Tropospheric Constraints</td>
<td>YES/NO: Spatial constraints, default = No (see Sec 8.3)</td>
</tr>
<tr>
<td>Use map.grid = N</td>
<td>Read mapping function coefficients from a grid</td>
</tr>
<tr>
<td>Use map.list = N</td>
<td>Read mapping function coefficients from a station list</td>
</tr>
<tr>
<td>Use met.grid = N</td>
<td>Read met data from a grid</td>
</tr>
<tr>
<td>Use met.list = N</td>
<td>Read met data from a station list</td>
</tr>
</tbody>
</table>

In the absence of \textit{in situ} met data, the best choice of a priori pressure and temperature for a site comes from the “global pressure and temperature” (GPT) model developed by Boehm and Schuh [2006]. It generates surface pressure and temperature values as a function of location and time of year based on a spherical harmonic fit to 20?? years of meteorological data, and reduces biases in height estimates compared with adopting standard temperature and pressure (STP) for all stations at all times. If actual pressure

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and temperature values are available, however, from either measurements at the station (RINEX met file) or a grid or station-list file generated from a numerical weather model (NWM), these should be used. For example, if you have RINEX met files for some stations and a station list file from a current NWM, you could set

\[
\text{Met obs source} = \text{RNX UFL GPT 50}
\]

to indicate that model should check first for a RINEX met file, then for the station on the u-file, then revert to GPT. The last value is the assumed relative humidity (%), which, being a poor representation of integrated water vapor, may be set only approximately. The source of pressure and temperature on the u-file is determined by the grid and list files available. The VMF1 mapping function grid and list files (see below) can have either the pressure and temperature or the zenith hydrostatic delay (ZHD) included, in which case only \text{map.list} and/or \text{map.grid} need be specified. If you are not using VMF1, however, you may input pressure and temperature values via a \text{met.list} and/or \text{met.grid} files. If the input pressure and temperature are from a RINEX file, they are assumed to be values at the height of the station; if from a u-file, GPT, or STP, they are assumed to be surface values and are converted to values at the station height using expressions from Hopfield [1972] with a lapse rate of 4.5 °C/km. Careful studies above sea level should use \textit{in situ} measurements or a weather-specific lapse rate.

The mapping functions are set with the \text{Dmap} and \text{Wmap} commands. The defaults with Release 10.3 are now the “global mapping functions” (GMF) of Boehm et al. [2006a], which introduce a longitude dependence as well as the latitude and time-of-year dependence of the older Niell mapping functions (NFM) [Niell, 1996]. Highest accuracy for vertical studies is obtained by using the VMF1 mapping functions [Boehm et al., 2006b], derived at 6-hour intervals from numerical weather models. To invoke VMF1, link \text{map.list} and/or \text{map.grid} to a VMF1 file for the year you are processing, set \text{Use map list} and/or \text{Use map grid} to \text{Y[es]}, and include \text{ufile} (or \text{UFL}) in the \text{Met obs source list}.

If you wish to specify pressure, temperature, and humidity values explicitly for each station, you can do this in the sittbl. It is also possible to specify the zenith model and mapping functions for each station in the sittbl., though there is little reason to do this.

\[
\text{SITE} \quad \text{FIX} \quad --\text{COORD.CONST}-- \quad \text{DZEN} \quad \text{DMAP} \quad \text{WMAP} \quad --\text{MET.\_VALUE}--
\]

<table>
<thead>
<tr>
<th>SITE</th>
<th>FIX</th>
<th>--COORD.CONST.--</th>
<th>DZEN</th>
<th>DMAP</th>
<th>WMAP</th>
<th>--MET._VALUE--</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATO Castro Peak</td>
<td>NNN</td>
<td>100.</td>
<td>100.</td>
<td>100.</td>
<td>SAAS</td>
<td>NMFH</td>
</tr>
</tbody>
</table>

7.3 Estimating zenith delay parameters

Since the water vapor contribution to atmospheric delay is poorly modeled using surface meteorological data, GAMIT allows estimation of corrections to the zenith delay. The partial derivative of phase or pseudorange with respect to the zenith delay parameter is simply the mapping function, approximately equal to the cosecant of the elevation angle of the satellite as viewed from the station. For stations in a regional network the
elevation angles viewing a particular satellite will be nearly equal, producing high correlations among the estimated zenith delays. Even for stations a few meters apart, however, separate zenith delays can be estimated without causing numerical problems in \textit{solve}; although the uncertainties in all of the zenith-delay parameters will be large, the relative values of the estimates themselves can be trusted. To extract from the solution the uncertainties of the differences, however, you should fix or tightly constrain one of the values.

The first 10 entries control the estimation of zenith delays and gradients. To absorb adequately the atmospheric effects when estimating heights and horizontal position, it is usually optimal to use a 10-degree elevation cutoff angle, invoke elevation dependent weighting (N-file), and to estimate a zenith delay parameter every 2 hours and a single gradient for the session. For meteorological studies, however, you may want to give higher weight to low elevations and to estimate zenith and gradient parameters more frequently, particularly if you use elevation-dependent

The model for zenith delay can take the form of a single parameter for each station and session, or a piecewise linear function of zenith-delay over the session. In the latter case, the tabular points of the function can be constrained using a first-order Gauss-Markov process. Controls for estimation of zenith delay are input via the \textit{sestbl} and/or \textit{sittbl}. The \textit{sestbl} inputs, adopted as common to all stations are as follows:

\begin{verbatim}
Zenith Delay Estimation = YES ; YES/NO
Number Zen = 5                 ; number of zenith-delay parameters
Zenith Model = PWL             ; PWL (piecewise linear)/CON (step)
Zenith Constraints = 0.50      ; zenith-delay a priori constraint in meters
Zenith Variation = 0.02 100.   ; zenith-delay variation, tau; units m/sqrt(hr), hrs
\end{verbatim}

Specifying \textit{Number Zen = 1}, and \textit{CON} for \textit{Zenith Model} will invoke a single parameter for the zenith delay over the session. The best representation of zenith-delay variations is usually accomplished with a new zenith delay parameter for every 2–6 hours during the day using a piecewise-linear (PWL) function. To get estimates at 2-hr intervals for a 24-hr session, set \textit{Number Zen = 13} or \textit{Interval Zen = 2} (the latter is more convenient if you have different-length sessions during your survey). There is little gain in accuracy of station heights under most weather conditions between estimating zenith delays every 2 hours and every 6 hours, and the shorter intervals will increase running time for \textit{solve} considerably. The overall zenith constraint should be set loose enough to encompass comfortably any error in the wet delay; 0.5 meters is the default and reasonable. The variation is specified as parameters of a first-order Gauss-Markov process. The first value in \textit{Zenith Variation} is the point-to-point variation allowed, in units of meters. The second value is the correlation time (\textit{tau}) in hours. Setting \textit{tau} long compared to the observation span results in a random walk process, which is both reasonable and easy to interpret (and has the practical advantage of persistence with large error bars for spans with few observations). The default value of 100. hrs accomplishes this for 24-hr spans. Setting \textit{tau} equal to a value short compared with the tabular point interval will result in a white-noise process for the variation in tabular points; in this case the constraint will be
applied with respect to the default model value rather than the value of the last tabular point.

There is an additional entry in the sestbl,

\texttt{Tropospheric Constraints = NO ; YES/NO}

which invokes a spatial constraint on the zenith-delay parameters. This constraint can be useful for tying together the zenith-delay adjustments for closely-spaced sites in a network. This feature was coded originally for a single zenith delay, however, and does not yet work for time-dependent models.

Different values for the zenith constraints can be invoked using sittbl entries, shown below:

\begin{verbatim}
SITE              ---MET. VALUE----    ZCNSTR ZENVAR ZENTAU
CATO Castro Peak  1013.25  20.0 10.0   0.5000  0.005   100.
TROM TROMGPSM     1013.25  20.0 50.0   0.5000  0.020   100.
\end{verbatim}

It is currently a requirement that the number of zenith delays in the session be the same for all stations.

### 7.4 Estimating gradients

The effects of azimuthal asymmetry in the atmospheric delay are not included in model but may be estimated in \textit{solve}. The coded partials imply a model of the form

\[ \text{ATDEL(EL,AZ)} = \text{GRADNS*AZMAP(EL)*COS(AZ) + GRADEW*AZMAP(EL)*SIN(AZ)} \]

where EL is the elevation angle, AZ the azimuth, and AZMAP the mapping function for gradients, given by

\[ \text{AZMAP} = 1. / ( \text{SIN(EL)}*\text{TAN(EL)} + C ) \]

and C is a constant equal to 0.003 [\textit{Chen and Herring}, 1997]. Since the gradient parameters, GRADNS and GRADEW, have small and non-intuitive values near the zenith (i.e., for AZMAP = 1), we rescale them to represent the difference between the the north (or east) and south (or west) delay at 10 degrees elevation. At 10 degrees the rms scatter of gradients observed from VLBI observations are about 5 mm. Our default a priori constraint is 30 mm.
7.5 Extracting estimates of precipitable water

The utility *metutil*, invoked by `sh_metutil` allows you to extract the zenith delay estimates from the *solve* o-file, apply corrections for the hydrostatic delay, and convert the residual wet delay to precipitable water. The source of the hydrostatic corrections can be either the pressure values input to *model* as a priori or measurements of station pressure recorded in a RINEX met (*yyym*) file. In the first instance, the command line has the following form:

```
sh_metutil -f oeuraa.223 -z zkosg4.223
```

where oeuraa.223 is the name of the o-file from *solve* (*oexpta.ddd*) and zkosg4.223 is the name of the z-file from *model* (*zssssy.ddd*). The o-file contains the parameters of the piecewise-linear model estimated from the data, which *metutil* will interpolate to obtain zenith total delay (ZTD). Instead of an o-file, you may input a SINEX file with ZTD values. The z-file contains the zenith hydrostatic (dry) delay (ZHD) used as a priori, with the pressure and temperature input as a constant via the sittbl. or read from a w-file.

If the pressure and temperature are to be read from a RINEX file, the command line has the following form:

```
sh_metutil -f oeuraa.223 -m zimm32230.04m
```

where zimm2230.04m is the name of the RINEX met file (*ssssddds.yy*).

The output of *metutil* is a file named `met_[site].[yyddd]` containing the zenith wet delay (ZWD) and precipitable water (PW) and their uncertainties, in the form

```
* Estimated atmospheric values for ZIMM
* Input files: oeuraa.223  zimm0223.04m  ZTD-file sigmas scaled by  1.0
  Yr   Doy   Hr   Mn   Sec     Total Zen  Wet Zen  Sig Zen    PW   Sig PW (mm)
2004  1     1    0    0.  2126.70    48.34    0.60    7.43    0.09
2004  1     2    0    0.  2125.50    46.00    0.95    7.07    0.15
2004  1     3    0    0.  2124.30    46.16    1.20    7.10    0.18
2004  1     4    0    0.  2120.60    44.52    1.47    6.84    0.23
2004  1     5    0    0.  2116.90    42.64    1.70    6.56    0.26
...
```

The start time of the output file is always the beginning of the observation session, which will be the same as the first tabular point of the piecewise linear model estimated in *solve*. The default interval for the output is also the interval of the estimated tabular points. For the case of a z-file, you can add `-i O` to the command line for `sh_metutil` to set the interval to be that of the observations themselves as recorded on the z-file. For both the z-file and RINEX-file cases, you can also set the output interval explicitly using `-i interval` where *interval* is given in integer seconds.

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8. Utility Programs and Auxiliary Tables

8.1 Plotting and computing statistics from GAMIT solutions

Although the preferred method of plotting coordinate or baseline repeatabilities is to run `glred` and `sh_plotcrd` or `sh_baseline` (see the Introduction to GAMIT/GLOBK and Chapter 4 of the GLOBK Reference Manual), it is possible to generate plots from a GAMIT solution using `sh_gamit_baseline`. The instructions for running the script can be generated by typing its name with no arguments; these are reproduced below:

Use GMT to make a multiple panel GAMIT baseline plots with uncertainty scaling. It also creates inputs for wrms/nrms scatter plots, which can be plotted with `/stdrel/com/sh_globk_scatter`

Requirements : GMT(netcdf/gmt/ghostscript)
               : gamit/bin/poly01 (linked to gamit/utils)

USAGE : sh_gamit_baseline <options>.

EXAMPLES: for time-series plots
sh_gamit_baseline -o o* -b PIN2_VNDP PIN2_YAM2
sh_gamit_baseline -u 1 -o o* -b PIN2_VNDP PIN2_YAM2

-o[files]   list    : ofile names. MUST have this.
-f[ile]     file    : Baseline names.
-b[aseline] list    : command line argument for baselines. If -f and
                     -b are both omitted, all baselines are plotted.
-free       : Biases free solution--Default.
-fixed      : Biases fixed solution.
-d[elete]   <sites/baselines etc> : names of unwanted sites.
-[delete_file] : file contains the names of unwanted sites
-u[nc_scale] value   : scale all uncertainties by this.. Default =1.
-y[cale]    min max  : vertical scale. If not issued it will be calculated.
-x[cale]    min max  : horizontal scale. If not issued it will be calculated.
-frame      value   : gmt border day-axis frame ticks. Default =1.
-anot       value   : gmt border day-axis label intervals. Default =1
-a          ext      : Add more descriptors to postscript file name.
                   Default is psgamit.#

There is a similar script available for plotting the atmospheric zenith delay parameters estimated from one or more `solve` runs. It also reads each of the o-files in an experiment directory to produce a multiday plot. Its usage is described in the on-line documentation obtained by typing the script name:
Use GMT to make a multiple panel GAMIT atmospheric parameters plots.

**USAGE**:  
sh\_gamit\_atmos  <options>.

**EXAMPLE**:  
sh\_gamit\_atmos  -o o* -b PIN2 VNDP YAM2

```
+=+=+=+=+=+=+=+=+=+=+=+=+OPTIONS+=+=+=+=+=+=+=+=+=+=+=+=+=
-o[files]  list  : ofile names. MUST have this.
-f[ile] file : Site names.
-sites list : command line argument for selected sites. If -f and -b are both omitted, all sites are plotted.
-free : Biases free solution Default.
-fixed : Biases fixed solution.
-both : Biases free with fixed solution. Fixed is dashed.
-stats refer to free sol.
-d[delete] <sites etc> : names of unwanted sites.
-t[otal] : total atmospheric zenith delay (Default is adjustment to a priori model).
-df file : file contains the names of unwanted sites.
-[delete\_file]: Makes life easier for -d
-u[nc\_scale] value : scale all uncertainties by this.. Default =1.
-y[scale] min max : vertical scale. If not issued it will be calculated.
-x[scale] min max : horizontal scale. If not issued it will be calculated.
-frame value : gmt border day-axis frame ticks. Default is 1.
-anot value : gmt border day-axis label intervals. Default is 1.
-a ext : Add more descriptors to postscript file name. Default is psgamit.#
```

The program **wbslfilt** ("Weighted BaSeLine Filter") can be used to scan the O-files from the observation sessions of an experiment and compute the mean and weighted rms scatter of the estimated baseline vectors. You can choose the estimates you wish to use by keying on the characters in columns 19-21 of the baseline summary in the O-file; i.e.

```
'R N'  bias-free  N E U
'R N'  bias-fixed  N E U
'R X'  bias-free  X Y Z
'R X'  bias-fixed  X Y Z
```

To get the NEU, components from the bias-fixed solution out of a group of O-files, try:

```
grep -h _ o*.??? | grep 'X N' | sort | wbslfilt >! mine.r.neu.wbsl
```

Note that **wbslfilt** must have *sorted* input to work properly.

Here is some example output:

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### ALS0_AR00 RMS
11 N 45242.5761 +- 0.0082 E 11595.5381 +- 0.0408 U -263.6538 +- 0.0838 L 46705.6390 +- 0.0131

### ALS0_AR00 PPB
11 N 45242.5761 +-174.6840 E 11595.5381 +-874.4694 U -263.6538 +-******** L 46705.6390 +-279.9606

### ALS0_AR00 SIG
11 N 45242.5761 +- 0.0072 E 11595.5381 +- 0.0131 U -263.6538 +- 0.0073 L 46705.6390 +- 0.0073

### ALS0_AR00 CORR
11 N-W 0.0187 N-U 0.0883 W-U -.0225 ST DEV OF UNIT WGT 8.6480

The RMS denotes the standard deviation of one measurement (a.k.a., the square root of the sample variance). This is what most people mean by "repeatability". This RMS value is expressed as parts per billion on the PPB line. The SIG value is the standard error of the mean. The weighted mean value is available on all three of these lines. The 11 in this example denotes the 11 individual day measurements. The correlations follow. The individual day entries are deviations from the weighted means, with their uncertainties from the input file.

Here is a script to generate a bunch of statistics and plot them using gnuplot, the local XY plotter at IGP. You could use your own.

```bash
#!/bin/csh
# generate repeatability statistics
#
# collect the O-files:
# $1 is name of run

set files = ../3*/o$1?.???

grep Normalized $files

# collect the baselines in NEU

if (-e tmp.bsl) then
    /bin/rm tmp.bsl
endif

# Get the bias free solution
grep -h _ $files | grep 'R N' | sort >! $1\r.neu.bsl

# Get the bias free solution XYZ
grep -h _ $files | grep 'R X' | sort >! $1\r.xyz.bsl

# Get the bias fixed solution
grep -h _ $files | grep 'X N' | sort >! $1\x.neu.bsl

cat $1\r.neu.bsl | wbslfit >! $1\r.neu.wbsl

cat $1\x.neu.bsl | wbslfit >! $1\x.neu.wbsl

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cat $1.r.neu.wbsl | grep RMS | colrm 132 | sort -rn +14 >! $1.r.neu.rms

cat $1.x.neu.wbsl | grep RMS | colrm 132 | sort -rn +14 >! $1.x.neu.rms

# Plot files for free solutions

cat $1.r.neu.rms | awk '{print $17/1000., $7*1000.} ' >! $1.r.n

cat $1.r.neu.rms | awk '{print $17/1000., $11*1000.} ' >! $1.r.e

cat $1.r.neu.rms | awk '{print $17/1000., $15*1000.} ' >! $1.r.u

# Plot files for fixed solutions

cat $1.r.neu.rms | awk '{print $17/1000., $7*1000.} ' >! $1.r.n

cat $1.x.neu.rms | awk '{print $17/1000., $7*1000.} ' >! $1.x.n

cat $1.x.neu.rms | awk '{print $17/1000., $11*1000.} ' >! $1.x.e

# Plot on screen

cat rep.gnu | sed s/NAME/$1/ | sed s/F/r/ | sed s/TITLE/"Repeatability for $1 (free) `date`"/ > r.gnu; gnuplot r.gnu

cat rep.gnu | sed s/NAME/$1/ | sed s/F/x/ | sed s/TITLE/"Repeatability for $1 (fixed) `date`"/ > x.gnu; gnuplot x.gnu

# Plot on paper

grep -v continue r.gnu > r.lgnu; lasergnu -b -f r.lgnu -p -Psparc

grep -v continue x.gnu > x.lgnu; lasergnu -b -f x.lgnu -p -Psparc
8.2 Creating RINEX or FICA files from NGS ARGOS files

Prior to May, 1992, CIGNET tracking data were aggregated at NGS by GPS Week in the ARGOS format. There are three files for each station (each week), one containing phase and pseudo-range data (usually called a "data" or "tape" file), one containing broadcast ephemeris and satellite clock information ("orb" file), and one containing the meteorological data ("met") file. There may also be a fourth file of descriptive information. The first step in using the CIGNET data is to FTP or transfer from tape at least the "data" and "orbit" files. Once transferred, the file names should contain the (4-character) standard station identifier plus the GPS week; e.g., for Yellowknife in week 437, the two required files should be named yknf437.dat and yknf437.orb.

A sample data (.dat) file is shown below:

```
YELLOWKNIFE            437  143 198   5  22
88  5 24 21 51 59.0800000 251519.080000 1  6
-69283.6838536321073582.10107  53744718.7507536299753069 .45818 40.5 39.5
88  5 24 21 51 59.0800000 251519.080000 1  6
-69283.6838536321194922.50099  53744718.7507536299753069 .45818 40.5 39.5
```

The first (title) record gives the station name, GPS week number, and the calendar date of the first day of the week. For each set of simultaneous observations, there is a time-tag record, with the epoch given in calendar date, (GPS) hours, minutes, seconds, and GPS seconds-of-week, followed by the number of satellites at that epoch and their pseudo-random noise (PRN) code numbers. For each epoch there are one or more measurement records containing (in order) L1 phase (cycles), L1 pseudo-range (meters), L2 phase, L2 pseudo-range, L1 carrier power-to-noise ratio (dB-Hz), and L2 carrier power-to-noise ratio (dB-Hz).

A sample orbit (.orb) file is shown below:

```
437 : GPS WEEK #

6 88 5 25 0 0 0.0 -.116699375212D-03 -.192130755750D-10 -.27755756156D-16
-1228800000000D+05 -.925000000000D+01 .101825670448D-08 .183378419704D+00
-586733220000D-06 .531821721233D-02 .104252249002D-04 .515364718437D+04
-259200000000D+06 -.111758708954D-07 .192736365505D+01 -.726431608200D-07
-111946399330D+01 .254187500000D+03 -.202961194281D+01 -.621168731314D-08
-.232152527227D-10 .100000000000D+00 .437000000000D+00 .000000000000D+00
-1000000000000D+00 .000000000000D+00 .000000000000D+00 .430080000000D+05

6 88 5 25 1 0 0.0 -.116767274212D-03 -.192130755750D-10 -.27755756156D-16
-163840000000D+05 -.687500000000D+01 .101647091580D-08 .708941445227D+00
-.396743416786D-06 .531794375274D-02 .104773789644D-04 .515364661980D+04
-262800000000D+06 -.18624514923D-08 .192734131190D+01 -.614672889924D-07
-111946907937D+01 .253406250000D+03 -.202958492564D+01 -.621847331009D-08
-.292869342041D-10 .100000000000D+00 .437000000000D+00 .000000000000D+00
-1000000000000D+00 .000000000000D+00 .000000000000D+00 .430080000000D+05
```

The first (title) record contains only the GPS week number. Satellite clock and ephemeris information are listed as they are received. The first line gives satellite PRN number, GPS date and time, clock bias (seconds), clock drift (sec/sec), and clock drift rate (sec/sec2). The following four or six lines contain the standard ephemeris information, similar to that given in the GAMIT E-file. A description of each value may be found in the NGS documentation distributed with the tape. Note that there was a change at Week 424.

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The meteorological data (.met) file gives simply the temperature (°C), pressure (mb), and relative humidity (percent) at hourly intervals. A sample is shown below:

```
YELLOWKNIFE  GPS WEEK  437
88  5 22  0  0  0.00      3.60    978.00     37.39
88  5 22  1  0  0.00      3.70    979.00     39.53
88  5 22  2  0  0.00      3.50    982.00     40.41
88  5 22  3  0  0.00      3.40    985.00     41.01
88  5 22  4  0  0.00      2.90    984.00     42.49
```

To convert an ARGO data (.dat) file into a RINEX observation (.YYo) file, use the shell script `sh_argo2rx`:

```
sh_argo2rx  -f  < ARG0-file >  -apr < apr file > [ -o ]
```

where the ARGO file name must begin with the 4-character station ID; apr-file is the name of a GLOBK file of a priori station coordinates; and the optional final argument (-o) signifies that an existing RINEX file of the same name will be overwritten. If available, `station.info` and `rcvant.dat` will be read to get the RINEX header information.

To convert an ARGO orbit (.orb) file into a RINEX navigation (.Yyn) file, use the program `argo2nav`, which takes as a single command-line argument the name of the ARGO orbit file; viz: `argo2nav algo537.orb`

To convert ARGO data and orbit files into FICA files, use the program `argo2fic`. To run the program simply type its name followed by the filename prefix (station and week number) and the receiver software version used to collect the data (CORE 4.1, 4.7, or 4.8 for the TI4100, 1.49, 1.50, or 1.61 for the MINI-MAC):

```
argo2fic yknf437 4.1
```

`Argo2fic` will read the weekly .dat and .orb ARGO files and open and write a FICA file for each calendar day, naming the file by the station and day number. (If a .orb file is not available for a site, you can create one to satisfy `argo2fic` by renaming the orbit file from another site since the orbital information is the same.). For Yellowknife in week 437, seven files will be created, named `yknf8.143.fic`, `yknf8.144.fic`, ...., `yknf8.149.fic`. The number of FICA blocks of each type will be displayed on the screen and written to an information file named, for the example shown, `yknf437.inf`. Note that both (week-long) ARGO files and (daily) FICA files are large compared to (daily) X-files, so some planning of disk space should be done before beginning the conversions.

### 8.3 Creating RINEX files from FICA files

Program `fic2rx` (in the `makex` directory) can be used to create RINEX observation and navigation files from FICA files. It has been tested for TI4100 blocks 101, 6, and 9 (all from GESAR), and is coded (but untested) for the TI4100 using CORE or ROM software, and for MiniMac, Rogue, and Trimble receiver blocks, as well as the short (RINEX-like) blocks (70, 80, 1080, 1180, 1280, 1380) created for all receivers near the end of FICA's useful lifetime. To run the program type

```
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```
If either of the command-line arguments is omitted, the program will prompt you to enter them. Omission of the L-file is allowed but will result in zeroes being entered for the approximate station coordinate in the RINEX header. *Fic2rx* is currently coded (*makex* version 9.58 of March, 1997) to remove the nearest integer of the initial phase as per RINEX standards, but this feature of the code may be easily commented out.

### 8.4 Creating X-files from C-files

In order to conserve disk space and maintain "clean" archival data files, it is useful to convert edited C-files back to X-files whenever possible. This is done using the program *ctox*. It can be run from a single C-file or a list of C-files contained in a D-file. When you invoke the program, it will prompt you for the name of the input C- or D-file. If a D-file is used as input, *CTOX* will give you the opportunity to change the series letter associated with the input C--files. Finally, you will be prompted for the series letter to be associated with the output X-files.

### 8.5 Creating RINEX files from X files

Whenever data are exchanged with another institution, they should be transcribed in to RINEX format. This is easily accomplished using the program *xtorx* (in the *makex* directory). *Xtorx* accepts two command-line arguments: the first is the name of the input X-file or D-file containing a list of X-files; the second, used only in the case of a D-file, gives the series letter associated with the X-files (which might have a different series letter in the D-file list).

*(Program etorx to write RINEX navigation files from FICA Blk 9 files to be written)*

### 8.6 Creating and maintaining datum, time, spacecraft, and ephemeris tables

Many of the modules of GAMIT require a table giving the parameters of geodetic datums. *arc* and *model* require tables for TAI-UTC, TAI-UT1, pole position, nutation, and spacecraft parameters. *Arc* also requires tables for the positions of the sun and moon. The data for these tables are available from MIT or Scripps but may also be obtained from national astronomical and geodetic agencies or the International Earth Rotation Service (IERS). In this section, we describe how these data should be formatted for use by GAMIT.

*Geodetic Datums* (gdetic.dat)
Table 7.1 is an example of the geodetic datum file. There is a one-line header followed by descriptions, not read by the program, of the columns of the table. Five-character names are used to denote each datum, which is then specified by the standard ellipsoid parameters, semi-major axis (in meters) and inverse flattening, and cartesian offsets (in meters) from the geocenter.

Table 8.1

<table>
<thead>
<tr>
<th>Geodetic Datums</th>
<th>last updated by rwk 96.10.30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datum</td>
<td>a 1/f DX DY DZ</td>
</tr>
<tr>
<td>WGS84</td>
<td>6378137. 298.257223563 0. 0. 0.</td>
</tr>
<tr>
<td>NAD83</td>
<td>6378137. 298.257222101 0. 0. 0.</td>
</tr>
<tr>
<td>WGS72</td>
<td>6378135. 298.26 0. 0. 4.5</td>
</tr>
<tr>
<td>NAD27</td>
<td>6378206.4 294.9876982 -12.01 -162.97 189.74</td>
</tr>
<tr>
<td>CLK80</td>
<td>6378249.145 293.465 0 0 0 English Clarke</td>
</tr>
<tr>
<td>CLI80</td>
<td>6378249.2 293.4660208 0 0 0 Clarke 1880 IGN</td>
</tr>
<tr>
<td>INT24</td>
<td>6378388. 297. 0 0 0</td>
</tr>
</tbody>
</table>

Spacecraft parameters (svnav.dat)

The file svnav.dat gives the correspondences between spacecraft (Navstar) numbers (NSN) and pseudo-random noise (PRN) numbers for each GPS satellite, its mass, and its yaw parameters. The tables is updated after each launch or chance in yaw status, usually by Paul Tregoning of ANU based on data supplied by Yoaz Bar-Sever of JPL. The beginning and end of the current (Dec 96) table is shown below:

```
<table>
<thead>
<tr>
<th>NSN/PRN #s, masses, and yaw rates satellites.</th>
<th>Updated by R. King 4 Jun 98</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRN  SV BLK MASS(G) BIASED YAW RATE YR MO DY HR MN DX DY DZ (see key at bottom)</td>
<td></td>
</tr>
<tr>
<td>4, 1 1 453800. U 0.1990 78 02 22 00 00 0.210 0.0 0.854</td>
<td></td>
</tr>
<tr>
<td>6, 3 1 453800. U 0.1990 78 10 06 00 00 0.210 0.0 0.854</td>
<td></td>
</tr>
<tr>
<td>2, 13 2 878200. U 0.1130 89 06 10 00 00 0.279 0.0 0.9519</td>
<td></td>
</tr>
<tr>
<td>2, 13 2 878200. Y 0.1130 93 01 01 00 00 0.279 0.0 0.9519</td>
<td></td>
</tr>
<tr>
<td>2, 13 2 878200. N 0.1130 95 07 05 01 10 0.279 0.0 0.9519</td>
<td></td>
</tr>
<tr>
<td>2, 13 2 878200. P 0.1130 95 11 17 00 00 0.279 0.0 0.9519</td>
<td></td>
</tr>
<tr>
<td>14, 14 2 887400. U 0.0870 89 02 14 00 00 0.279 0.0 0.9519</td>
<td></td>
</tr>
<tr>
<td>13, 43 4 1100000. P 0.1230 97 07 23 00 00 -0.0031 -0.0012 0. -- yaw values provisional</td>
<td></td>
</tr>
<tr>
<td>8, 38 2 972900. P 0.1230 97 11 06 00 20 0.279 0.0 0.9519 -- yaw values provisional</td>
<td></td>
</tr>
</tbody>
</table>

BLK: 1=Blk I 2=Blk II 3=Blk IIA 4=Blk IIR
Temporary: Blk IIA (SV 23-30) set =2 for backward compatibility (releases < 9.63)
BIASED (yaw): Y=normal A=anti-normal P=+ive only, N=-ive only U=unbiased
SVANT-DXYZ: Antenna offsets from center of mass (m)
```

The mass, along with the block number, is used to calculate non-gravitational accelerations. The block number is used to determine the offset of the transmitter antenna phase center from the center of mass of the spacecraft when a model for this is not available in the antmod.dat (ANTEX) file. The yaw "bias" and rate determine how model treats the spacecraft attitude during eclipse. Prior to June, 1994, all of the GPS satellites had unbiased (U) yaw when in sunlight, leading to difficult-to-predict behavior during eclipse. Under these conditions GAMIT does not attempt to model the eclipse.
orientation. In June, 1994, DoD added a small (0.5 degree) bias to the nominal yaw of some satellites, increasing the number to the entire constellation by November, 1995. The bias causes a satellite to yaw at a predictable rate and direction during eclipse. There are four direction "conditions" that have been in effect for at least a short period on some satellites since June, 1994: positive (clockwise) (\textit{P}), negative (\textit{N}), "normal" (\textit{Y}, positive or negative, depending on the angle between the orbit plane and the Sun, and "anti-normal" (\textit{A}, opposite of normal). For a complete discussion of the yaw history and the model, see \textit{Bar-Sever} [1996]. The last three columns contain the offsets of the spacecraft (LC) antenna phase-center from the center of mass. The values shown here and hardwired into the code prior to Release 9.71 are nominal offsets determined by DoD and its contractors, known now to be in error by up to 1 m.

\textbf{TAI-UTC (leap.sec)}

Although GAMIT files and internal calculations are now mostly GPS time, UTC is used for some old X-files and is useful for informational purposes. The conversion from one system to another is performed by reading the table \textit{leap.sec} which gives leap seconds since 1 January 1982, at which time TAI-UTC was 20.0 seconds. The format of the table is given below:

\begin{table}
\centering
\begin{tabular}{ll}
\textbf{Table 8.2} & \\
\hline
\textbf{LEAP SECOND TABLE} & \textbf{CREATED 87-12-15} & \textbf{UPDATED 98-01-08} \\
\hline
(1X,F9.1) & 2449169.0 & JUN 30 1993 \\
2445151.0 & \textit{!JUNE 30, 1982 LEAP SEC INCREMENT} \\
2445516.0 & \textit{!JUNE 30, 1983 LEAP SEC INCREMENT} \\
2446247.0 & \textit{!JUNE 30, 1985 LEAP SEC INCREMENT} \\
2447161.0 & \textit{!DEC 31, 1987 LEAP SEC INCREMENT} \\
2447892.0 & \textit{!DEC 31, 1989 LEAP SEC INCREMENT} \\
2448257.0 & \textit{!DEC 31, 1990 LEAP SEC INCREMENT} \\
2448804.0 & \textit{!JUN 30, 1992 LEAP SEC INCREMENT} \\
2449169.0 & \textit{!JUN 30, 1993 LEAP SEC INCREMENT} \\
2449534.0 & \textit{!JUN 30, 1994 LEAP SEC INCREMENT} \\
2450083.0 & \textit{!DEC 31, 1995 LEAP SEC INCREMENT} \\
2450630.0 & \textit{!JUN 30, 1997 LEAP SEC INCREMENT} \\
2451179.0 & \textit{!DEFAULT LATER DATE (Guess: Dec 31 1998)} \\
\hline
\end{tabular}
\end{table}

The first line of the table is a comment. The second line gives the format of the tabular entries to follow and the last date for which the current table is valid. If a date beyond that given on line two is requested by the program, a message will be printed and execution will stop. The tabular entries are simple the PEP Julian dates (PJD) for each leap second (PJD = MJD + 2400001; see the discussion with the lunar table below). The calendar dates to the right of each entry are comments not read by the program.
TAI-UT1 Table:

Table 7.3 shows a UT1 table, which consists of a two-line descriptive header and a series of values as a function of time modified Julian date (MJD). In the example shown, the comments on the first line indicate that the values in the table came from IERS Bulletins A and B. The second line includes the format of the data lines, an integer ("2" in the example) indicating whether the values are TAI-UT1 (UT1 type = 4) or TAI-UT1R (UT1 type = 2), the PEP Julian days over which the table is valid, the number of values per line ("6"), the spacing of the values in days ("5"), and the factor to be used to convert the tabulated values to the units required by the program (seconds of time). The designation "UT1R" means that TAI-UT1 has been "regularized" (smoothed) by removing the effects of zonal tides with periods shorter than 35 days, which can introduce short-period variations up to 2.5 milliseconds. Model and arc add these terms back in from conventional models when computing the angular orientation of the earth. If UT1 values are computed and tabulated at intervals of 5 days, as in IERS Bulletin B, it is useful to use UT1R to avoid errors in interpolation. If values are computed at intervals of 1 day or less, however, unregularized values are preferred. GAMIT UT1 tables are constructed from IERS circulars on a regular basis at Scripps to support PGGA operations and may be copied from the public directories. Users should note whether the values for recent dates are "predicted" (IERS Bulletin A or B), "rapid service" (Bulletin A), or "final" (Bulletin B) and consider whether errors in the values are important for your particular analysis.

Table 8.3

<table>
<thead>
<tr>
<th>2445499</th>
<th>2446824</th>
<th>6</th>
<th>5</th>
<th>1.E-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>45499</td>
<td>2122110</td>
<td>2123100</td>
<td>2123990</td>
<td>2124790</td>
</tr>
<tr>
<td>45529</td>
<td>2126940</td>
<td>2127620</td>
<td>2128280</td>
<td>2128940</td>
</tr>
<tr>
<td>45559</td>
<td>2131350</td>
<td>2132230</td>
<td>2133100</td>
<td>2133960</td>
</tr>
<tr>
<td>45589</td>
<td>2136420</td>
<td>2137310</td>
<td>2138270</td>
<td>2139300</td>
</tr>
</tbody>
</table>

Pole Position Table:

Table 7.4 shows a pole-position table, which, like the TAI-UT1 table, consists of a two-line header and a series of values as a function of time. The first line is a comment describing the source of the table. The second line has exactly the same form as the TAI-UT1 table except for the "type" parameter, giving the format, span, number of values per line, tabular interval in days, and the factor to be used to convert the tabulated values to the units required by the program (seconds of arc). The pole position values are stored in pairs, with the x position given as the first value of each pair and the y position the second. As for UT1, the pole-position values from the IERS can be "predicted", "rapid service", or "final", with different levels of accuracy. For the highest accuracy in your analysis, you should use a set of pole-position values estimated from VLBI and/or GPS data simultaneously with your site coordinates. If you do not estimate these values in 28 September 2006
your own analysis (using GLOBK), you can copy the MIT tables /sites/vg_yymmdd and /tables/pole.vlbi_yymmdd

**Table 8.4**

B1979 Wobble: Updated WCB 01/05/87 RAP. SER. FROM 46744, PRED. FROM 46794 (1X,I9,12I5,8X,I2)

<table>
<thead>
<tr>
<th>PEP JD</th>
<th>2445499</th>
<th>2446824</th>
<th>6 5</th>
<th>1.E-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>45499</td>
<td>222</td>
<td>497</td>
<td>238</td>
<td>480</td>
</tr>
<tr>
<td>45529</td>
<td>298</td>
<td>384</td>
<td>309</td>
<td>363</td>
</tr>
<tr>
<td>45559</td>
<td>333</td>
<td>256</td>
<td>331</td>
<td>235</td>
</tr>
<tr>
<td>45589</td>
<td>293</td>
<td>131</td>
<td>280</td>
<td>112</td>
</tr>
<tr>
<td>45619</td>
<td>189</td>
<td>43</td>
<td>167</td>
<td>34</td>
</tr>
<tr>
<td>45649</td>
<td>55</td>
<td>18</td>
<td>33</td>
<td>19</td>
</tr>
</tbody>
</table>

**Lunar Table:**

Table 8.5 shows the beginning section of a Lunar table, which has the same format as the UT1 and pole tables except that there is an additional character entry at the end of the second header line indicating whether the ephemeris is in a B1950 or J2000 inertial frame.

**Important note on Julian Day numbers:** In the lunar, solar, and nutation tables, we have followed the convention of the MIT Planetary Ephemeris Program (PEP) and designated a day, beginning at midnight, by conventional Julian Day which begins the following noon. Thus, the PEP JD (PJD) is the conventional Julian Date + 0.5. The Modified Julian Day (MJD) used by the IERS in the earth rotation tables is one day (plus 240000) less than the PEP Julian Day, i.e., PJD = MJD + 1 + 2400000.

For each following line of the table, the first number is the PEP Julian day number of the table entry minus 2400000. (Note that the time interval spacing between table entries is 0.5 day. Therefore, two table entries will have the same Julian day number.) The second, third and fourth numbers are the x, y and z of the Moon's position on that Julian date. The units are meters and the values are with respect to the mean equator and equinox of 1950.

**Table 8.5**

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>49641 338866941 -190113511 -44831903</td>
<td></td>
</tr>
<tr>
<td>49641 359853304 -154961265 -30778560</td>
<td></td>
</tr>
<tr>
<td>49642 3764110611 -117854817 -16331906</td>
<td></td>
</tr>
<tr>
<td>49642 388399920 -74273638 -1673630</td>
<td></td>
</tr>
<tr>
<td>49643 395737251 -39701958 13016720</td>
<td></td>
</tr>
<tr>
<td>49643 398392214 376099 27563394</td>
<td></td>
</tr>
</tbody>
</table>

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Solar Table:

Table 8.6 shows the beginning section of a Solar table (which is actually a tabulation of the position of the Earth with respect to the Sun). The header entries are at 4 day intervals, the PEP Julian day number has 2400000 subtracted, and the x,y,z position components are in kilometers.

Table 8.6

J2000 Earth ephemeris for 1995 Nov 94 - Mar 96 rwk/MIT 95/6/16

<table>
<thead>
<tr>
<th>J2000</th>
<th>Earth ephemeris for 1995</th>
<th>Nov 94 - Mar 96</th>
<th>rwk/MIT</th>
<th>95/6/16</th>
</tr>
</thead>
<tbody>
<tr>
<td>(lx,i5,6i11)</td>
<td>0 2449641 2450197 3 4</td>
<td>1.E+00 J2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49641</td>
<td>138814695 50128193 21733554</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49645</td>
<td>134547714 58751821 25472708</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49649</td>
<td>129639597 67095038 29090431</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49653</td>
<td>124109860 75118738 32569486</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nutation Table:

Table 8.7 shows the beginning section of a nutation table. The first line is again a comment line describing the table. That comment line indicates that the table is good from the 335th day of 1984 to the 180th day of 1985 and that the table was generated March 26, 1985. The second line gives the format of each table line and then five numbers. The start and stop Julian day numbers of the table are the first two. The third numbers indicates that each line will contain four pairs of table values. The fourth number (-1) indicates that the tabular interval is 0.5 (i.e. 2⁻¹) day. The fifth number indicates the value that the table values must be multiplied by to get the proper units (arc seconds) for the program. Only the start and stop Julian day numbers are actually used from these headers. On each following line of the table, there is the PEP Julian day number - 2400000, followed by four pairs of values of Δψ and delta Δε, the conventional angles describing the nutation in longitude and obliquity (in units of 10⁻⁴ arcseconds, according to the fifth entry in the second header line). Note that the table lines are at time intervals of two days, which means that each pair of nutation angle values is 0.5 days apart.

Table 8.7

Nutation ephemeris for 1995 Nov 94 - Feb 96 rwk/MIT 94/10/4

<table>
<thead>
<tr>
<th>Nutation ephemeris for 1995</th>
<th>Nov 94 - Feb 96</th>
<th>rwk/MIT</th>
<th>94/10/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(lx,i5,8i8,8x,i2)</td>
<td>2449641 2450200 4 -1</td>
<td>1.E-04</td>
<td></td>
</tr>
<tr>
<td>49641</td>
<td>117182 -59269 116620 -59240 116001 -59247 115344 -59290</td>
<td></td>
<td></td>
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</table>

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Appendix 1. Antenna Specifications

A.1.1 Introduction

GAMIT computes the instantaneous position of an antenna's phase center with respect to the geodetic monument in three pieces. File station.info records the vertical or slant distance from an accessible point on the antenna structure (specified in the entry) to the monument, and also any horizontal offsets of the center of antenna from the monument deriving from a setup error. File hi.dat contains the mechanical dimensions of each supported antenna, used by subroutine lib/hisub.f to convert the field measurement to an offset of the IGS-defined antenna reference point (ARP)—usually the bottom center of the pre-amp—from the monument. Finally, the instantaneous positions of the L1 and L2 phase centers with respect to the ARP are computed by subroutine model/phasecc.f using the elevation-dependent “phase center variation” (PCV) models specified in table antmod.dat.

This Appendix deals primarily with the mechanical specifications of the most commonly used ground antennas, though for some of the older antennas lacking PCV models, we have included some comments. For a discussion of the offsets and variations in the electrical phase centers of both ground antennas and satellite antennas, see Schmid et al. [2005] and references therein.

Pictures and diagrams of antennas, as well as further discussion of phase-center calibrations may be found at http://www.grdl.noaa.gov/GPS/PROJECTS/ANTCAL

A.1.2 TI 4100 antennas

TI 4100 Conical Spiral

In field operations there are two conventional points on the antenna structure to which height measurements are referred: the center and the outside edge of the base of the pre-amp. Vertical measurements to the center of the base are designated DHPAB and are simply added to the table values to get the L1 and L2 phase centers. Slant height measurements to the edge of the base are designated SLPAB and converted to vertical heights using the pythagorean rule and a base radius of 0.8415 m.

The phase center offset values given in the antmod.dat.mit for the early series 100 and 2000 antennas, designated TI_100 and TI2000, respectively but both aliased to TI4100, are taken from Sims [1985]. For the newer and more common 4000 series antennas, designated TI4000, the values were determined by Schupler et al. [1992] and confirmed by our own analysis. Use of the Schupler et al. PCV model will increase the estimated from LC observations by about 15 mm.

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TI 4100 FRPA-2 microstrip

These antennas have been used only at the CIGNET fiducial stations at Richmond (Florida), Mojave (California), and Kauai (Hawaii). The offsets given in antmod.dat.mit are based on UNAVCO short baseline tests (personal communication, John Braun, 21 May 1994). They are untested in MIT or SOPAC analyses.

A.1.3 Trimble antennas

Trimble 4000 SST

The 4000 SST antenna (TRMSST), part # 145321 and usually designated "4000ST L1/L2 Geodetic", is a microstrip which has a round ground plane with horizontally scalloped and vertically beveled edges. Below the ground plane is a small square box containing the pre-amp. Field height measurements are commonly made to the outer edge of the ground plane—either the top, middle, or bottom of the beveled edge. Subroutine hisub is coded to accept slant height measurements to the top (SLTGP, radius 0.2403 m), middle (SLMGP, radius 0.2413 m), or bottom (SLBGP, radius 0.2403 m) of the ground plane, and also a direct height to the bottom of the ground plane (DHBGP). If the Trimble measuring rod is used, the height measurement is usually made to the inside of one or more of the notches (radius 0.2334), on either the top (SLTGN) or bottom (SLTBGN) of the ground plane. The bottom of the ground plane is 0.060 m, the middle 0.0615 m, and the top 0.063 m above the ARP (base of pre-amp).

With no PCV model, Trimble specifications and UNAVCO tests put the L1 phase center 6.2 mm above, and the L2 phase center 4.7 mm above the top of the ground plane. Use of the variable phase-center model will increase heights estimated from LC observations by about 15 mm. Rotation tests and anechoic chamber measurements suggest that there are differences of at least several millimeters, in both the vertical and horizontal directions (C. Rocken, personal communication, 1995; Rothacher and Mader, 1996). The IGS_01 model reflects these differences.

Trimble 4000 SSE

The antenna accompanying all but the first SSE receivers, and also SSi receivers, is different from the SST antenna in having separate microstrips for L1 and L2; it is part # 22020.00, is usually designated "Geodetic L1/L2", and carries the GAMIT code TRMSSE. Subroutine hisub allows the same types of measurements but uses slightly different dimensions. The bottom of the ground plane is 0.0556 m, the middle 0.0574 m, and the top 0.0591 above the ARP. The radius to the edge of the ground plane (top, middle, or bottom) is 0.2415, and to the inside of the notches 0.2335 m.
The no-model offsets given in antmod.dat.mit are currently set to be the same as for the SST antenna, as indicated by the manufacturer, but anechoic chamber and field measurements suggest that there are differences of at least several millimeters, in both the vertical and horizontal directions (C. Rocken, personal communication, 1995; Rothacher and Mader, 1996).

Trimble 4000 SL

The 4000 SL antenna, part # 10877.10, is a microstrip which has a round ground plane with a smooth edge. In release 9.8 we changed the 6-character code for this antenna from TRMSLD to TRSLMC to avoid confusion with the square-ground-plane antenna (part # 12562.10) which Trimble calls 4000 SLD and which is not supported by GAMIT. Below the ground plane is a square box, 0.198 m on a side, containing the pre-amp. Field measurements of the slant height are commonly made to the top (SLTGP) or bottom (SLBGP) edge of the ground plane or the bottom corner of the pre-amp base (SLPAC). The bottom of the ground plane is 0.0529 m, and the top 0.0512 m above the pre-amp base, the ARP. The ground plane has a radius of 0.2413 m, and the diagonal from the center to the corner of the pre-amp is 0.140 m.

Trimble 4000 SXD

The 4000 SXD antenna (4000SX, part # 10877.10) is a microstrip which has a square ground plane with rounded corners. Below the ground plane is a square box containing the pre-amp. Field measurements of slant height are commonly made to the bottom of the ground plane at one of the corners (SLCGP) or to the bottom corner of the pre-amp base (SLPAC). The ground plane is 3.4 mm thick and the bottom is 0.048 m above the pre-amp base, the ARP. The side of the ground plane is 0.3048 m and the diagonal (rounded) corner (the measurement point) 0.4153 m from the center. The pre-amp has a half-width of 0.0984 m and a diagonal of 0.1391 m.

A.1.4 Rogue antennas

Dorne-Margolin with choke ring

There are three antennas used with Rogue, MiniRogue, and TurboRogue receivers, all variations of a Dorne-Margolin element mounted with the circular ground plane and choke rings based on a JPL design. The antennas used with the original Rogue SNR-8 were built at JPL and are designated model "R" (ROGSNR, DMRCHR, or ROGDMR); the early models built by Allen Osborne Associates (AOA) are designated model "B" (ROGAOA, DMBCHR, or ROGDME); and the AOA models currently distributed with the TurboRogue are designated model "T" (TRBROG, DMTCHR, or ROGDRT). If the antenna is mounted on a tripod, height measurements are usually made to the bottom of the choke ring or an underlying baseplate. If the antenna is spike-mounted on the ground, the measurement is
made to the bottom of the baseplate. In some permanent mounts surveyed by theodolite, the direct height may be specified to the the top of the choke rings (DHTCR).

For the "R" model, the ARP is the bottom of a base plate, 0.381 mm in diameter and 6 mm thick. The choke ring above is 64 mm high, so that the top of the choke ring is 70 mm above the ARP. Measurements made to the bottom of the assembly are all to the ARP, whether designated "pre-amp base" (DHPAB) or "bottom of choke ring" (DHBCR or SLBCR).

The "B" model replaced the thin base plate with one 11 mm high and 351 mm in diameter, and increased the choke ring height to 70 mm. For this model the ARP is the bottom of the choke rings, not the bottom of the baseplate, so that the top of the choke rings is still 70 mm above the ARP.

The "T" model has a choke ring 67 mm high including the baseplate and a pre-amp 35 mm high. The ARP is the bottom of the pre-amp, so that the top of the choke rings is 102 mm above the ARP. The width of the choke rings is 381 mm.

According to the manufacturers' nominal specifications, with PCV model, the L1 phase center is 8 mm, and the L2 phase center 26 mm above the top of the choke rings for all three models.

A.1.5 Ashtech antennas

There have been primary three models, with several variations each, of the Ashtech dual-frequency micro-strip antennas. The first two models (both part #700228) both use a Ball Corporation microstrip patch and have a 28-cm ground plane but have different amplifiers and different configurations of ground planes. The third model has a different microstrip patch and a larger ground plane. The Ashtech choke-ring antenna is patterned after the TurboRogue (DM-T) antenna but has had several revisions and has been used with and without one of several radomes.

Ashtech L

The early models of the 700228 antenna have been used mostly with the MD-XII (codeless) receiver and are designated the "Geodetic L1/L2" or "L" model (ASHL12). They have a 28-cm ground plane with closed holes near the edge for measuring height and an external low noise amplifier (LNA). The two versions (700228A and 700228B both had a leveling bubble but used different LNAs. The third (700228C) removed the leveling bubble. GAMIT allows different designations for these revisions (ATGEOB and ATGEOC, respectively), but does not yet have phase-center models to distinguish them. Field measurements are commonly made by placing a measuring rod through holes 115 mm from the center near the outer edge of the ground plane (SLHGP or SLAGP). The ground plane itself is rounded on the edge, with bottom outer edge 142.4 mm from the
center. The top of the ground plane, where the holes are located, is 64 mm above the base of the pre-amp (ARP). Subroutine hisub also supports slant height measurements to the outermost part of the bevel on the bottom of the ground plane (SLBGP). There is a provision for adding extender sections to the ground plane, but this configuration has rarely been used and is not supported by hisub.

Ashtech P/Topcon P

The later model (D) of the 700228 has been used chiefly with the Ashtech P12 and Topcon GP-RIDP receivers (but possibly also with the Ashtech Z-12 and Topcon GP-RIDY) and is designated the "Geodetic II L1/L2 REV B" or "P" (ASHP12/TOPP12). It also uses a 28-cm ground plane but with the holes open and at the edge, at a distance of 131.8 mm from the center, and no ability to extend the ground plane. The allowable measurement codes are the same as for the "L" model.

Ashtech III/Topcon

The "Geodetic Antenna III" antenna (ASHGD3 part #700718A or TOPGD3 part #700779) uses a different micro-strip patch and a larger (34-cm) ground plane (sometimes termed the "Whopper") with open holes. It has been used with the Ashtech Z-12 and Topcon GP-RIDY receivers. The antenna has an internal LNA in the center hub. The US Coast Guard version has a radome and is designated ASHGDR and has part #700829. As for the L and P models, the top of the ground plane is 64 mm above the base of the pre-amp (ARP). The radius of the ground plane is 173.7 mm, and the pre-amp 40.0 mm. GAMIT supports measurement of the direct height to the top of the ground plane (DHTGP) and slant height to the outside of the holes (SLHGP or SLLGP).

At the present time, the effective phase centers of the Ashtech microstrip antennas is uncertain. Short baseline GPS and anechoic chamber measurements give inconsistent results. In table antmod.dat.mit we have maintained the offsets determined for Release 9.2, which place the L1 phase center ~33 mm, and the L2 phase center ~13 mm above the ground plane. Previous GAMIT releases assumed that both L1 and L2 phase centers are in the ground plane. The IGS_01 model in antmod.dat.igs gives elevation-dependent models for these antennas but they are based on limited, non-redundant tests and do not have the reliability of the models for the Trimble microstrip or the choke-ring antennas.

Ashtech Dorne-Margolin with Choke Ring

There have been 14 different versions of the Ashtech choke-ring antenna, some trivially different and some with changes that might affect the phase pattern. All have been designed to be mechanically and electrically equivalent to the Turbo-Rogue ("T") antenna, and in the current version of antmod.dat are assigned the same (null) model as the D-M T. To allow tracking of small potential changes, however, each of these models is assigned a different name, both by the IGS and in GAMIT (see rcvant.dat). One possibly important difference arises when the antenna is used with the Ashtech-supplied conical
radome. Tests at UNAVCO [Rocken et al., 1995] and MIT [Neill et al., 1996] suggest that the phase center changes in vertical by 5–15 mm when this radome is used, but similar tests at AIUB (Bern) and NGS obtain differences less than 3 mm [Rothacher and Mader, 1996]. The use of a centered spherical radome of the type currently employed by SCIGN produces no significant change in the phase pattern.

A.1.6 MACROMETER antennas

Min-Mac 2816 AT

The Macrometer antenna used with the Mini-Mac 2816 AT is a crossed dipole above a thick square ground plane (MINXDP or MIN6AT). The ARP is the base of the ground plane structure, which contains the pre-amp. GAMIT supports only direct height measurements to the ARP (DHPAB) or reference to the L1 phase center (L1PHC).

According to the manufacturer's specifications, the L1 phase center is 107.1 mm, and the L2 phase center 91.7 mm above the ARP [J. Ladd, private communication, 1989]. Use of a PCV model corrects this by several centimeters.

A.1.7 SERCEL antennas

For the SERCEL TR5S and NR52 antennas, we have only scant information conveyed by K. Feigl from the log sheets for the Djibouti 1991 observations. There are no mechanical dimensions coded in hisub, so that only measurements to the ARP (DHPAB) are allowed. The difference between the L1 and L2 phase centers is unknown. In antmod.dat, we currently give for the TR5S (SRTR5S) phase center offsets from the ARP of 264 mm for the TR5S (SRTR5S) and 210 mm for the NR52 (SRNR52).

A.1.8 Leica antennas

The Leica SR299/SR399 "Sensor", AT201/302, and AT303 antennas are attached directly to a rotating bubble level ("carrier"; e.g. GRT44), or a "stop/go" kinematic pole via a screw hole on the bottom of the antenna. The ARP is defined as the bottom of the antenna housing, coincident with the top of the carrier. With the carrier mount and tripod, measurements are commonly made using a pull-down tape measure attached to a "height-hook", with the top of the tape measure (the read point) located 0.350 m below the ARP. You can specify a direct height to the ARP (DHPAB) or a direct height read from the height-hook tape (DHHHK). In using values recorded on field logsheets, be aware that the height hook tape suggests to the operator adding 0.441 m to the measured value to account for both the offset to the ARP (0.350 m) and the nominal L1 phase center (0.091 m above the ARP). Be sure that you understand what value has been recorded. Also, the Sensor antennas may be used with a "ranging pole" (different from a "stop/go kinematic
pole") via an "adaptor with 5/8-in thread"; in this configuration the ARP, corresponding to the top of the pole, is 12 mm lower with respect to the phase centers. The range-pole configuration is not coded in GAMIT. With the choke-ring antennas (AT303 and AT504), you may also specify slant-height measurements to the outside bottom edge of the choke rings (SLBCR).

The IGS_01 phase-center model in antmod.dat.igs has three elevation-dependent models for the phase center, corresponding respectively to the SR299 or SR399 internal antennas (LC299I or LC399I), and the series 200 external antenna with (LC202G) or without (LC202N) a ground plane. The AT303 was intended by Leica to be slightly different from the IGS standard (DM-T TurboRogue antenna), so antmod.dat includes the NGS_02 model for this antenna. The AT503 (LC_503) is assumed be the same as the DM-T.
Appendix 2. Description of Data Exchange Formats

Two formats (FICA and RINEX) have been used to distribute GPS phase and pseudorange data from single tracking sessions, and a third (ARGOS) used by NGS to distribute week-long data from CIGNET stations prior to 1992. In addition, each of these formats has a file or blocks defined to contain ephemeris and clock information broadcast by the satellites. Finally, orbital ephemerides in tabular (XYZ per epoch) format are distributed in the SP1 or SP3 ("Standard Product") format developed by NGS and now used by the IGS. The ARGOS format is described in Chapter 8 (Section 8.2); the others are described below.

A.2.1 RINEX

The Receiver INdependent EXchange format for GPS data provides the current IGS standard for the distribution of phase and pseudorange data ("o" file) and the navigation message ("n") file recorded by a receiver. There is also a less used file for meteorological data. Version 1 of the RINEX formats is described in Gurtner et al. [1989] and Gurtner and Estey [2006].

A 2.2 FICA

TI4100 data prior to 1989 were usually distributed in the Floating-Integer-Character-ASII (FICA) format devised by the Applied Research Laboratory at the University of Texas. A description of the format and definitions of the standard TI 4100 blocks and (ad hoc) MIT-defined blocks used to create an acceptable input file for MAKEX from NGS ARGO format, see the comments in subroutines blknnn.f in gamit/makeX.

A.2.3 Navigation files

The navigation ("Broadcast Ephemeris") file consists of one or more "blocks" of orbital data as recorded by the receiver from the satellites' transmissions. For convenience we have not introduced a new format for these data; rather, they may be either in RINEX navigation file format (preferred) or in FICA format as defined by GESAR Block 9 for the TI 4100. To create a navigation file from a TI FICA file, use the program ficachop and specify Block 9.

The RINEX navigation file is described in Gurtner and Estey [2006]. An example, with an ephemeris block for only one satellite, is given below:

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The first line is a header giving the RINEX version number (1) and the type of file (the "N" in column 21 is the critical character). The second line is a comment describing how the file was created. Additional comment lines can be added by putting "COMMENT" in columns 61-67. A blank line separates the header from the data blocks.

The first line of each data block has the PRN number (8 here), epoch in GPST, and the three satellite clock polynomial coefficients (see Section 2.6). The next 24 describe the ephemeris of the satellite. The correspondences are listed in Table A.3.1 below.

An example of one block of a FICA-type E-file is given below. The first line indicates that there are 60 floating point numbers in the block (and no integers or character strings).

For the most part, the numbers in the FICA Blk 9 are the same as those used in the RINEX-type E-file but in a different order.
Table A.2.1  Broadcast ephemeris values in RINEX and FICA E-files

<table>
<thead>
<tr>
<th>Description</th>
<th>RINEX file Index</th>
<th>FICA Blk 9</th>
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</thead>
<tbody>
<tr>
<td>Clock drift rate ( sec/sec² )</td>
<td>SV Clk 3</td>
<td>14</td>
</tr>
<tr>
<td>Clock drift (sec/sec)</td>
<td>SV Clk 2</td>
<td>15</td>
</tr>
<tr>
<td>Clock bias (sec)</td>
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<td>16</td>
</tr>
<tr>
<td>Age of ephemeris data (GPS sec of week)</td>
<td>Orb 1 1</td>
<td>26</td>
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<tr>
<td>Radial sine correction (CRS) (meters)</td>
<td>Orb 1 2</td>
<td>27</td>
</tr>
<tr>
<td>Correction to mean motion (radians/sec)</td>
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<td>28</td>
</tr>
<tr>
<td>Mean anomaly at epoch (radians)</td>
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<td>29</td>
</tr>
<tr>
<td>In-track cosine amplitude (CUC) (radians)</td>
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<td>30</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>Orb 2 2</td>
<td>31</td>
</tr>
<tr>
<td>In-track sine amplitude (CUS) (radians)</td>
<td>Orb 2 3</td>
<td>32</td>
</tr>
<tr>
<td>Square root of the semi-major axis ( meter¹/² )</td>
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<td>33</td>
</tr>
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<td>34</td>
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<tr>
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<td>46</td>
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<td>HOW word (GPS seconds of week)</td>
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<tr>
<td>Age of ephemeris data (GPS sec of week)</td>
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</tbody>
</table>

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A 2.2 SP3 orbit file

Tabulated GPS orbits are usually distributed using the “Special Products 3” (SP3) format developed at the U.S. National Geodetic Survey. Descriptions of the original and current versions of this format are found in Spofford and Remondi [1999] and Hilla [2002], respectively. An example for the official IGS orbit is shown below:

```
# aP1996 4 21 0 0 .00000000 96 ORBIT ITR93 HLM IGS
## 850 .00000000 900.00000000 50194 .0000000000000
+ 25
  1 2 3 4 5 6 7 9 14 15 16 17 19 20 21 22 23
+ 24 25 26 27 28 29 31 18 0 0 0 0 0 0 0 0 0
++ 5 5 6 5 5 5 5 5 5 8 5 6 5 5 5 5
++ 5 5 6 5 5 8 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
% cc cc cc ccc ccc cccc cccc cccc ccccc ccccc ccccc ccccc
%f .0000000 .000000000 .00000000000 .000000000000000
%f .0000000 .000000000 .00000000000 .000000000000000
% i 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
% i 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
/* RAPID SERVICE ORBIT COMBINATION FROM WEIGHTED AVERAGE OF:
/* cod emr esa gfr jpl ngs sio
/* REFERENCED TO GPS CLOCK AND TO WEIGHTED MEAN POLE:
/*
*  1996 4 21 0 0   .0000
P  1 -20844.049743  16468.077022    682.661913     53.575584
P  2  12944.844539 -10393.087331 -20299.519500   -249.520521
P  3  -8227.617128  20375.326181 -15102.650518      4.597767
P  4  13744.791940  -9683.391414  20694.419314     22.047268
P  5 -12352.621960 -20060.938827  12297.360719     36.113385
P  6 -19546.655943  -1100.613728  18148.758754      8.140737
P  7  20712.125279 -16356.600000   -518.876248    719.138221
P  9 -17764.134276 -16037.093050 -11757.505817    -18.951339
P 14  12179.034086  18588.450559  14478.113351     13.465001
P 15  19057.231547  15809.204514  -9780.269336    293.252400
P 16  -1083.799746 -26408.146377   2349.366780      8.084014
P 17 -24486.194361  -4762.735719  -9703.838269   -112.969182
P 19  25533.173686   3886.160764   -640.473223  459.005144
P 20 -15478.615183  -9745.065423  21780.182095    14.598467
P 21 -12024.261423  12964.155803 -19620.557712    19.797230
P 22 -3194.548377  24157.840245  10016.934756    301.593609
P 23 -15229.629690  -1727.102967 -21438.845352     9.526407
P 24  544.423674  -15500.071774  21780.182095   -179.844909
P 25 -11610.793056  11908.640383  20691.294205   -1.623070
P 26 -3511.667947 -15876.253008 -20761.867092   -183.285168
P 27  21532.343236  -3952.280131 -15530.087869     26.271555
P 28 -12532.981692  20254.408891 -11789.931632    78.225844
P 29  12432.232182  9589.973773  21587.240169     8.991759
P 31  4170.173983   9589.973773 -21199.804060    447.481331
P 18  21074.390097 -2889.491428  15694.503544  999999.999999
*  1996 4 21 0 15   .0000
P  1 -20841.140297  16195.390000  -2157.407872  53.634533
```

The characters in columns 1 and 2 indicate the type of line. The first line (#a) includes the GPS time and date (year, month, day, hour, minute, second) of the start of the orbital information, the number of epochs (96 in the example), the terrestrial coordinate system used (ITR93, for ITRF-93) and the agency computing the the orbit (IGS). The keyword in columns 41–45 indicates the type of data used to compute the orbit. For individual analysis centers this will indicate, e.g., doubly differenced carrier phase (d), but for the IGS combined orbit the orbits of the individual analysis centers are the

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"observations". The second line (##) repeats the start time but in terms of GPS week (850) plus seconds of week and Modified Julian Day plus fraction-of-day; it also gives the interval of the tabulated ephemerides in seconds (900).

The third to the seventh lines (+ ) have the number of satellites followed by their respective PRN numbers. The 8th to the 12th lines (++ ) indicate the accuracy of the orbit of each satellite, given by the exponent of 2 in millimeters; e.g., 5 implies an accuracy of 2^5 mm, or 3.2 cm. Lines 13–18 are reserved for addition of character (%e), floating-point (%f) or integer (%i) variables to the format. Lines 19–22 have free-form comments (/*).

For each epoch there is a header line (• ) and data lines (p ) for each satellite. The data lines contain Cartesian coordinates in kilometers and the clock offset in microseconds.
Appendix 3. Modeling Satellite Clock Variations due to SA

For precise geodesy, the most troublesome aspect of the policy of "selective availability" (SA) is the dithering of the frequency of the satellite oscillators. Between March and August of 1990, the level of dithering reached 1-2 Hz (~1 part in 10^9), making the oscillators of the Block II satellites appear to be no more stable than the better crystal oscillators used in field receivers. Dithering is a problem because receivers do not generally sample the phase of the same transmitted wavefront. Even if the nominal sampling time is the same, receivers separated by intercontinental distances sometimes sample wavefronts transmitted at times different by a few tens of milliseconds due to the difference in propagation time. For the level of SA active in 1990, the phase error in the case of simultaneously sampling sites at intercontinental distances is only a few millimeters in equivalent distance. For receivers that sample at times differing by ~1 second (e.g. TI 4100 and MiniMac 2816 or Trimble 4000SST), the error can reach a cycle or more (see Feigl et al. [1991] for a more complete discussion).

The satellite oscillator phase (or frequency) variations can be determined rather easily from the carrier-beat phase residuals from a station using an atomic oscillator (Rubidium, Cesium, or Hydrogen-maser). Program makej performs this task using the phase-residuals from one or more C-files to compute satellite clock corrections at each epoch and to write these into a J-file which has the same form as the J-file created from the broadcast clock polynomial (see Chapter 4). The only complication is the need to clean the phase data and to use the residuals from several stations in order to avoid gaps. A reasonable strategy is to process the data from a global network of 3–10 atomic-oscillator stations using Type of Analysis = QUICK and to perform only minimal manual editing in order to get a set of C-files to be used as input to makej. If you start with enough stations, you can afford to omit problematic C-files.

To invoke this mode of makej, choose option 2 at the first prompt and then enter the name of the J-file to be created:

Choose source of SV oscillator frequency corrections:
1  E-file broadcast message. [OK for MAKEX and MODEL without S/A]
2  Second order fit to C-file from site with H-maser [best for S/A]
Pick a number.2

Enter output J-file name >: jtrex0.086
Opened J-file: jtrex0.086

Makej will then ask you whether you want to see extra (debug) information (usually not) and display a list of the C-files available in the directory:

Wanna debug? (Y/N) n

Choose one or more C-files from stations with atomic standards
Available files:
1 carot0.086
2 cblhl0.086
3 ccent0.086
4 cjpl10.086
5 clock.doc
6 cmadc0.086
7 cmojm0.086
8 covro0.086
9 cpver0.086
10 cricm0.086
11 ctox.bat
12 cvndn0.086
13 cwsfm0.086

Enter file names or pick numbers:
1 7 10 13

In this example, we have chosen C-files from four VLBI sites (Algonquin, Mojave, Richmond, and Westford) all equipped with Hydrogen-maser frequency standards.

You will next be asked to provide as input the J-file used by MODEL in the analysis that produced the C-files. Since the phase residuals were generated with the satellite-clock terms from this J-file, it is crucial that you use this file as reference in generating the new epoch-by-epoch J-file.

Choose as input reference the J-file used by MODEL to produce the C-files

Available files:
1 jrefj0.086
2 jtrex0.086

Enter a file name or pick a number: 1

Makej will then read the time and phase residuals from all of the C-files and estimate a series of satellite-clock coefficients defined in the same way as for the broadcast J-file. The clock-offset term (units = seconds) is taken from the input J-file directly. Makej will estimate from three successive values of the phase residuals at each station a frequency-offset coefficient (dimensionless) and frequency rate (or clock acceleration) coefficient (1/seconds). The values from each station are then averaged, with outliers detected and removed, and written on the J-file. Part of a J-file for day 86 of 1990 is shown below:

The estimates can be made, of course, only if the satellite is visible from the station whose C-file is being used, so if a non-global network is used, you will obtain many messages of the form

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Estimate failed for PRN 19 at epoch 2; using reference values
Estimate failed for PRN 19 at epoch 3; using reference values
....
Estimate failed for PRN 19 at epoch 20; using reference values

As long as at least one "good" station is available in the region of your primary network, you will have a valid estimate for most or all of the epochs of interest. Use of a global network and an observation span longer than that of your primary data session will avoid endpoint problems, which arise inevitably since phase data from three epochs are needed to estimate frequency and its rate of change (see Chapter 2 of Feigl [1991]). If a good estimate cannot be obtained at any epoch, the coefficients from the input J-file are written. In the example shown above, broadcast coefficients have been used after 3h 46m 24s, when PRN 2 is no longer visible from any of the four stations. Note the difference in the stability of the clock as reported by the satellite (3 parts in 10\(^{13}\)) and as actually measured (3 parts in 10\(^{10}\)) (although part of this difference might be attributed to time period of averaging—hours versus minutes).

After writing the complete J-file, *makej* will display a summary:

J-File written for 9 satellites

| Start: | 90 86 0 44 |
| Stop:  | 90 86 8 42 |

Valid estimates PRN: 2 3 6 9 11 13 14 16 19

| 362 433 542 562 832 710 499 159 369 |

Outliers PRN: 2 3 6 9 11 13 14 16 19

| carot0.086 | 0 0 0 0 0 0 0 0 0 |
| cmojm0.086 | 0 0 0 0 0 0 0 0 0 |
| cricm0.086 | 0 0 0 0 0 0 0 0 0 |
| cwsfm0.086 | 0 0 0 0 0 0 0 0 0 |

Jfile: j4stn0.086 contains PRNs 02 03 06 09 11 13 14 16 19

In estimating the clock coefficients, *makej* uses only phase residuals which are flagged as "good" for *solve* and not flagged as a cycle slip requiring an extra bias parameter. If the data have been completely cleaned no outliers will be detected.
References


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