Observational Geophysics

GEOL447

Fall 2012, 3 Credits

Instructor:
Dr. Ved Lekic
Assistant Professor
Department of Geology
University of Maryland, College Park
Geology Building (#237) Room 3113
Office Phone #: (301) 405-4086
E-mail: **ved@umd.edu**
Website: geol.umd.edu/~ved

Lecture and Discussion: Tuesdays and Thursdays, 4:30-5:15 pm

Required texts: Selected readings from the primary literature will be on ELMS.

Recommended texts:
Time Series Analysis and Inverse Theory for Geophysicists, by D. Gubbins.
Supplemental readings from *Data Analysis: a Bayesian Tutorial,* by D.S. Sivia and *Of Poles and Zeros: Fundamentals of Digital Seismology*, by F. Scherbaum.

Prerequisites:
MATH140; MATH141; and PHYS141, PHYS161, or PHYS171. In addition, non-degree-seeking students require the permission of the instructor.

Course Description:
This course aims to introduce advanced undergraduate and beginning graduate students to practical signal processing, data analysis, and inverse theory in geophysics.

Topics Covered:
Students will be confronted with a variety of geophysical datasets: magnetotelluric and geodesic timeseries, seismic waveforms, free oscillation spectra, gravity data. Each dataset will motivate the introduction and investigation of a data analysis technique or concept, including: Fourier, Laplace and Z Transforms, transfer functions / impulse response, (de)convolution, principal /independent component analyses, canonical coherence analysis, wavelet analysis, and simple Bayesian inference. The MATLAB/OCTAVE programming environment will be used to introduce students to practical digital processing via group-based in-class examples and exercises, reinforced through homework problems.

Course Structure and Objectives:

Grading: Your grade in this course will be a weighted average of your performance on the one midterm exam, the homework assignments, and the individual class project. The weighting factors will be:

- 25% in class exam;
- 40% homework assignments;
- 35% class project.

Homework: Homework problems will be assigned and due every other week and will account for 40% of the grade. The homework assignments will involve applying techniques discussed in class to various geophysical datasets and will involve simple programming in MATLAB/OCTAVE as well as write-ups designed to help develop effective communication skills. The goal of the homework assignments is to build intuition with students of the advantages and limitations of different analysis / modeling techniques. While students are encouraged to work in groups on these assignments, the homework write-up that is handed in should represent an individual student's own work. This means that each student should answer questions in his/her own words – identical phrasing / wording is unacceptable and will result in no credit.

Class project and paper: Group projects will be coordinated outside of lectures. Students will work in groups of 2-3 in identifying a dataset that can address an outstanding problem in Earth and Planetary science. Ideally, the problem set would be related to an undergraduate or graduate research project; however, students can get assistance in obtaining and identifying appropriate data sets from the instructor. Each group is expected to meet with Prof. Lekic during the week of November 5th – 9th to discuss their proposed topic. After this discussion, each group will hand in a 1 page summary of the problem, dataset, and short description of data analysis / modeling methods that will be used. The final project should have the format of an article in *Geophysical Research Letters* (the template can be found on the course website). It should clearly describe the problem being addressed, the dataset used, and the appropriateness of data processing / analysis / modeling techniques used. Results of the data analysis / modeling should be presented, along with the implications they hold for the problem at hand.

Class website: The class website will host the up-to-date version of this syllabus, homeworks, requisite datasets in ASCII or .mat format, and supplemental readings.

Policies:

Academic integrity: The University of Maryland has a nationally recognized Code of Academic Integrity, administered by the Student Honor Council. This Code sets standards for academic integrity at Maryland for all undergraduate and graduate students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit http://www.studenthonorcouncil.umd.edu/whatis.html

The University of Maryland is one of a small number of universities with a student-administered Honors Code and an Honors Pledge, available on the web at http://www.jpo.umd.edu/aca/honorpledge.html. The code prohibits students from cheating on exams, plagiarizing papers, submitting the same paper for credit in two courses without authorization, buying papers, submitting fraudulent documents, and forging signatures. The University Senate encourages instructors to ask students to write the following signed statement on each examination or assignment: "I pledge on my honor that I have not given or received any unauthorized assistance on this examination (or assignment)."

Academic Accommodations: If you have a documented disability, you should contact Disability Support Services 0126 Shoemaker Hall. Each semester students with documented disabilities should apply to DSS for accommodation request forms which you can provide to your professors as proof of your eligibility for accommodations. The rules for eligibility and the types of accommodations a student may request can be reviewed on the DSS web site at http://www.counseling.umd.edu/DSS/receiving_serv.html.

Religious Observances: The University System of Maryland policy provides that students should not be penalized because of observances of their religious beliefs, students shall be given an opportunity, whenever feasible, to make up within a reasonable time any academic assignment that is missed due to individual participation in religious observances. It is the responsibility of the student to inform the instructor of any intended absences for religious observances in advance. **Notice should be provided as soon as possible but no later than the end of the schedule adjustment period (September X)**. Faculty should further remind students that prior notification is especially important in connection with final exams, since failure to reschedule a final exam before the conclusion of the final examination period may result in loss of credits during the semester. The problem is especially likely to arise when final exams are scheduled on Saturdays.

CourseEvalUM Spring 2013: Your participation in the evaluation of courses through CourseEvalUM is a responsibility you hold as a student member of our academic community. Your feedback is confidential and important to the improvement of teaching and learning at the University as well as to the tenure and promotion process. CourseEvalUM will be open for you to complete your evaluations ****. Please go directly to the website (www.courseevalum.umd.edu) to complete your evaluations starting ****. By completing all of your evaluations each semester, you will have the privilege of accessing online, at Testudo, the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.

Preliminary schedule –

1	Aug 30	Syllabus is distributed, and expectations and goals for the class are explained. Introduction to the power of geophysical data, dilemmas of inference, demonstrations of filtering, demonstrations of spectrograms, demonstration of independent component analysis in separating voices.	Think about how you can formulate problems related to your research and/or interest in terms of data inference. What do you want to know? What can you observe?
2	Sept 4	"From continuous to discrete:" sampling theorem, Nyquist frequency, timeseries as vectors in N-dimensional space.	Make sure that you have verified your computer log-in and MATLAB/OCTAVE access.
3	Sept 6	Introduction to MATLAB/OCTAVE, basic data input/output, vector and matrix operations. In-class computer demonstrations / exercises on vector dot products, matrix diagonalization.	Homework 1 distributed.
4	Sept 11	Generalization of the concept of the mean to N dimensions. Abstraction of the concept of distance. Quantifying similarity.	
5	Sept 13	Cluster analysis: distance, linkage, uses.	
6	Sept 18	Principal Component Analysis.	
7	Sept 20	Histograms, mean, skewness, kurtosis, probability density functions, normal distribution, independent component analysis.	Homework 1 is due. Homework 2 is distributed.
8	Sept 25	Z transform, its properties and utility.	
9	Sept 27	Discrete Fourier transform as an extension of the Z transform, as discretization of continuous Fourier Transform. Demonstrate differences / limitations.	
10	Oct 2	From infinite to infinite: Windowing and its effects. Multi-taper analysis.	
11	Oct 4	Moving time window Fourier transform → spectrogram. Correcting for effects of time window.	Homework 2 is due. Homework 3 is distributed.
12	Oct 9	Linear, time-invariant systems: impulse response and transfer functions. Instrument response.	
13	Oct 11	Pole-zero representations of filters.	
14	Oct 16	Causal vs. acausal filters and phase distortion.	
15	Oct 18	Convolution and deconvolution in time and frequency domains.	Homework 3 is due. Homework 4 is distributed.
16	Oct 23	Coherence and canonical coherence analysis.	
17	Oct 25	Wavelets: scaling function and mother wavelet. Harr wavelet.	
18	Oct 30	Wavelets – tiling the frequency-time space.	
19	Nov 1	Daubeschies constructions – signal compression, identification of peaks.	Homework 4 is due. Homework 5 is distributed.
20	Nov 6	Bayes' Theorem, marginal probability. P(m|d) α P(d|m)P(m). Simplifying assumptions – Gaussian distribution of uncertainty.	Set up a time to discuss your group data analysis / modeling idea with Prof. Lekic during the week of 11/5-11/9.
21	Nov 8	P(d) Data covariance matrix – independent constraints. Quantifying data misfit. L_1, L_2, L_∞ norms.	

22	Nov 13	P(m) A priori model covariance matrix – smoothing and damping.	Each group hands in 1 page summary of proposed class project.
23	Nov 15	Occam's Razor: how many parameters are justified?	
24	Nov 20	P(d|m) Calculating the forward problem – relationship between m and d. Bias vs. uncertainty.	Homework 5 is due. Homework 6 is distributed.
25	Nov 27	P(m|d) Estimating model parameters from data. Most likely model. Linear least squares problem.	
26	Nov 29	Linearizable and iterative least squares inverse problem. Newton's method. Conjugate gradients.	
27	Dec 4	Quantifying uncertainty using the a posteriori model covariance matrix. Resolution matrix.	
28	Dec 6	Highly nonlinear problems – grid search and Monte Carlo methods.	Homework 6 is due.
29	Dec 11	In-class exam.	