CERI 7104/8104
Data Analysis in Geophysics

When and Where:
Fall Semester, TR 11:20 a.m. to 12:45 p.m.
Computer Lab, Long Building, CERI

Instructor:
Thomas Göbel, office: CERI House 2, room 107, 901-678-4885
Office hours: T 2 to 4 p.m. 3890 Central Avenue, EQ2, Room 107

Course Description
This class focuses on quantitative analyses of different types of geo-data from fault roughness and reservoir pressures to earthquake locations and GPS-velocities. We will take advantage of the many tools and libraries available for matlab and python. These libraries greatly simplify the solution to complex problems. The class includes a large suite of examples from different geoscience disciplines (geology, hydrology, seismology, geodesy…). These examples can easily be adapted to specific research problems to advance the students' degree progress. Following this concept, students are encouraged to apply the newly attained skills to a relevant research project. The final project consists of term paper and oral presentation.

Who should take this course?
This class is for earth science and geophysics students at the beginning of their graduate studies. Interested undergraduate can be admitted after consulting the instructor. Students are expected to have some knowledge of calculus and geophysics. We will cover the basics of programming in matlab and python so no programming prerequisites are required. Many examples and problem sets stem from different geoscience fields but anybody interested in quantitative data analysis and basic numerical analysis is encouraged to take the class.

Course Goals
After completing the course 'Data Analysis in Geophysics' students will be able to:

A.	Develop a general understanding of data analysis workflow
B.	Identify best software to solve specific problems in geophysics
C.	Quantitatively analyze data with *Matlab* and *Python*
D.	Correlate data in space and time
E.	Generate high-quality figures and animations
F.	Synthesize data analysis results in a well-structured report

Course Topics

Topics include: Basic scientific programming in matlab and python, geo-referenced plotting, correlating data in space and time, analyzing seismic waveforms and seismicity data, quantifying fault roughness, modeling fluid-flow and pressure diffusion.

Textbooks, Supplementary Materials, Hardware and Software Requirements

Required Textbooks

We will work with several text books that are available as eBooks or hard copies at the University library:

1. Raschka, Sebastian. *Python machine learning*. Packt Publishing Ltd, 2015.
2. Linge, Svein, and Hans Petter Langtangen. *Programming for Computations-Python: A Gentle Introduction to Numerical Simulations with Python*. Springer Nature, 2016.
3. Trauth, Martin H., et al. *MATLAB recipes for earth sciences*. Vol. 34. Berlin: Springer, 2007.

Supplementary Materials

1. Downey, Allen B. *Think stats*. " O'Reilly Media, Inc.", 2011.
2. Molnar, C. (2019). *Interpretable machine learning. A Guide for Making Black Box Models Explainable* (1st ed.). Retrieved from https://christophm.github.io/interpretable-ml-book
3. Witten, Ian H., and Eibe Frank. "Data mining: practical machine learning tools and techniques with Java implementations." *Acm Sigmod Record* 31.1 (2002): 76-77

Hardware and Software Requirements

Mac computers will be available at CERI. Guest accounts have to be created prior to class be contacting Deshone Marshall (dlmrshll@memphis.edu). Alternatively, students can bring and work on their own laptops.

Assessment and Grading

Grading Procedure

- 50% Homework, 50% Term Project
- Homework and term paper topics may differ depending on course registration (7104 vs 8104).

Grading Scale

A: >95%
A-: 90 - 94%
B+: 86 -89%
B: 82 - 85%

B-: 78 - 81%
C+: 74 - 77%
C: 70 - 73%
C-: 66 - 69%
Fail

Assignments and Projects

1. Numerical analysis example: Solve wave equation, Matlab
2. Spatial analysis: fault roughness data, Matlab
3. Statistical analysis: Seismicity statistics, Python
4. Waveform analysis: waveforms and earthquake locations with obspy
5. Machine learning analysis with scikit-learn

Final Project:

A large part of your class assessment will be based on the final project. Make sure you contact me early (i.e. about half-way through the class) so that we can find a suitable and interesting topic for your final project. It is Okay to choose a topic that is closely related to your MSc or PhD research. The final project has to include a significant portion of quantitative analysis using Matlab or Python. Students can work on quantitative data-analysis problems or numerical modeling. The final project includes three components: (i) your python or matlab code (ii) a short term-paper (max. 10 pages) and (iii) a ~15min presentation. Details will be announced during the class.

Class Schedule

The following class schedule is preliminary and subject to change

Week	Topic	Learning Objectives	Assessment/Activity
1	Introduction to scientific data analysis, Unix operating systems, interpreted programming languages, command line operations	By the end of this module students will be able to: Compare different programming languages, utilize the terminal and other command line prompts to navigate and run software	
2	Latex	Prepare latex templates for term-papers and publications	Activity: create homework and term paper templates
3	Matlab Tutorial, matrix operations, data I/O, plotting, functions, code structure in matlab	Analyze and plot data files, create matlab functions,	Activity: for loops and sums
4			

Week	Topic	Learning Objectives	Assessment/Activity
	Numerical analysis in matlab: PDE example	Students will be able to calculate derivatives, and implement finite difference approximations and solve the wave equation in 1D	HW1: Solve wave/diffusion-equation
5	Data file formats, file manipulation, data I/O matlab	Analyze data files: read and write, Perform spatial gridding of irregularly spaced data, smoothing and outlier removal	HW2: fault roughness analysis
6	Python tutorial: modules, IDEs, scripts	Create python functions, compare code structure in Matlab and python, implement basic algorithms	Activities: example problems from Linge & Langtangen
7	Earthquake catalogs and geo-referenced plotting, seismicity animation	Assess data structure in ASCII files, Perform statistical analyses and plot earthquake data, identify statistical distributions, fit statistical parameters	HW3: Earthquake catalog analysis
8	Obspy tutorial I	Access waveform data, Plot waveforms, determine phase picks and instrument corrections	
9	Obspy tutorial II	create data products (phase picks, earthquake locations, magnitudes) from raw-waveforms, determine earthquake magnitudes, describe frequency content of earthquakes	HW4: Phase picking and earthquake locations
10	Machine Learning I	Compare ML to standard statistical analysis, Describe machine learning workflow, implement basic analysis in python	Discussion: Advantages/Disadvantages of Machine Learning algorithms
11	Machine Learning II	Implement different machine learning algorithms	

Week	Topic	Learning Objectives	Assessment/Activity
12	Machine Learning III	Perform complete analysis from input data generation, to modeling and model performance evaluation	HW5: - machine learning (phase picks, event detection or association, image recognition)
13	Model fitting and optimization: Pressure recession data example	Create figures and fit models based on optimized parameters	Activity: fit RMA pressure recession data
14	GMT tutorial: earthquake plotting, discuss term paper	Create geo-referenced figures of earthquake data	Activity: Load, modify and plot earthquake data with GMT
15	Term Paper	Work on Final Projects	Term Paper / Presentation

Plagiarism and Integrity

Plagiarism, cheating, and other forms of academic dishonesty are prohibited. Students guilty of academic misconduct, either directly or indirectly, through participation or assistance, are immediately responsible to the instructor of the class in addition to other possible disciplinary sanctions which may be imposed through the regular institutional disciplinary procedures. Expectations for academic integrity and student conduct are described in detail on the website of the Office of Student Accountability. Please read in particular, the section about "Academic Misconduct".

Turnitin.com

Your written work may be submitted to Turnitin.com, or a similar electronic detection method, for an evaluation of the originality of your ideas and proper use and attribution of sources. As part of this process, you may be required to submit electronic as well as hard copies of your written work, or be given other instructions to follow. By taking this course, you agree that all assignments may undergo this review process and that the assignment may be included as a source document in Turnitin.com's restricted access database solely for the purpose of detecting plagiarism in such documents. Any assignment not submitted according to the procedures given by the instructor may be penalized or may not be accepted at all.

Library, Tutoring, and Other Resources

- The myMemphis Portal system, eCampus Student tab provides access to University library.
- The tutoring link in the course navigation bar provides access to free online tutoring through UpSwing tutoring.

Students With Disabilities

Qualified students with disabilities will be provided reasonable and necessary academic accommodations if determined eligible by disability services staff at the University of Memphis. Prior to granting disability accommodations in this course, the instructor must receive written verification of a student's eligibility for specific accommodations from the disability services staff. It is the student's responsibility to initiate contact with Disability Resources for Students (DRS) and to follow the established procedures for having the accommodation notice sent to the instructor.

Sexual Misconduct and Domestic Violence Policy

This policy specifically addresses sexual misconduct which includes dating violence, domestic violence, sexual assault, and stalking. The policy establishes procedures for responding to Title IX-related allegations of sexual misconduct. Complaints can be reported to the Office for Institutional Equity (OIE). You may contact OIE by phone at 901.678.2713 or by email at oie@memphis.edu. Complaints can be submitted online at File a Complaint. OIE's office is located at 156 Administration Building.

Non-Discrimination and Anti-Harassment Policy

University policy prohibiting discrimination and harassment based on protected characteristics and classes. Complaints of discrimination and harassment can be reported to the Office for

Institutional Equity (OIE). You may contact OIE by phone at 901.678.2713 or by email at oie@memphis.edu. The full text of the policy can be found at GE2030 - Non-Discrimination and Antiharassment.

Technology Requirements

The following is a list of the minimum requirements to use our learning management system. Some courses will have more advanced requirements.

- Access to a reliable, high-speed Internet connection (DSL or Cable).
- Test your device to ensure it is compatible with our LMS (Learning Management System) using the System Check Wizard.
- Open PDF files using the free downloadable PDF software.
- Access Flash-based content with Adobe Flash Player (free).
- Use Microsoft Office for document creation (available for students via http://umapps.memphis.edu/)

Play media content with Real Player (free), QuickTime (free), or Windows Media Player(free).

Syllabus Changes

The instructor reserves the right to make changes as necessary to this syllabus. If changes are necessitated during the term of the course, the instructor will immediately notify students of such changes both by individual email communication and posting both notification and nature of change(s) on the course bulletin board.

Technical Support

Call the Helpdesk: 901-678-8888
Online Helpdesk