ESS 502 January 5, 2016

Read Fowler Chapter 3: Past Plate Motions

Solid Earth Geophysics

A traditional solid earth geophysics course:
includes lectures and homework sets
emphasizes theory to derive models
provides excellent training for "next generation" specialists
excludes non-specialists who are insufficiently prepared
to follow the theoretical derivations
may have an overemphasis on details at the expense of concepts

This "hybrid" course will include about half lecture and half "active learning" discussion. We will cover fundamentals through lecture and using the reference texts. We then will incorporate reading of papers. Per the syllabus, we will require weekly reading and writing, class discussion (attendance is important)

This is a "theme-based" course:
Earth as heat engine and chemical processing factory
Cascadia subduction zone

Focus on the nature of "models" : the connection between theory and observables
identify that which is "well understood" vs "controversial ideas"

The recurring problems in the Earth sciences:
imperfect data (both random and systematic)
incomplete data coverage (time and space)
non-unique solutions (different models fit the data)
incorrect or incomplete conceptual framework (theory)

As noted in the Preface of Fowler's "Solid Earth Geophysics" text, an interdisciplinary approach is essential in understanding or making progress. We want this course to be accessible to the non-specialist in geophysics. The class learning goals are:

- Learn fundamental geophysical principals that underlie ongoing scientific controversies
- Read, analyze and critique scientific papers and hypotheses
- Effectively communicate scientific concepts to peers
- Understand the distinction and use of data and models
- Gain an appreciation for the importance of multidisciplinary approaches
- Recognize the human dimension in underlying global scale Earth processes

1. A list of the common elements of "geophysical" approaches
    a. Seismology: study of elastic wave propagation to understand source properties and earth structure: Vp, Vs, Q, anisotropy
    b. Geodesy: motion/deformation of Earth's surface
    c. Heat Flow: diffusion, advection, and sources of heat
    d. Gravity: acceleration, potential field, density
    e. Magnetics: Geodynamo, reversals, plate motions
    f. Magnetotellurics: electrical conductivity
    g. (plus a little basic geochemistry)

2. Typical geophysical observables
    a. Lateral/vertical motions of Earth's surface – GPS, inSAR
    b. Topographic features – Lidar
    c. Earthquake distributions and focal mechanisms – seismograms: P-and S-wave arrival times
    d. Heatflow distribution – thermal gradients
    e. Features in gravity and geoid fields – sea surface topography, GRACE, gravimeters
    f. Record of Earth's magnetic field (space/time)– satellite, airplane, rocks
    g. Seismic structure (radial, lateral, anisotropy) – travel times, surface wave dispersion, normal-mode eigenfrequencies
    h. Seismic sources: earthquakes (fast and slow), nuclear explosions, volcanic, glacial, ocean, atmosphere, …
    i. Geochemical patterns

3. The "Standard Model" that implicitly underlies discussions of global geophysics. Almost every point is controversial. Think of them as concepts that can generate testable hypothesizes.
    a. Earth formed by homogeneous accretion of essentially solar composition minus volatiles – a homogeneous composition for the mantle requires only small deviations from "solar" values
    b. Core separated from mantle early in Earth history as a result of gravitational instability or following a rare large impact.
    c. The whole mantle convects - driven by internal heating, heating from core, and secular cooling
    d. The mantle is "dry" (less than 1% water content)
    e. Melts rise to the top of the mantle
    f. Plumes arise from instabilities on the core-mantle boundary
    g. Mantle seismic discontinuities are the result of phase transitions
    h. Lateral seismic structure is primarily thermal in origin
    i. Earth's magnetic field is created by MHD processes in the core
        i. Reversals are expected
        ii. Process is powered mainly by gravitational energy associated with formation of inner core

4. Anomalies and alternative ideas
    a. The lower mantle must have a different composition from the upper mantle since the upper mantle (Mg+Fe)/Si ratio is not consistent with "solar" composition
    b. Mantle convection is intrinsically layered.
    c. Deep originating mantle plumes do not exist
    d. The transition zone contains large amounts of water
    e. Some melts sink.
    f. Some seismic evidence suggests that not all plates penetrate into the lower mantle

5. Gross structure of Earth
    a. radius 6371 km (21 km difference in radius from equator to pole)
    b. inner core radius 1200 km, outer core radius approx. 3000 km. continental crust – 40 km, oceanic 5-7 km
    c. mass distribution 67% mantle, 32.5% core 0.5% crust (1.7% inner core)