GEOL 695-Environmental Geodesy
Assignment #2 - Lectures 4-5

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Problem 1: What are key physical constants related to gravitation and the gravity field of a planet and how well are these known?

The two key physical constants are the universal gravitational constant *G* and the mass *M* of the planet.

By itself, *G* is perhaps the least-well-known of all fundamental physical constants. In [*Fixler et al.,* 2007] the authors give a value of "G = 6.693×10^{-11} km^3s^{-2}, with a standard error of the mean of $\pm 0.027 \times 10^{-11}$ and a systematic error of $\pm 0.021 \times 10^{-11}$ km^3s^{-2}." Likewise, the absolute mass of any planet is not well-known. On the other hand, the combined quantity GM_{earth} is known to a greater degree of certainty. According to the Wikipedia page (I couldn't find a better reference in this limited time), $GM_{earth} = 398600.4418 \pm 0.0008 \; km^3 s^{-1}$.

Problem 2: Name and characterize the main equations related to the gravity potential.

The main partial differential equations which describe the gravity potential are the Laplace and Poisson equations; the former applies when the point for which the potential is to be computed lies outside of any attracting mass, while the latter applies, for example, to a point below the surface of the earth.

Problem 3: How large are the deviations of the geoid from the reference ellipsoid and how are these deviations explained?

The largest deviations of any widely-accepted geoid from the corresponding reference ellipsoid are on the order of 100 meters. Most simply, these deviations are explained by density variations within the earth.

Problem 4: Explain in simple words the origin of tides.

The lunisolar tide on earth is caused by the difference between the homogeneous centrifugal force arising from the constant revolution of two bodies (e.g. the earth and moon) about their center of mass (barycenter) and the inhomogeneous gravitational attraction between the two bodies. According to Thayer Watkins of San Jose State University, "This balance of gravitation and centrifugal force is exact at the centers of the Earth and moon. But at points closer or farther away than the center there is a slight imbalance that produces the tides." (http://www.sjsu.edu/faculty/watkins/tides.htm)

Problem 5: Why do we see ocean tides?

Ocean tides are apparent because the fluid ocean responds to tidal forces much more easilly than does the solid/viscoeleastic crust. Ocean tides are most visible in locations on the earth where there is resonance between the ocean eigenperiods and the tidal periods. Examples where such resonance is great include the Bay of Fundy and Panama City.

Problem 6: Why are the amplitude and phases of semidiurnal and diurnal tides varying irregularly in space?

Again, this has to do with natural resonnances in the irregular ocean basins. The most important factors governing such spatial variability are the Coriolis effect, the location of land, and ocean depth.

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Problem 7: How large is the largest equilibrium tide on Earth?

(I have had trouble finding this information.) Some of the largest *dynamic* tides occur in the Bay of Fundy, with a tidal variation on the order of 17 m. As far as I can tell, the *equilibrium* tide should only amount to a meter or so.

Problem 8: Why does the Moon keep the same face toward the Earth?

This lock-in is due to the tidal friction.

Problem 9: How large is the tidal bulge of the Moon?

According to the Wikipedia entry on the moon, which cites an article in *The Astronomical Journal*, "The lunar surface also experiences tides of amplitude ~10 cm ...".

Problem 10: What are the main rotational eigenmodes of the Earth and to which parts of the Earth are they mainly attributed?

The first rotational eigenmode of the earth, which is associated with the Chandler wobble, has a period of around 433 days. There is also an annual wobble caused by seasonal variations, a "nearly diurnal free wobble" and "free core nutation" giving rise to the second rotational eigenmode and associated with the fluid core with a period of approximately 460 days, and the "free inner core nutation" due to coupling between the inner and outer core, giving rise to the third rotational eigenmode.

References:

Fixler, J.B., G.T. Foster, J.M. McGuirk, and M.A. Kasevich (2007). Atom interferometer measurement of the Newtonian constant of gravity, Science, 315, 74-77.