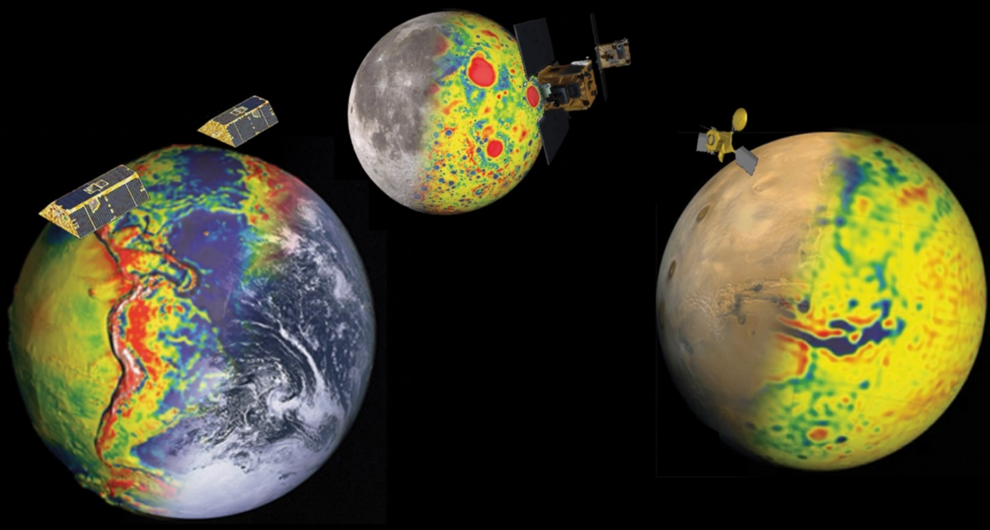
GEOL 1950H: Gravitational Fields and Data Analyses
Course Syllabus

Explore the evolution of Earth and other worlds across the Solar System and unravel their mysteries.
Topics Include: Climate Change, Core Dynamos and Magnetic Fields, Advanced Data Analyses, Potential Field Theory, Pattern Recognition



The Instructor: Alexander J. Evans, Assistant Professor of Earth, Environmental and Planetary Sciences
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Contact: alex_evans@brown.edu, x3-1287
Office Hours: Tuesday 1:00 PM – 3:00 PM or by appointment
Put 'GEOL 1950H' in subject of any email sent to Prof. Evans regarding class

The Website: http://ghosst.alexjevans.com/courses/GEOL1950H

The When: T/Th 10:30 AM – 11:50 AM in GeoChem 150

The Course Description

This course will explore the evolution of Earth and other worlds across the Solar System and unravel their mysteries using gravitational data. Gravity data revealed by Earth and interplanetary missions have a pivotal role in our understanding of climate change (e.g., GRACE), the structure and interior of planetary bodies (e.g., MESSENGER, GRAIL, MRO, MGS, Dawn), and the history of the Solar System. The course is structured to provide students hands-on experience with gravity data throughout the course and to teach students how to represent, analyze, manipulate, and interpret gravitational data.

Another key aspect of this course is to teach students fundamental and cutting-edge methods for data analyses and interpretation, that can be applied to ***ANY*** dataset (inside or outside of this field). ***The topics covered in this course provide a foundation for a wide variety of advanced data analysis, representation, and manipulation techniques that extend well beyond Earth and planetary sciences.***

The course will include topics on potential field theory, geomagnetic data, pattern recognition methods, Monte Carlo methods, and computer modeling techniques.

The Prerequisites

The following courses are recommended prerequisites (and/or permission of the Professor):

- MATH 0090, 0100;
- PHYS 0030, 0040 or 0050, 0060 or 0070; and,
- GEOL 0250 or previous programming experience in MATLAB or a high-level programming language (e.g., C, C++, Fortran, etc.).

The Learning Goals

The intended purposes and desired achievements of this course are listed below.

- Ability to convert planetary data fields, particularly gravity, between the spectral and cartesian domains
- Ability to competently manipulate and analyze gravitational data of planetary bodies
- Ability to discern strengths and weaknesses of gravitational data, analyses techniques, and corrections
- Development of a profound understanding of the numerous acquisition and application techniques for planetary gravity data
- Recognition of fundamental and cutting-edge techniques being applied to planetary gravitational data
- Development of an independent high-quality research proposal using gravitational analyses, techniques, and data

The Schedule

Note: Dates, topics, and assignment dates are subject to change. All changes will be announced during class time. Students are responsible for keeping up-to-date on changes to syllabus and coordinating with classmates to obtain any lecture material missed during absences.

Week	Module	Assignments
1–2	**1. The Enterprise of Gravity** **What is gravity?** Let's explore the major contributions of gravity in revolutionizing how we view and understand the Earth, other planetary bodies, and the Universe as a whole. This module will also provide an overview of topics that will be covered in detail later in the course as well as explore their potential importance.	Reading; Homework 1 Out
2–4	**2. May the Gravitational Force Be with You!** **How do we represent gravity data?** Let's explore the gravitational signatures that are accommodated at varying planetary wavelengths including flattening, polar ice sheet reductions, large-scale accretionary events, cratering, mantle anomalies, and cores. We will develop a framework (spherical harmonics) that will greatly aid in our ability to distinguish	Reading

	gravitational signatures on the basis of frequency and amplitude. This module will provide the chief mathematical foundation for later modules.	
4–6	**3. Show Me the Mascon!** 🌚 **How do we acquire, manipulate, and represent the data?** A variety of surface and spacecraft gravimetry techniques are used to acquire gravity data and each dataset is tailored to its planet based on the variability of the gravitational field and the sources of gravitational anomalies. We will use planetary bodies such as Earth, the Moon, and Mars to explore gravimetry and how to best tailor the representation of gravity data based on the features of interest. *Note: A mascon is a mass concentration and refers to a region of a planet or moon's crust that contains a large positive gravitational anomaly (often used in reference to the Moon).*	Reading; Homework 1 Due
7	**MIDTERM EXAM 1**	
7–9	**4. Fire and Ice** **How do we use gravity to illuminate scientific mysteries?** From the fiery molten bowels of planets to the shallow depths of water, ice, and sediment covered surfaces, let's explore the unseen and unknown with gravity. Let's apply what we know about gravity to constrain the state, history, and evolution of planetary bodies. We will explore and analyze the gravity data of several planetary bodies within the spatial and spectral domains.	Reading; Homework 2 Available
10	**The Fundamentals of a Good Research Proposal** This class will provide an overview of how to develop a good research proposal. This lecture will provide insight into how to develop the research project required later in the course.	Pre-Class Reading
10	**Gravity of the Terrestrial Planets** For this class, student groups will present gravity data and answer questions on their assigned planetary body.	Group Presentations Due
11–13	**5. With Great Power, Comes Great Responsibility** **How do we wield gravity data to understand large-scale planetary structure?** Gravity can be used to make major pronouncements on the structure, state, and composition of planetary bodies. Within this module, we will explore how the state and structure of a planetary body is determined with gravity. This module will explore key concepts regarding moments of inertia, Love number, and crustal thickness.	Homework 2 Due; Draft Proposal Due; Homework 3 Available
12/13	**MIDTERM EXAM 2**	
14–15	**6. The Final Frontier** **The latest and greatest cutting-edge techniques** Now that we have established the basics of gravitational analyses, let's explore the latest and greatest cutting-edge techniques that are currently being used to provide	Homework 3 Due Final Proposal Due

	a new understanding of Earth and other planetary bodies. In this module, we will explore gradiometry, time-varying gravitational fields, and other techniques.	

The Work Expectations

Over 15 weeks, students will spend an average of 12 hours per week on the class (180 hours total). Two lectures will account for 2.66 hours per week (40 hours), required reading and preparation for class is expected to take approximately 1 hours per week (15 hours), the first two homework assignments are expected to take 15 hours each (45 hours), preparation for each of the two exams is expected to take 10 hours (20 hours). In addition, preparation of the research proposal is estimated to total approximately 60 hours over the course of the term. Workload was estimated using online tool at cte.rice.edu/workload. There is no final examination associated with this course.

The Grading Scheme

I. **PROBLEM SETS (30%)**

There will be three problem sets throughout the semester. Each problem set will cover a different set of the topics discussed throughout the course. For each problem set, students will have been provided an overview of the relevant techniques, models, and an example by which they can verify their homework set answers. Generally, the homework sets will be structured such that students will need to apply the basic concepts and techniques and learned in the classroom. Note: Office hours will be a time where students can get feedback and guidance on homework assignments.

Assignments are due at the beginning of class. ***Late assignments will be reduced in grade by 20% for each day overdue, beginning 5 minutes after class commencement on the due date. No late assignments will be accepted after 3 days past the due date.***

Students may work and collaborate on their assignments. However, all students must hand in their own work – distinct from and independent of classmates' work. If you do work collaboratively, you must provide the list of names of the people that you worked with on your assignment.

II. **GROUP PRESENTATION (10%)**

Students will be assigned to a group and will be required to present an overview of a gravitational field for a given planetary body. The presentation will be based on a template provided by the instructor. During this presentation, the group will be expected to (a) compare and contrast with another planetary body as determined by the instructor, (b) determine and present on admittances and surface densities, (c) highlight notable excursions from the reference geoid, and (d) discuss features of planetary gravitational field including, but not limited to amplitude range, notable topographic features, and subsurface density anomalies. Each presentation will be limited to 15 minutes with at least 3 minutes allotted for questions.

III. **EXAMS (30%)**
Two exams will be administered throughout the course. At least one exam will be a take-home exam. Each exam will count as 15% of a student's final grade.

IV. **RESEARCH PROPOSAL (30%)**
Over the duration of the course, each student is expected to develop a six-page research proposal where the primary techniques and methods to execute the research are based on gravity, gravitational analyses, or data analyses techniques covered in the course. The research topic is to be chosen by the student and may be related, but not duplicative, of ongoing research by the student. The research topic must be approved by the instructor prior to the "topic due date" in the syllabus. The research proposal will be graded based on how well the proposal answers the following questions: (a) Why is the work important? (b) Who will care? and (c) Why are you the one to complete the proposed work? (i.e., does the proposal demonstrate that you are capable of executing the proposed work?).

Textbook and Pre-Class Reading Assignments

There is no textbook assigned for this course. Pre-class reading assignments noted on the syllabus will be, on average, less than 15 pages each. Readings will be provided by instructor and may consist of excerpts from books, papers, online media, or other materials specifically developed for this course.

Diversity and Inclusion

The instructor is committed to creating and sustaining a learning environment for all students that supports a diversity of thoughts, perspectives, experiences, and identities. Please feel free to communicate to the instructor suggestions on ways to improve the effectiveness of the course for you personally, or for other students or student groups. Your suggestions are encouraged and appreciated.

Accommodations

The instructor is committed to full inclusion of all students. Please inform the instructor early in the term if you have a disability or other conditions that might require accommodations or modification of any of these course procedures. You may speak with the instructor after class or during office hours. For more information, please contact Student and Employee Accessibility Services at 401-863-9588 or SEAS@brown.edu. Students in need of short-term academic advice or support can contact one of the deans in the Dean of the College office.