GEOL 695-Environmental Geodesy
Assignment #1 - Lectures 1-3

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2/15/11

Problem 1: Define geodesy as a science and describe concisely the three pillars of modern geodesy.

Geodesy, as defined by F.R. Helmert, is "the science of the measurement and mapping of the earth's surface" [*Torge*, 1991]. (Sometimes other celestial bodies are included in the definition.) Although this definition may seem somewhat antiquated, the so-called "three pillars" do arise organically from this definition since all must be considered for accurate measurement and mapping. These three pillars are 1) geometry/kinematics, 2) gravity field, and 3) earth (or planetary) rotation (orientation).

Problem 2: What is a geodetic "reference system" and what a "reference frame"?

A reference *system* defines the parameters and models to be used in realizing a reference *frame*. From the lecture notes, "The IERS defines: '*By Reference System it is meant the set of prescriptions and conventions together with the modeling required to define at any time a triad of axes' ".* The realization is done by assigning a set of positions (and velocities) to a set of fundamental reference points (fiducials). These points may be celestial objects in the case of a celestial frame or points on the earth's surface in the case of a terrestrial frame.

Problem 3: What are the two fundamental global geodetic reference systems and what physical quantity links these two systems together? What are the two conventional systems accepted by IAG and IAU, and what are the corresponding most accurate reference frames? What organization maintains the systems and frames, and where are the conventions published?

The two fundamental geodetic reference systems are a Celestial Reference System (CRS) and a Terrestrial Reference System (TRS). These two systems are linked by the direction of the earth's rotation axis and rotation rate, usually specified by the earth orientation parameters (EOPs), and specifically the Celestial Ephemeris Pole (CEP). The link is realized though the use of very-long-baseline interferometry (VLBI).

The two conventional systems accepted by the IAG and the IAU are the International Celestial Reference System (ICRS) and the International Terrestrial Reference System (ITRS). The frame corresponding to the ICRS is the International Celestial Reference Frame (ICRF), and the corresponding terrestrial frame is the International Terrestrial Reference Frame (ITRF). Both are maintained by the International Earth Rotation Service (IERS). IERS published information on the ICRF can be found at their website at

http://www.iers.org/IERS/EN/DataProducts/ICRF/ICRF/icrf.html?__nnn=true

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while the corresponding information on the ITRF can be found at

http://www.iers.org/IERS/EN/DataProducts/ITRF/itrf.html?__nnn=true .

Problem 4: For the International Terrestrial Reference Frame (ITRF):

1. **How is the ITRF given and published?**

The ITRF is specified by a set of station coordinates and velocities, along with corresponding uncertainties. There are different IRTFs for different reference epochs.

2. **How do reference coordinates for ITRF reference points change over time?**

Coordinates are propagated forward in time from the frame's reference epoch using the given reference velocities and other defined time-variable processes such as solid earth tides, ocean and atmospheric loading, and post glacial rebound (PGR).

3. **What is the general mathematical relationship between two versions of the ITRF?**

Different realizations of the frame are related by a seven-parameter similarity (Helmert) transformation, usually using the small-rotation approximation. Since 1993 rates of change of the transformation parameters are also considered.

4. **How can the coordinates of a point in the two systems be compared?**

These can be compared by using equations (13-the infinitesimal similarity transformation) and (14-time propagation) in [*Plag,* 2006].

Problem 5: What are the mathematical shapes of the solid Earth that are related to the main phases in the development of geodesy since its beginning and what are the main parameters of these shapes that were the focus of research/observations in these phases?

Per Soffel, from the lecture notes:

Phase A: 200 BC to mid-17th century AD – spherical earth with radius being parameter of interest

Phase B: Mid 17th century to mid 19th century – rotational ellipsoid; oblateness quantity of interest

Phase C: Mid 19th century to mid 20th century – the geoid. The deviations of the geoid from the ellipsoid are usually defined globally by a spherical harmonic expansion, so I guess the coefficients of this expansion are the parameters of interest.

Phase D: Mid 20th century onwards – The evolution from a static to a dynamic view. Since the earth is now viewed as a system, there are many parameters involved.

Problem 6: How is the geodetic reference ellipsoid for the Earth defined and what are the key parameters?

The reference ellipsoid's defining constants are the equatorial radius, the geocentric gravitational

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constant, the dynamical form factor, and the reference angular velocity. All other geometric and physical properties of the reference ellipsoid can be derived from these quantities.

Problem 7: What are the main endogenic and exogenic processes impacting the shape of the Earth from periods of sub-seconds to millions of years?

Endogenic processes, in order of decreasing periods, include tectonic motion, volcanic and other magmatic activity, co-seismic displacements, and co-seismic displacements.

Exogenic processes, again in order of decreasing periods, include glaciation and deglaciation, sediment transport, climatic-scale atmospheric loading, ocean loading, weather-scale atmospheric loading, tides, and tsunamis.

References:

Plag, H.-P. (2006) National geodetic infrastructure – current status and future requirements: the example of Norway, Nevada Bureau of Mines and Geology Bulletin 112.

Torge, W. (1991) Geodesy, 2nd Edition, Walter de Gruyter, Berlin.