SIO229 – Gravity and Geomagnetism

Winter 2015
Mon/Wed/Fri 9:30~10:20 am
Munk Conference Room, IGPP

Instructors:
Adrian Borsa (aborsa@ucsd.edu), Munk 318. Office hours: drop in anytime 9~5 during the week, but email to reserve specific times.
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This web page is a repository for class notes, assignments, and other items of possible interest for SIO229, a 4-unit graduate class on gravity and geomagnetism. Required course reading will be in the form of notes (authored by Bob Parker and Cathy Constable) posted below in PDF format, with assigned sections for each lecture.

The class is an introduction to potential theory in the context of gravity and geomagnetism at a level suitable for the advanced nonspecialist in geophysics. The subtext is to get you familiar with spherical harmonics, which are ubiquitous functions in global geophysics. After a brief warm-up we are going to introduce spherical harmonics, derive some of their properties and apply them to various problems in potential fields, with emphasis on the geoid. Along the way we will meet some old topics, like the precession of the equinoxes and classical problems of potential theory, as well as some newer ones, like the satellite-derived geoid and gravity models of other bodies in the solar system.

Theoretical topics include spherical harmonics, Laplace's equation, boundary-value problems on a sphere, and Fourier methods. Applied topics include the global geoid, gravity anomalies, geomagnetic field modeling and sources, and paleomagnetic observations.

Grading for this class will be based primarily on homework assignments. Students may work together on assignments, but each student must turn in their own solutions based on their own work. Any code written to complete assignments (e.g. Matlab routines) should be submitted along with results. Short presentations of topics from the text or homework may be assigned, and a final exam may be given if the instructors. Prerequisite: graduate standing or consent of instructors.

Course Materials (Gravity):

Gravity Notes #1 (pages 1-16)
Gravity Notes #2 (pages 17-26)
Gravity Notes #3 (pages 27-36)
Gravity Notes #4 (pages 37-50)
Gravity Notes #5 (pages 51-65)
Appendix – Some Vector Identities
Appendix B – Orthogonality of Spherical Harmonics
Appendix P – Jean's Formula

Gravity Lecture Contents:

Lecture 1 - 1/5/2015
Topics: Introduction to the gravity portion of the course; moments of inertia for an arbitrary body
Reading: Gravity Notes #1, sections 0, 1
Homework: Problem Set #1 (due Friday, 1/9) Solution #1

Lecture 2 - 1/7/2015
Topics: Moments of inertia for an arbitrary body; principal axes of the inertia tensor; angular moment of Earth and the Chandler Wobble.
Reading: Gravity Notes #1, section 2

Lecture 3 - 1/9/2015
Topics: Multipole expansion of the gravitational potential of Earth (MacCullagh's Formula); relationship between potential and moments of inertia.
Reading: Gravity Notes #1, section 3

Lecture 4 - 1/12/2015
Topics: Inertial parameters for Earth via MacCullagh's Formula.
Reading: Gravity Notes #1, section 4
Homework: Problem Set #2 (due Friday, 1/16) Solution #2

Lecture 5 - 1/14/2015
Topics: MacCullagh's Formula in spherical coordinates; J2 and mass distribution; a quick look at the solar system – mass, spin rates, J2s.
Reading: Gravity Notes #1, section 4

Lecture 6 - 1/16/2015
Topics: Measuring gravity with a pendulum; Newton's method for determining the flattening of Earth; introduction to the geoid.
Reading: Gravity Notes #1/#2, section 5

Lecture 7 - 1/21/2015
Topics: The basic shape of the geoid via Clairaut's Formula.
Reading: Gravity Notes #1/#2, section 5
Homework: Problem Set #3 (due Friday, 1/23) Solution #3

Lecture 8 - 1/23/2015
Topics: Introduction to spherical harmonics via a general solution to Laplace's equation.
Reading: Gravity Notes #2, sections 6~7
Additional resources: Blakely Chapters 1, 3, 6; Heiskanen & Moritz 1-1, 1-2, 1-7 (we'll cover Stokes' theorem later), 1-9, 1-10, 1-11

Lecture 9 - 1/26/2015
Topics: Hilbert spaces, Euclidean space, and the relationship between eigenvectors and eigenfunctions.
Reading: Gravity Notes #2/#3, section 7; Appendix B (Orthogonality of S.H.)
Homework: Problem Set #4 (due Friday, 1/30) Solution #4

Lecture 10 - 1/28/2015
Topics: Spherical harmonics as an orthonormal basis on a unit sphere; a field guide to the spherical harmonics. (Lecture Slides)
Reading: Gravity Notes #2/#3, section 7~8; Appendix B (Orthogonality of S.H.)

Lecture 11 - 1/30/2015
Topics: The Table of Spherical Harmonic Lore; perspectives on the concept of "wavelength" in the context of spherical harmonics.
Reading: Gravity Notes #3, page 29; Appendix P (Jean's Formula)

Lecture 12 - 2/2/2015
Topics: Summary of topics covered in Lectures 1~11. Introduction to the global geoid and global gravity.
Reading: Gravity Notes #3/#4, section 10
Homework: Problem Set #5 (due Friday, 2/6) Solution #5

Lecture 13 - 2/4/2015
Topics: Reference ellipsoids; Brun's Formula for calculating geoid height; the gravity anomaly; spherical harmonic solution to Brun's Formula
Reading: Gravity Notes #3/#4/#5, sections 9, 15
Additional resources: H&M 2-8, 2-11, 2-13

Lecture 14 - 2/6/2015
Topics: Global gravity models

Supplementary Material:

Physical Geodesy
W. Heiskanen and H. Moritz
W.H. Freeman and Company, San Francisco, 1967
[On reserve in the Munk reading room.]
A thorough treatment of much of the gravity material covered in the class notes.

Potential Theory in Gravity and Magnetic Applications
Richard J. Blakely
Cambridge University Press, New York 1995
[available from ROGER (roger.ucsd.edu) in electronic format]
Another look at potential theory, specifically in the context of gravity and geomagnetism.

Treatise on Geophysics, Volume 3, Geodesy
Volume Editor: T. Herring. Editor-in-Chief: G. Schubert
Elsevier, Amsterdam, 2007
[available from ROGER (roger.ucsd.edu) in electronic format]
Technical summaries of many current topics in gravity research, written by the best in the field.
