Basic knowledge for Georgia Tech Geophysics students

This document serves as a summary of the background knowledge and skills that are expected of PhD level students in Geophysics at Georgia Tech. Outside of the additional knowledge identified for specific subdisciplines (denoted by bold acronyms), the information listed here will mostly be covered in one of a few "core geophysics courses", short courses, individual research, or can be gained through participation in the geophysical seminar series. Much of the basic knowledge and math skills should have been covered in undergraduate courses (e.g., *Physics (I,II), Calculus series, Intro. Geophysics*), and hence may not be explicitly covered in these courses. The graduate-level "core courses" are *Geodynamics*, *Seismology*, and *GeoFluids*. Note that these courses are not meant to be requirements for all students, but are the first-level graduate courses that most students will take.

Basic Knowledge:

- Plate tectonics theory: kinematic and dynamic processes, major current plate organization
- Planetary atmospheric structure (P,T,ρ)
- Fundamentals of heat transfer (conductive, radiative and convective)
- Major earth materials, elemental composition, density and location
- The 1D mechanical, compositional, density, and seismic velocity Earth model
  - 1st order deviations as associated with continental and ocean lithosphere and plate tectonics
  - Similar information for relevant planetary bodies (**Sp**)
- Fluid and solid mechanics: real-earth elastic and viscous moduli, stresses, flow and strain values
- Gravity: Universal law of gravity, the geoid, and structural anomalies
- Scaling, self-similarity and power-laws in nature
- Simplified phase diagrams
- Tsunami: Gravity wave propagation, causal factors, run-up height factors
- Fluid through porous media: Darcy's law
- Basic understanding of radioactive nuclide decay
- Electromagnetism: Basic (E/M relationship, potentials, etc.)
- Statistics and error analysis: T-,F-tests, χ^2 , random vs. systematic error
- Hazard analysis of earthquakes, volcanism, tsunami, and space weather
- Basic scientific paper writing and presentation skills
- Basic knowledge of geophysics tools: reflection/refraction seismology, airborne/satellite remote-sensing (gravity, magnetism, InSAR, Lidar), GPS
- Time series analysis: digital signal processing, FFT, f-domain, filtering, convolution, correlation (**Gd, S**)

Math Skills

- Taylor, Fourier series
- Mathematical background: Scalars, vectors, and tensor, Matrix algebra, Vector Calculus
- Analytical diffusion/conduction calculations (computation of 1-D diffusion eqn,)
- Non-dimensionalize equations

Basic Computer Skills

- Matlab
- Computational algorithms (basic familiarity with compiled languages;, e.g. Fortran)
- ArcGIS (**Gm**)
- Basic Unix/Linux, cluster and networked computer theory/tools, Unix shell scripting, GMT (**Gd, S, V**)
- SAC (**S, Gd**)

Seismology

- Elastic wave propagation
- Snell's Law (including Fermat's and Huygen's principles)
- Types of seismic waves, controls on velocity, important seismic phases within the Earth
- Geometric spreading, anelastic and scattering attenuation (**S**)
- Seismic anisotropy (**S, Gd**)

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additional knowledge necessary for: (**S**) Seismology, (**Gd**) Geodesy, (**V**) Volcanology/Multiphase Flow, (**Sp**) Space Physics, and **(Gm)** Geomorphology

Geodesy

- Okada models of slip induced deformation (**S**, **Gd**)
- Mogi model of spherical source deformation (**Gd**, **V**)
- Limitations of analytic vs. numerical models of deformation (**Gd**)
- Basic theory of InSAR and GPS data reduction (**Gd, Gm**)

Earthquakes and Faults

- Elastic rebound theory
- Fault characterization using geologic, geophysical, and lab studies
- Controlling factors for earthquake occurrence: geographic location, strength and stressing requirements
- Basic earthquake source parameters:
  - Earthquake rupture properties: directivity, length, width, slip and strength
  - Magnitude-types and calculations, seismic moment, stress drop (**S, Gd, Gm**)
  - Corner frequency, and radiated energy (**S**)
- Focal mechanisms, moment tensors, Anderson's Theory of Faulting, deviations (**S, Gd, Gm**)
- Mohr-Coulomb failure, slip-weakening, Coulomb/Amonton friction, rate- and state friction, (**S, Gd, Gm**)
- Omori's law of aftershock occurrence (**S, Gm, Gd**)
- Modified Mercalli Intensity scale, contributing factors in ground shaking intensity (**S, Gd, Gm**)

Fluid Dynamics

- Conservation relationships for thermal energy, mass and momentum
- Boundary layer analysis (**V, Sp**)
- Reynolds number, Stokes number, Froude number, particle flow and forces (**Gm, V**)
- Plumes, jets and gravity currents (analytic models and scaling) **(V)**
- Turbulent flows and Kolmogorov theories (and transition from laminar to turbulent flow) (**Gm, V**)
- Familiarity with compressible fluid dynamics (shock relations and choked flow) (**V**)
- Kinetic theory of gases (**V**)
- Basic understanding of algorithms for convection/melting including source terms (radioactive nuclides, linear melting models) **(V)**

Volcanology and Magma Dynamics

- Mantle melting relations (wet and dry)
- Basic understanding of compositional variation in magmas (basalt – rhyolite) and their physical properties
- Volcanic system types, eruption styles and mechanisms
- Fragmentation criteria for magma in volcanic conduits, and its relation to eruptive style (**V**)
- Convection scaling and relate this to cooling magma chambers (and describe the Biot effect) (**V**)

Planetary and Rock Magnetism

- Magnetic dipole field, basic dynamo theory, magnetic reversals (field evidence)
- Curie point and magnetic susceptibility
- Space weather (sun-earth connection)
- General understanding of magnetic reconnection (**Sp**)
- Magnetospheric/Auroral generation and dynamics (**Sp**)
- Electromagnetism: Plasma, and wave dynamics (**Sp**)

Geomorphology and Geology

- Basic understanding of geochronologic/thermochronologic techniques
- Feedbacks between mountain building, erosion, and climate
- Fundamentals of geologic mapping
- Field methods (geomorphic mapping, landform surveying, geochronology sample collection) (**Gm**)
- Paleoseismology and observations of faulting (**S, Gd, Gm, V**)
- Threshold of critical power in streams (**Gm**)
- Landscape response to changes in base level (incision, terrace formation, knickpoint migration) (**Gm**)
- Hillslope characteristics, processes, and evolution (**Gm**)
- Glacier characteristics and dynamics (**Gm**)

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