Environmental Geodesy: Course description and syllabus

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Motivation:

Geodetic techniques are increasingly used in many fields of Earth science for studies of the solid Earth, the troposphere, the ionosphere, the ocean, terrestrial hydrosphere, the cryosphere, and the climate system. In addition, these techniques increasingly support many societal applications requiring georeferencing. Therefore, students in many fields would greatly benefit from a principle understanding of the fundamental geodetic concepts and an overview of the applications of the geodetic techniques in Earth sciences and adjacent fields.

Level and prerequisite, and potential students:

The course will be designed for all students in Earth science fields, including geophysics, geology, geography, hydrology, meteorology, climatology, oceanography. The course will also be of interest to engineering students who want to build a principle understanding of these techniques in their relevance for other applications. The requirements in terms of prerequisite will be kept at a minimum, however, PHYS 180/181 and MATH 181/182 would be an advantage.

Description:

The course will give an introduction to the so-called three pillars of geodesy, that is, the shape of the Earth (including ocean and ice surfaces), the gravity field of the Earth and the rotation of the Earth, as well as the fundamentals of geodetic reference systems and their realization through geodetic reference frames. Based on these concepts, an overview of the geodetic techniques, in particular the space geodetic techniques will be provided with focus on their individual strengths and weaknesses. The impact of environmental processes on the geodetic observations will be addressed, both as a noise limiting accuracy and precision and as a signal increasing the versatility of the geodetic techniques for environmental studies. The third and last part of the course will use a number of examples to illustrate the versatility of geodesy in many Earth science and adjacent fields. Examples will include but not be limited to the determination of surface displacements of the solid Earth due to earthquakes, tectonic deformations, and surface loading; determination of atmospheric water content; atmospheric and ionosphere seismology; space weather; determination of variations in land water storage; georeferencing in GIS; and tsunami early warning.

Syllabus:

Part 1 (weeks 1 to 5): The basics

Week 1: Introduction to geodesy, the science of measuring the Earth's shape, gravity field, and rotation: brief history of geodesy, introduction of today's situation with three distinct pillars, mentioning of emerging new applications, and introduction of the key terms related to geodetic reference frames.

Week 2: Geodetic reference systems and frames: introduction of terrestrial and celestial reference systems and Earth rotation as the link between terrestrial and celestial systems. Introduction of the concept of realization of these systems through reference frames, and discussion of the challenges of doing this on a dynamic, changing Earth. Review of existing systems and frames, and differences in the frames. Future developments.

Week 3: Earth's shape: Descriptive approach to changes in Earth's shape including the ice and ocean surface. The long-term mean shape of the Earth will be considered briefly. Main focus will be on changes in the shape: starting from co-seismic displacements, seismic waves and free oscillations, going over Earth and ocean tides, atmospheric, hydrological, and glacial loading, to sediment loading and tectonic changes, the various phenomena of surface displacements will be considered.

Week 4: Gravity field of the Earth: basic terms related to the gravity field will be introduced, including the geoid.

Week 5: Earth's rotation: The principle ideas and phenomena related to Earth's rotation will be introduced, including the nearly diurnal free wobble, the Chandler wobble, and precession and nutation. The current understanding of the rotational dynamics and the origin of Earth's rotation perturbations will be presented.

Part 2 (weeks 6 – 9): The techniques

Week 6: Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Lunar Laser Ranging (LLR), Global Navigation Satellite Systems (GNSS) and Doppler Orbitography and Radiopositioning Integrated by Satellites (DORIS): observing point motion and maintaining global geodetic reference frames.

Week 7: CHAMP, GRACE, GOCE: observing the Earth gravity field from space.

Week 8: Satellite altimetry, InSAR, LIDAR, GNSS reflectometry: observing surface displacements with imaging geodesy.

Week 9: Absolute and cryogenic gravimeters: observing gravity changes on the Earth's surface.

Part 3 (weeks 10 – 15): Applications

Week 10: Surface displacements and their relation to tectonic strain, temporal changes in strain rates, co-, pre-, and postseismic deformations.

Week 11: Surface displacements associated with hydrological, cryospheric, oceanic, and atmospheric loading.

Week 12: Geodetic observations and numerical weather forecast, climatology, and space weather.

Week 13: Observing sea level and ice sheet changes.

Week 14: Tsunami early warning, atmospheric/ionospheric seismology.

Week 15: Monitoring the global water cycle with geodetic observations.

Week 16: Finals