EAS 8803 - Obs. Seismology
Lec#19: Inverse Problem/EQ Location

- Dr. Zhigang Peng, Spring 2016

Figure 7.2-1: Geometry for earthquake location in a homogeneous halfspace.
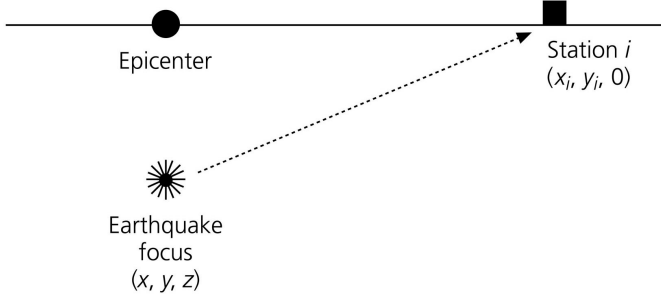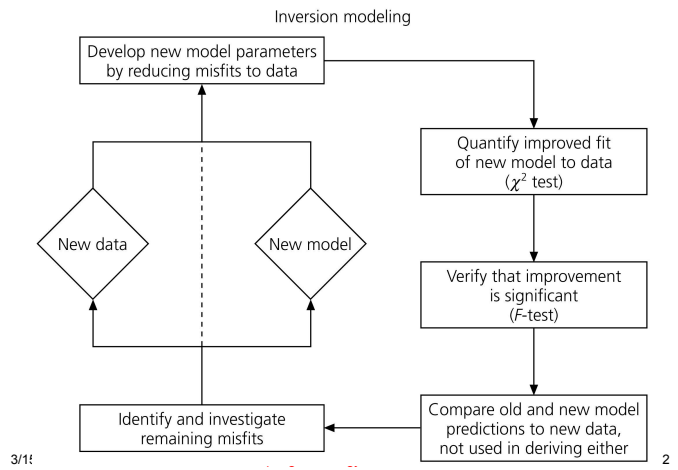
Epicenter

Station i
$(x_i, y_i, 0)$

Earthquake focus
(x, y, z)

Figure 1.1-8: Inversion modeling flow chart.

Inversion modeling

Develop new model parameters by reducing misfits to data

Quantify improved fit of new model to data (χ^2 test)

New data

New model

Verify that improvement is significant (F-test)

Identify and investigate remaining misfits

Compare old and new model predictions to new data, not used in deriving either

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416   *Inverse Problems*

Table 7.1-1 Some large-scale reference models.

Model for	Observables inverted and predicted	Para
Laterally homogeneous earth structure	Travel times, eigenfrequencies	Aver versi
Relative plate motions	Rates and azimuths of plate motion	Eule
Thermal evolution of oceanic lithosphere	Variation with age in depth, heat flow, and geoid	Plate temp prop

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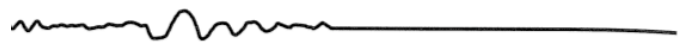
Parameters estimated	Misfits ("anomalies") indicate
Average velocity and density versus depth	Lateral velocity variation (subduction zones, continental–ocean differences, etc.)
Euler vectors	Nonrigid plate behavior (plate interiors and boundary zones)
Plate thickness, asthenospheric temperature, physical properties (e.g., α, κ, k)	Lateral thermomechanical variations (swells, etc.)

Earthquake Location

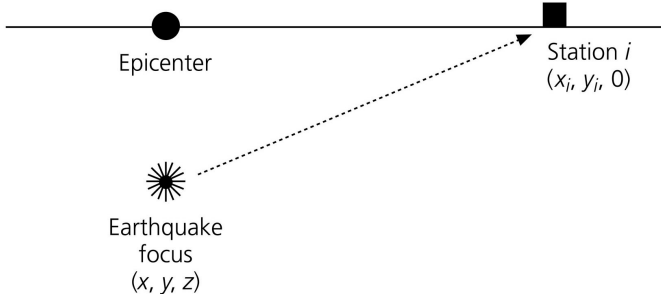**Figure 7.2-1: Geometry for earthquake location in a homogeneous halfspace.**

Epicenter

Station i
$(x_i, y_i, 0)$

Earthquake focus
(x, y, z)

Figure 7.2-2: Illustration of the the effect of linearizing about an inverse problem starting model.

$\mathbf{d} = A(\mathbf{m})$

Linear approximation

Predicted by starting model

Data

Observed

First iteration
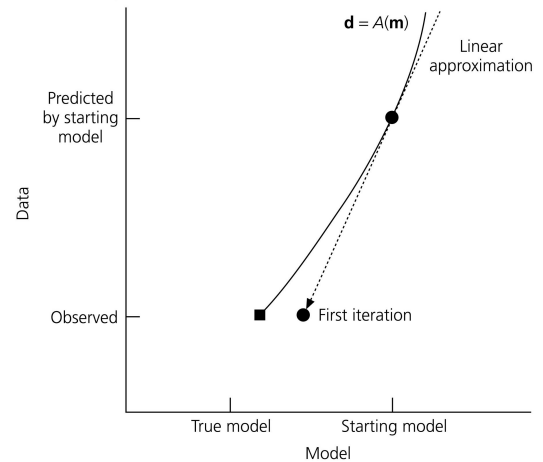
True model   Starting model

Model

Figure 7.2-3: Illustration of the misfit to data as a function of inverse problem iteration.
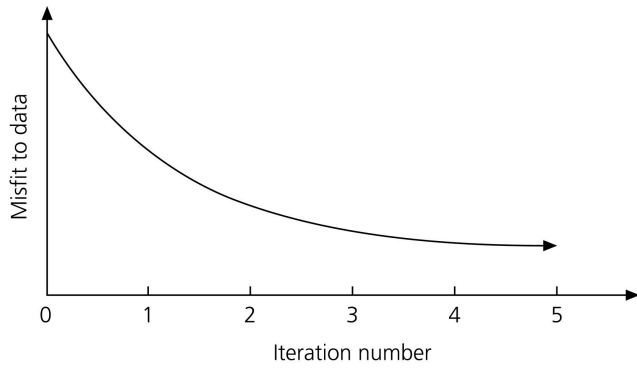
Table 7.2-1 Earthquake location example with error-free data.

Invert for location and origin time

model evolution

parameter	actual value	model for iteration number		
		0	1	2
x	0.0	3.0	−0.5	0.0
y	0.0	4.0	−0.6	0.0
z	10.0	20.0	10.1	10.0
origin time	0.0	2.0	0.2	0.0

station location		residual for iteration number		
		0	1	2
35.0	9.0	−2.1	−0.4	0.0
−44.0	10.0	−3.0	−0.2	0.0
−11.0	−25.0	−3.8	−0.1	0.0
23.0	−39.0	−3.0	−0.2	0.0
42.0	−27.0	−2.6	−0.3	0.0
−12.0	50.0	−2.0	−0.3	0.0
−45.0	16.0	−2.9	−0.2	0.0
5.0	−19.0	−3.7	−0.2	0.0
−1.0	−11.0	−4.1	−0.2	0.0
20.0	11.0	−2.4	−0.4	0.0
error		92.4	0.6	0.0

Invert for location, origin time, and velocity

model evolution

parameter	actual value	model for iteration number		
		0	1	2
x	0.0	3.0	0.2	0.0
y	0.0	4.0	0.3	0.0
z	10.0	20.0	10.2	10.0
origin time	0.0	2.0	0.7	0.0
velocity	5.0	4.0	4.9	5.0

station location		residual for iteration number		
		0	1	2
35.0	9.0	−4.0	−0.9	0.0
−44.0	10.0	−5.6	−1.0	0.0
−11.0	−25.0	−5.7	−0.9	0.0
23.0	−39.0	−5.6	−1.0	0.0
42.0	−27.0	−5.2	−1.0	0.0
−12.0	50.0	−4.6	−0.9	0.0
−45.0	16.0	−5.6	−1.0	0.0
5.0	−19.0	−5.2	−0.9	0.0
−1.0	−11.0	−5.3	−0.9	0.0
20.0	11.0	−3.8	−0.8	0.0
error		261.3	8.3	0.0

Table 7.2-2 Earthquake location example with errors.

Invert for location and origin time

model evolution

parameter	actual value	model for iteration number			
		0	1	2	3
x	0.0	3.0	−0.2	0.2	0.2
y	0.0	4.0	−0.9	−0.4	−0.4
z	10.0	20.0	12.2	12.2	12.2
origin time	0.0	2.0	0.0	−0.2	−0.2

station location		residual for iteration number			
		0	1	2	3
35.0	9.0	−2.0	−0.1	0.1	0.1
−44.0	10.0	−3.0	−0.1	0.0	0.0
−11.0	−25.0	−3.8	0.0	0.1	0.1
23.0	−39.0	−3.2	−0.1	0.0	0.0
42.0	−27.0	−2.8	−0.2	−0.1	−0.1
−12.0	50.0	−2.1	−0.3	−0.1	−0.1
−45.0	16.0	−2.9	−0.1	0.0	0.0
5.0	−19.0	−3.7	−0.1	0.0	0.0
−1.0	−11.0	−4.0	−0.1	0.0	0.0
20.0	11.0	−2.5	−0.3	0.0	0.0
error		93.74	0.33	0.04	0.04

data standard deviation   0.10

model variance–covariance matrix

0.06	0.01	0.01	0.00
0.01	0.08	−0.13	0.01
0.01	−0.13	1.16	−0.08
0.00	0.01	−0.08	0.01

model standard deviation

x	y	z	origin time
0.25	0.28	1.08	0.10

Slow   Fast

Bias moves locations off fault
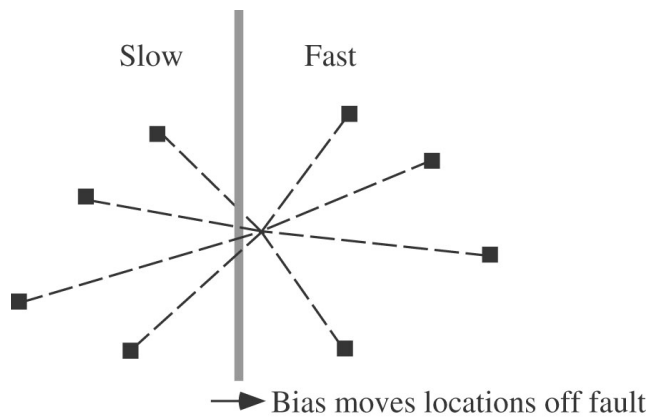
Earthquakes located along a fault will be mislocated if the seismic velocity changes around the fault.

Error ellipse elongated away from array

Seismic network
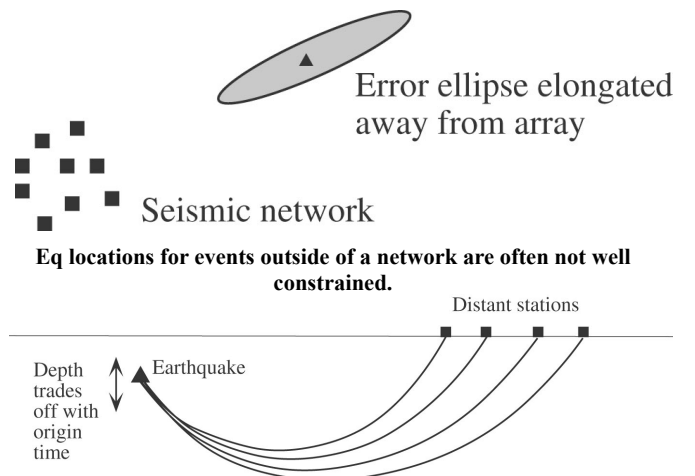
Eq locations for events outside of a network are often not well constrained.

Distant stations

Depth trades off with origin time   Earthquake