270.307: Geoscience Modeling
Spring Semester 2021.

Draft Synopsis of December 5, 2020

Tuesdays & Thursdays 1:30pm–2:45pm
Online

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> The universe is made of stories, not of atoms.
>
> — Muriel Rukeyser

> The most common misunderstanding about science is that scientists seek and find truth. They don't–they make and test models.
>
> — Neil Gershenfeld

> All models are wrong, but some are useful.
>
> — George Box

> The purpose of models is not to fit the data but to sharpen the questions.
>
> — Samuel Karlin

> The one who does the work is the one who does the learning.
>
> — Terry Doyle

Synopsis

This course is an introduction to ways to build and interpret conceptual and numerical models in Earth & Planetary Sciences. There will be a three-way focus on: Philosophy and Theory, Real-World Applications, and Hands-on Practical experience. The course covers data analysis, model building, and scientific method. Practical geoscience examples will be featured, from fields including: oceanography, climate dynamics, paleoclimate, and planetary science. And we'll spend about half of our time working on assignments that illustrate and apply the theoretical ideas. This part of the course introduces the powerful Matlab software which is widely used in science and industry (you're free to use another language, e.g., Python). The class is worth 4 credits because we'll spend significant time in the computer lab.

Prerequisites (in decreasing order of importance) are: linear algebra, statistics, basic physics, and calculus. Much of the course is quantitative with only brief refreshers on background math. Basic familiarity with a programming language is an advantage but not essential.

Class materials will be posted to Blackboard.

Assessment

Five computer assignments will be written up and turned in for credit. You'll work in small groups on the computer assignments, but do the write ups on your own. In addition, there will be 2 tests that are open-book and timed. We may also have impromptu, but ungraded, quizzes to review material and test understanding. Be aware that the marking and grading schemes used in this class are not like those used in K–12 schools (scores tend to be lower, although final grades are distributed about the same). As time permits, students can revise and resubmit their graded assignments. This boosts your score, but more importantly, it enhances your learning. **Attendance and active participation in the computer assignments are essential to achieving a good grade.**

If you want to audit this class, speak to the instructor.

Ethics

The following guidelines are taken seriously in this class:

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition.

In addition, the specific ethics guidelines for this course are: *Collaboration on computer assignments in the classroom is encouraged. I also encourage you to ask questions throughout our classes; this is a habit that you should practice! Unless specifically told otherwise, the write-ups of the computer assignments must be done individually, without any collaboration other than sharing of printouts of your programs and results. If you have questions about this policy, please ask the instructor.*

Report any violations you witness to the instructor. You may consult the associate dean of student conduct (or designee) by calling the Office of the Dean of Students at 410-516-8208 or via email at integrity@jhu.edu. For more information, see the Homewood Student Affairs site on academic ethics: `https://studentaffairs.jhu.edu/student-life/student-conduct/academic-ethics-undergraduates` or the e-catalog entry on the undergraduate academic ethics board: `http://e-catalog.jhu.edu/undergrad-students/student-life-policies/#UAEB`.

On every exam, you will sign the following pledge: "I attest that I have completed this exam without unauthorized assistance from any person, materials, or device. [Signed and dated]"

Old exams from this course may be found at MSE Reserves, although be aware that the course content (and name) was revised a few years ago. I will also distribute an example test paper for practice, if you wish.

Disability Services

Any student with a disability who may need accommodations in this class must obtain an accommodation letter from Student Disability Services, 385 Garland, (410) 516-4720, studentdisabilityservices@jhu.edu

Illness and Class Attendance

If you are sick you should focus on getting well again and worry about class later. You should obtain a note from a medical professional when possible: I will be flexible in accommodating students who miss class due to illness. You will not be academically penalized for following the advice of health care professionals!

If you are struggling with anxiety, stress, depression or other mental health related concerns, please consider visiting the JHU Counseling Center. If you are concerned about a friend, please encourage that person to seek out their services. The Counseling Center is located at 3003 North Charles Street in Suite S-200 and can be reached at 410-516-8278 and online at `http://studentaffairs.jhu.edu/counselingcenter/`.

Religious Holidays

Religious holidays are valid reasons to be excused from class. Students who must miss a class or an examination because of a religious holiday must inform me as early as possible in order to be excused from class or to make up any work that is missed.

Drop Deadline

The last day to drop the class is 7 March. We should have completed the first two graded assignments by then.

Textbooks

There is **no required textbook**. But I've begun to write a textbook based on the class and I'll distribute some preliminary notes. Your input and feedback is very welcome. Relevant **recommended texts** are: *Menke* [1989] and/or *Wunsch* [2006] which cover everything on data analysis, statistics, and probability, but also extend way beyond. *Tung* [2007] covers the material on model building; we'll be using examples from this book. It also extends much further than we need to go. *Slingerland and Kump* [2011] is also relevant on model building and is at about the level of the class. If you have a strong geophysics background, you may be interested in the textbook by *Gubbins* [2004]. Finally, *Gauch* [2003] is a wonderful introduction to scientific method, including much wisdom on statistics and probability.

Gauch, H. G. (2003), *Scientific method in practice*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 435 pages.

Gubbins, D. (2004), *Time Series Analysis and Inverse Theory for Geophysicists*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 272 pages.

Menke, W. (1989), *Geophysical data analysis: Discrete inverse theory*, 2nd ed., 289 pp., Academic Press, San Diego, vol. 45 in International Geophysics Series, edited by R. Dmowska and J. R. Holton.

Slingerland, R., and L. Kump (2011), *Mathematical modeling of earth's dynamical systems: a primer*, Princeton University Press, Princeton, New Jersey and Woodstock, United Kingdom, Princeton, N.J, doi:10.1515/9781400839117.

Tung, K.-K. (2007), *Topics in mathematical modeling*, 1st ed., Princeton University Press, Princeton, New Jersey and Woodstock, United Kingdom, 300 pp.

Wunsch, C. (2006), *Discrete Inverse and State Estimation Problems*, 1st ed., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, doi:10.1017/cbo9780511535949, 371 pp.

Schedule

We will meet twice a week for two 90 minute hour classes on zoom. Our schedule is: Tuesdays and Thursdays at 01:30–03:30pm. These times are somewhat flexible–please let me know if you'd like to attend class, but have a conflict. I'll probably schedule another hour-long session each week so that you can work on the computer assignments in your small groups. The tentative schedule is as follows:

- Week 1: 26, 28 Jan. Introduction to class. Linear algebra refresher.
  Computer lab.: Matlab introduction.
- Week 2: 2, 4 Feb. Probability and Statistics refresher.
  Computer lab.: Matlab introduction.
- Week 3: 9, 11 Feb. Educated guessing: Interpolation, extrapolation, and regression.
  Computer lab.: Ocean Tides.
- Week 4: 16, 18 Feb. Celestial mechanics and the Copernican revolution.
  Computer lab.: Ocean Tides.
- Week 5: 23, 25 Feb. Hypothesis testing: Discovery of Neptune.
  Computer lab.: Celestial Mechanics.
- Week 6: 2, 4 Mar. Hypothesis testing: Discovery of Neptune.
  Computer lab.: Celestial Mechanics.
  DROP DEADLINE.
- Week 7: 9, 11 Mar. Revision class for mid-term exam. MID-TERM EXAM.
  Computer lab.: Celestial Mechanics.
- Week 8: 16, 18 Mar. Mid-term de-brief.
  Computer lab.: catch-up.
- Week 9: 23, 25 Mar. Gauss and least squares. Snowballs and hot-houses: Modeling planetary climates.
  Computer lab.: Climate model.
- Week 10: 30 Mar, 1 Apr. NO CLASS, Snowballs and hot-houses continued
  Computer lab.: Climate model.
- Week 11: 6, 8 Apr. Snowballs and hot-houses continued.
  Computer lab.: Climate model.
- Week 12: 13, 15 Apr. El Niño Southern Oscillation: Climate chaos.
  Computer lab.: ENSO model.
- Week 13: 20, 22 Apr. El Niño Southern Oscillation: Climate chaos continued, NO CLASS
  Computer lab.: ENSO model.
- Week 14: 27, 29 Apr. Wrap-up. Revision class for final exam.
  Computer lab.: catch-up.
- FINAL EXAM: 9-12pm ????.