Faculty of Science Course Syllabus (Section A)
Department of Earth and Environmental Sciences

ERTH 6353

Quantitative Methods in Earth and Environmental Sciences

Fall Term 2022

Dalhousie University is located in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq. We are all Treaty people.

We acknowledge the histories, contributions, and legacies of the African Nova Scotian people and communities who have been here for over 400 years.

Instructor(s): Miao Zhang, Miao.zhang@dal.ca, office hours by appointment

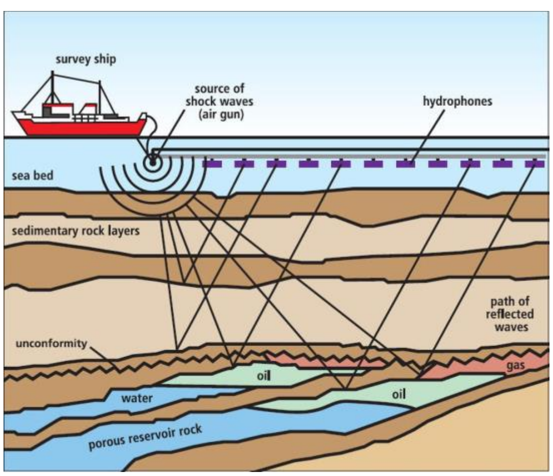
Lectures: Mondays and Wednesdays, 1:05 – 2:25 pm, LSC-BIOL&ERTH B4082

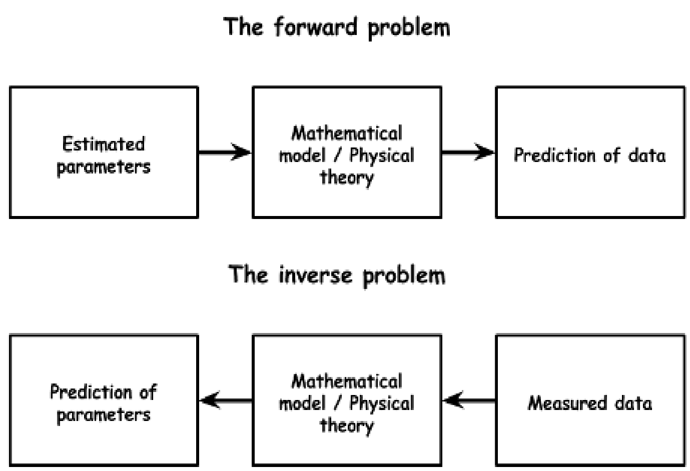
Labs/Tutorials: Mondays, 4:35-5:25 pm, LSC-BIOL&ERTH B7123

Course delivery: In-person

Course Description

The course focuses on the understanding and application of key quantitative methods in Earth and Environmental Sciences. This course introduces quantitative methods and their application including data processing and analysis, numerical modelling methods, inversion methods, etc. Labs provide practical exercises for strengthening understanding of the quantitative methods. Necessary software or computer codes will be provided. Other faculty members will occasionally give guest lectures.





Course Prerequisites

This course is restricted to current graduate students majoring in Earth and Environmental Sciences. Calculus (MATH 1000 or similar) and linear algebra (MATH 1030 or similar) are required prerequisites. Students need to get permission from the instructor and their supervisor before they register for the course.

Similar prerequisite courses for self-learning:

- Calculus: https://ocw.mit.edu/courses/mathematics/18-01sc-single-variable-calculus-fall-2010/index.htm
- Linear Algebra: https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/

Learning Objectives

By the end of this course, students will be able to:

- Evaluate quantitative methods and uncertainty/error
- Design mathematical/physical models for specific problems
- Employ numerical modelling for simulating specific processes
- Practice problem solving using various inversion methods
- Assess the strengths and weaknesses of different methods
- Solve problems through computer software/programming

Course Materials

Essential reading material will be emailed or handed out in class or posted on Brightspace.
Recommended textbook for Units 1 and 2: MATLAB® Recipes for Earth Sciences, fourth version.
Laptop is required for the labs.

Course Assessment

The final grade of the class will be based on the following:

Assignments (4)	60%
Take-home Final Examination	25%
Quizzes	10%
Participation	5%

Detailed descriptions could be found as below:

1. Assignments

Assignment 1, coverage: review of prerequisites, lessons 1.1-1.5, Due date: TBD	(15%)
Assignment 2, coverage: data processing and analysis, lessons 2.1-2.5, Due date: TBD	(15%)
Assignment 3, coverage: numerical modelling, lessons 3.1- 3.6, Due date: TBD	(15%)
Assignment 4, coverage: inversion problem, lessons 4.1- 4.6, Due date: TBD	(15%)

For assignments, necessary MATLAB/Python codes will be provided. Students will work on the performance comparison of the method with different parameter settings. For some problems, students may need to modify the codes as needed. Synthetic or field data would be provided if applicable.

2. Take-home Final Examination

Solve comprehensive problems with quantitative methods (e.g., data processing -> forward modelling -> inversion -> error analysis). Necessary open-source software/codes and synthetic/field data will be provided. (25%)

3. Quizzes

Review the past lectures. (10%)

4. Participation

Active participation in discussions and question sessions. Also see course policies. (5%)

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Conversion of numerical grades to Final Letter Grades follows the Dalhousie Common Grade Scale

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A+ (90-100)   B+ (77-79)   F (0-69)
A (85-89)   B (73-76)
A- (80-84)   B- (70-72)

Course Policies on Missed or Late Academic Requirements

Assignments handed in late will be deducted 10% per day. Assignments handed in more than 5 days late will not be graded. There will be NO make-up assignments and exams. If you must miss them because of extenuating circumstances (e.g., illness), your assignments and exams will be worth the balance of your mark. Additional information is in the supplemental syllabus.

Course Policies related to Academic Integrity

Discussion is encouraged, but plagiarism is not.

Course Content

Date	Lecture	Lab
	Unit 1. Review of Prerequisites	
09/07	1.1 Introduction	
09/12	1.2 MATLAB Programming	Lab 1
09/14	1.3 Python Programming	
09/19	1.4 Review of Matrix Algebra	Lab 2
09/21	1.5 Review of Calculus	
	Unit 2. Data Processing and Analysis	
09/26	2.1 Uncertainty and Error	Lab 3
09/28	2.2 Frequency Analysis	
10/03	2.3 Filtering and Correlation	Lab 4
10/05	2.4 Data Distribution and Fitting	
10/12	2.5 Principal Component Analysis and Cluster Analysis	Lab 5
	Unit 3: Numerical Modelling	
10/17	3.1 Partial Differential Equation (PDE)	
10/19	3.2 Examples of Important PDEs	Lab 6
10/24	3.3 First Order Finite-difference Method	
10/26	3.4 High Order Finite-difference Method	Lab 7
10/31	3.5 Pseudospectral Method	
11/02	3.6 Accuracy, Stability and Boundary Condition	Lab 8
	Unit 4: Inverse Problem	
11/14	4.1 Least Squares Inversion	
11/16	4.2 Regularization Methods	Lab 9
11/21	4.3 Deterministic Inversion I: Newton’s Method	
11/23	4.4 Deterministic Inversion II: Gradient Descent	Lab 10
11/28	4.5 Stochastic Inversion I: Monte Carlo	
11/30	4.6 Stochastic Inversion II: Simulated Annealing	Lab 11