COURSE SYLLABUS

GEO 5670/6670 Inverse Theory

Spring 2021 MWF 1:30–2:20 pm rm 310

Professor: Tony Lowry (Department of Geology)
● Geology Bldg Room 106 (Phone: 797-7096)
● Email: Tony.Lowry@usu.edu
● Office Hours: MWF 2:30-3:30pm (or by appt)

Website: http://aconcagua.geol.usu.edu/~arlowry/Inverse/index.html

LEARNING OBJECTIVES

Primary: Application of math/physics/chemistry to geological problems; Geophysical properties of the subsurface

Secondary: Create and interpret graphs; Create 3D "maps" from observational data; Communicate in written and oral formats

COURSE DESCRIPTION

Inverse theory is a set of methods used to extract useful inferences about the world from physical measurements: a toolbox that enables us to pin our quantitative observations to an optimally parameterized model. Historically, inversion has been most heavily used in the field of geophysics, but truth-be-told ***any*** geological, geochemical or other type of measurement that can be quantified and modeled can also be inverted for a "best" answer. (And, as it turns out, trendy topics such as "big data" and "machine learning" are essentially a repackaging of Inverse Theory for situations in which the underlying physical model is uncertain or poorly understood!)

Chances are, if you've ever done some sort of modeling or other data analysis, you have performed at least some crude form of data inversion. A simple application of inverse theory is the fitting of data to a straight line. Tomographic imaging performed for a medical CAT scan is another, more sophisticated application. Often our measurements of the Earth are made far from the location of interest; typically they are also relatively few in number and noisy to boot. Consequently it is critical to understand not just what the "best" model is given some metric, but also the limitations of the data and the range of more-or-less equally possible solutions. Inverse theory enables us to characterize the certainty or uncertainty that we can ascribe to a particular model, the spatial or temporal resolution of our data, and the fundamental limits of what we can say from a particular dataset.

Not surprisingly, the tools we will discuss in this course are fundamentally mathematical. I make no apology for that, but note that we'll be sticking to basic concepts of calculus, linear algebra and probability & statistics that should be familiar territory (and when they're not, we'll take it slow).

Ultimately, this course is meant to provide you (the student) with a set of tools and skills that will be helpful in both your current thesis research and your later career.

About the professor:

I am a geophysicist ("Physics of the Earth") who focuses on measuring and understanding how and why planets deform. On Earth, this relates directly to processes of fault slip, earthquakes and volcanoes, but also has implications for mass transfer in the atmosphere, hydrosphere and cryosphere.

Course Text

(Required): **Geophysical Inverse Theory** (Menke). (Online from the USU Library!)
(Recommended): **Geophysical Inverse Theory** (Parker).

TENTATIVE SCHEDULE

Date	Topic
20–22 Jan:	Introduction/Motivation; Probability & Statistics
25–29 Jan:	Ordinary Least Squares; Model Parameter Error
1–5 Feb:	Solution Appraisal; Weighted Least Squares
8–12 Feb:	SVD; the Generalized Inverse; Damped Least Squares (Feb 15 is President's Day; no class)
17–19 Feb:	Maximum Likelihood Method; Nonlinear Inversion
22–26 Feb:	Stabilizing Gauss-Newton Solutions; Deterministic Searches
1–5 Mar:	Monte Carlo and Simulated Annealing Methods
8–10 Mar:	L1 norms and Inequality Constraints; Linear Programming (Mar 12 is a Break Day: No class!)
15–19 Mar:	Inequality Constraints; Quadratic Programming
22–26 Mar:	Inequality Constraints for Nonlinear Problems
29 M–2 Apr:	Joint Data Inversion
5–8 Apr:	(Probabilistic) Likelihood Filtering and Joint Inversion (Apr 9 is a Break Day: Friday class held Apr 8!)
12–16 Apr:	Bayesian Inversion; Entropy & Information Theory
19–23 Apr:	Simulation Assessment of Parameter Error
26 Apr:	Special Topics/Reading

Final Course Project: This will require an oral presentation on the final exam date **(Friday, 30 April, 1:30-3:20 pm)** and a written report (due May 5).

Grading:		**5670**	**6670**
Exercises	~2	50%	25%
Take-Home Final Exam		50%	25%
(Grads) Semester Project			50%

Late Assignment Policy:

All assignments are due at the date & time specified, but recognizing that Covid-19 may affect student performance, late assignments will be accepted. **However**, recognize that falling behind can result in a cascade of unfinished work that results in a daunting workload (and some students who fell behind in courses I have taught never managed to complete the course). If an assignment is not quite complete at the date and time due, your best course of action (i.e., leading to the highest final grade) may be to turn in what you have and move on to the next assignment.

Differences between the 5000 and 6000 level course:
In addition to doing a semester project, as noted above, taking the course at the graduate level entails doing a few additional (more challenging) problems for the assignments and exam.

Notice to veterans and students with disabilities: Students with ADA-documented physical, sensory, emotional or medical impairments are eligible for reasonable accommodations. Veterans also are eligible for services. These are coordinated through the Disability Resource Center, Rm 101 of the University Inn, (435) 797-2444, (435) 797-0740 TTY, or toll free at 1-800-259-2966. Please contact the DRC as early in the semester as possible. Alternate format materials (Braille, large print or digital) may be made available with advance notice.