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GEOL 495
Homework 3

Problem 1: **Describe the main characteristics of point-geodetic observations versus imaging techniques in terms of spatial and temporal resolution and coverage.**

Geodetic techniques that track the location of points on the Earth's surface utilize satellites, or known fixed points in space, to observe exactly where that point is positioned at that specific time. Point techniques using GPS/GNSS and VLBI satellite missions passively monitoring existing signals, whereas SLR, LLR and DORIS missions are actively transmitting and monitoring signals. Both active and passive point tracking methods determine the location of established stations with a high accuracy, and provide observations on how a station is moving relative to other stations at regular time intervals. Remote sensing techniques use altimetry, InSAR, LIDAR, and reflectometry to record the precise return time and incident angle of a signal directed at the Earth's surface. These methods effectively scan or image any location, regardless of the presence of ground stations, with a more expansive field of view and much higher spatial resolution than point methods, sacrificing global correlation of survey points and temporal resolution on station motion.

Problem 2: **What is the "station motion model" and how does it enter into the analysis of point-geodetic techniques?**

Point-geodetic techniques accurately track the locations and movements of terrestrial stations, however these stations are moving with periodic and expected variations that need to be accounted for. Before geodetic data can be analyzed, it is necessary to develop a good understanding of how tidal, rotational wobble, or any other variation effects a stations position during the interval between observations. By modeling this predicted movement, we estimate what motion needs to be removed from the observations of station position and only track motion with anomalous trends.

Problem 3: **Which space-geodetic techniques provide the origin of the reference frame with respect to the center of mass and which provide the scale? Why?**

By its nature, an orbiting satellite will travel along a path of gravitational equipotential, or a geoid, that is equidistant from the center of mass (CM) of the object if orbits. Precisely knowing the distance from a satellite's path to the surface of the Earth will indicate the location of CM, the ILRS uses the laser ranging systems (SLR) to determine the ITRF and locate its origin at the CM. VLBI uses the time lag between when different stations receive a signal from a fixed and distant source to precisely determine the distance between stations, giving scale to those points on the Earth's surface that are then correlated to the ITRF origin so that further geodetic observations can be placed into an appropriate spatial and temporal context.

Problem 4: **Explain the principle of GNSS reflectometry.**

Microwave signals emanated from GNSS satellites (GPS most commonly) travel simultaneously to the Earth's surface, and to another satellite directly. The signal that travels to the Earth is reflected off the surface, back to the observing satellite where the temporal lag and Doppler shift are measured to determine the altitude, inclination, and roughness of the reflecting surface.

Problem 5: **Why are laser retro-reflectors on satellites like Global Navigation Satellites, altimeter satellites, and other satellites that use geometrical principles important?**

Laser retro-reflectors allow accurate ranging between a station and satellite, which is necessary to locate and interpret any time dependent signals from that satellite. By equipping a variety of satellites that employ geometrical principles with laser retro-reflectors, we not only increase our ability to precisely locate and analyze data from those satellites, but also increase our overall SLR capabilities in a cost effective and efficient manner.

Problem 6: **Explain briefly the principle of InSAR and identify the major limitations for accuracy and applicability. How could these challenges be addressed?**

Synthetic aperture radar (SAR) uses an antenna mounted on an air- or spacecraft to direct a radio signal at the Earth and record the reflections from that signal to create a detailed image of the surface below. By using multiple antennas, an interferometric SAR survey considers the offset in phase as the signal travels between the surface and the different antennas to generate an image with very high temporal and (three dimensional) spatial resolution. This active remote sensing technique effectively uses microwave radar to create a detailed stereoscopic image of large swaths of land, which can be compared with subsequent correlated images over time to monitor any change. InSAR is limited by atmospheric distortions in the signal, and from the difficulties of correlating its images with point tracking observations that would allow InSAR data to be linked to the ITRF. Problems with the signal in the atmosphere could be addressed by finding a more optimal EM frequency to transmit, or through software filtering. Placing retro-reflectors on InSAR craft and tracking their path could help to tie their observations to point stations and locate those within a reference frame.

Problem 7: **What are the main characteristics of in situ, airborne and spaceborne gravity measurements in terms of temporal and spatial resolution, as well as accuracy as function of spatial and temporal scale?**

In situ gravity measurements provide very detailed data on the geoid at a specific location with a high temporal resolution, over an extended time period. Gravimeters mounted on a moving platform sacrifice that resolution for the ability to survey large tracts, repeatedly over some regular time interval if necessary. Gravity measurements are very accurate, especially when multiple methods are combined with integrated data. Gravity measurements from space are of low spatial and temporal resolution; but they can cover the planet regularly and when results are integrated with measurements from stationary absolute gravimeters, with elevation and longitude determined by DORIS, observing orbital perturbations overhead with SLR, the results have both an accurate scale and high resolution.

Problem 8: **Explain the principle of GRACE and its main limitations in terms of accuracy.**

GRACE is a satellite mission involving two satellites in synchronous orbit, whose separation distance is closely monitored by GPS and microwave ranging between satellites (SLR also?). Since an orbital path is along a geoid, by observing when one satellite changes velocity relative to another, we can map the geoid very accurately. As with all satellite missions, GRACE has the advantage of making repeated passes, at periodic time intervals, along different planes for a high temporal accuracy. The main limitations to GRACE's accuracy are engineering and technology, and future missions will likely address the accuracy of microwave ranging and internal sensor disturbances.