Dalhousie University
Faculty of Science/Department of Earth and Environmental Sciences
ERTH 6353/03 Credit Hours/Quantitative Methods in Earth and Environmental Sciences
Fall Term 2020

Instructor(s): Miao Zhang
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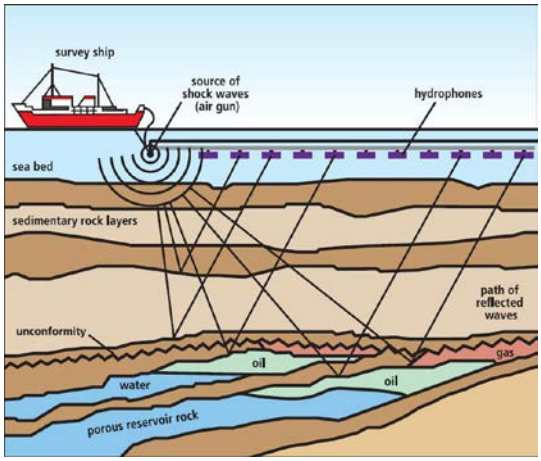
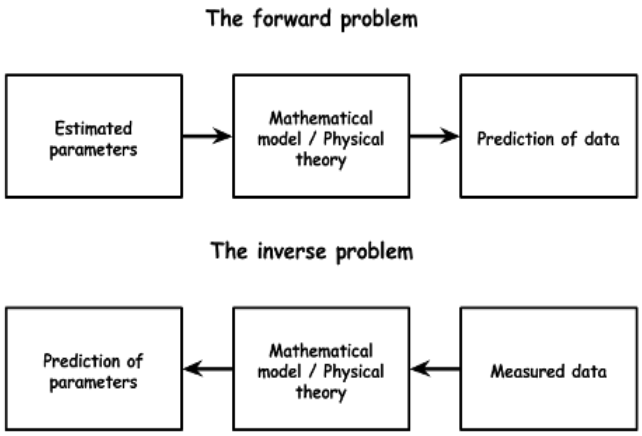
Lectures: 02:05 – 03: 25 pm, Tuesdays and Thursdays (synchronous)
Laboratories: 30 min lab following the second lecture each week

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. At the end of the course, students will be required to finish a small research project in their own field by applying the quantitative methods and software (or computer codes). Necessary software or computer codes will be provided.





Course Pre-requisites, Co-requisites and/or other Restrictions

This course is restricted to current graduate students majoring in Earth and Environmental Sciences. Students need to get permission from the instructor and their supervisor before they register for the course.

Course Rationale and/or Other Restrictions and Requirements

It is recommended that students have a working knowledge of one or more programming languages (e.g., MATLAB). Students should bring their laptop to the second class each week.

Learning Management System Site Information

Lecture materials, handouts and announcements will be posted on the course Brightspace page.

Course Learning Outcomes

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
- Develop skills in effective research report writing and presentation

Required Text(s)
Essential reading material will be emailed or handed out in class or posted on Brightspace.
Recommended textbook for Unit 1: MATLAB® Recipes for Earth Sciences, fourth version

Course Schedule
Classes will be scheduled in the Fall semester. The second class of each week in Units 1-3 will be followed by a 30-minute lab. Classes in Unit 4 will be on Thursdays.

Week	Lecture	Lab
	Unit 1. Data processing and analysis	
1	1.1 Introduction 1.2 Basic computer programming (MATLAB)	Lab 1
2	1.3 Math review 1.4 Uncertainty and error	Lab 2
3	1.5 Digital signal processing 1.6 Data fitting and analysis	Lab 3
	Unit 2. Numerical modelling	
4	2.1 Partial difference equation 2.2 Finite-difference method	Lab 4
5	2.3 Pseudospectral method 2.4 Finite-element method	Lab 5
	Unit 3. Inverse problem	
6	3.1 Least squares inversion 3.2 Regularization methods	Lab 6
7	3.3 Gradient-based deterministic inversion (steepest-descent and conjugate-gradient) 3.4 Stochastic inversion (Monte Carlo and simulated annealing)	Lab 7
	Unit 4. Research project	
8	4.1 Research proposal presentation	
9	4.2 Progress updates and next steps	
10	4.3 Progress updates and next steps	
11	4.4 Progress updates and next steps	
12	4.6 Research report presentation	

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

Assignments (3)	30%
Research Report	30%
Research Proposal Presentation	5%
Research Report Presentation	10%

Take-home Final Examination	20%
Participation	5%

Detailed descriptions could be found as below:

1. Assignments

Assignment 1, coverage: data processing and analysis, lessons 1.1-1.6, Due date: TBD (10%)
Assignment 2, coverage: numerical modelling, lessons 2.1-2.4, Due date: TBD (10%)
Assignment 3, coverage: inversion problem, lessons 3.1-3.4, Due date: TBD (10%)

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

2. Research Report

Evaluation criteria consist of:

- Building of mathematical/physical models (5%)
- Problem solving with proposed quantitative methods (20%)
- Results and discussion (5%)

3. Research Proposal Presentation (5%)

4. Research Report Presentation

Evaluation criteria consist of:

- Content and organization (3%)
- Presentation skills (4%)
- Questions (3%)

5. 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 data will be provided. (20%)

6. Participation

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

Graduate Courses Grading Scale

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

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

Course Policies

Assignments handed in late will be deducted 10% per day. Assignments handed in more than 5 days late will not be graded. Students must use the Student Declaration of Absence form for missed academic requirement in this course (at most twice). Additional information is in the supplemental syllabus.

Detailed Descriptions for Units 4

Research proposal:

Research proposal focuses on applying quantitative methods (one or multiple) that introduced in the course to students' research. Students and their supervisor develop the

research proposal together after consultation with the instructor. The two-page proposal should include 1) problems to be solved; 2) proposed quantitative methods (from the course); 3) dependent software or codes; 4) data availability; 5) necessary references. Students present their proposal at the first class of this unit.

Progress updates and next steps :

Students present their progress and introduce their next steps weekly (format: slides). The instructor will provide feedback and guidance.

Research report:

The general format consists of 1) statement of problem; 2) objectives; 3) approach and methods; 4) results and discussion; 5) references. Recommended length would be 8–10 pages (single line and 12 Times New Roman).

Research report presentation:

Students present their research report at the last class with their supervisor attendance (20 min presentation with following 10 min questions).

Learning and Support Resources

- General Academic Support – Advising
  Halifax: https://www.dal.ca/campus_life/academic-support/advising.html
  Truro: https://www.dal.ca/about-dal/agricultural-campus/student-success-centre/academic-support.html
- Fair Dealing Guidelines https://libraries.dal.ca/services/copyright-office/guidelines/fair-dealing-guidelines.html
- Black Students https://www.dal.ca/campus_life/communities/black-student-advising.html
- International Students https://www.dal.ca/campus_life/international-centre.html
- Indigenous Students https://www.dal.ca/campus_life/communities/indigenous.html
  - (You may wish to include the following): The Elders in Residence program provides students with access to First Nations elders for guidance, counsel and support. Contact the elders at the Indigenous Student Centre (1321 Edward Street), by email at elders@dal.ca or by phone at 902-494-6803.
- Student Health Services http://www.dal.ca/campus_life/health-and-wellness/health-services.html
- Counselling https://www.dal.ca/campus_life/health-and-wellness/counselling.html
- Library http://libraries.dal.ca
- Copyright Office https://libraries.dal.ca/services/copyright-office.html
- E-Learning website http://www.dal.ca/dept/elearning.html
- Writing Centre https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html
- Faculty or Departmental Advising Support: Studying for Success Program http://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html
- Student Finance page: https://www.dal.ca/admissions/money_matters.html

University Policies, Statements, Guidelines

This course is governed by the academic rules and regulations set forth in the University Calendar and the Senate. https://academiccalendar.dal.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog

Statements

- Academic Integrity

At Dalhousie University, we are guided in all of our work by the values of academic integrity: honesty, trust, fairness, responsibility and respect (*The Center for Academic Integrity, Duke University, 1999*). As a student, you are required to demonstrate these values in all of the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity.
(read more: http://www.dal.ca/dept/university_secretariat/academic-integrity.html)

- Accessibility

The Advising and Access Centre and the Student Success Centre (Agricultural Campus) serve as Dalhousie's centres for expertise on student accessibility and accommodation. Our work is governed by Dalhousie's Student Accommodation Policy to best support the needs of Dalhousie students. Our team work with students who request accommodation as a result of: disability, religious obligation, an experienced barrier related to any other characteristic protected under Canadian Human Rights legislation. (read more at: https://www.dal.ca/campus_life/academic-support/accessibility.html)

- Student Code of Conduct

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution.
(read more: https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/student-life-policies/code-of-student-conduct.html)

- Diversity and Inclusion – Culture of Respect

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported.
(read more: http://www.dal.ca/cultureofrespect.html)

- Recognition of Mi'kmaq Territory

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

- Missed or Late Academic Requirements due to Student Absence

Dalhousie students are asked to take responsibility for their own short-term absences (3 days or less) by contacting their instructor by phone or email prior to the academic requirement deadline or scheduled time and by submitting a completed Student Declaration of Absence to their instructor in case of missed or late academic requirements. Only 2 separate Student Declaration of Absence forms may be submitted per course during a term (Note: faculty, college, school, instructor or course-specific guidelines may set a lower maximum).

(read more:
https://cdn.dal.ca/content/dam/dalhousie/pdf/dept/university_secretariat/policy-repository/StudentAbsenceRegulation(OCT2017)v2.pdf)

University Policies and Programs

- Important Dates in the Academic Year (including add/drop dates) http://www.dal.ca/academics/important_dates.html
- Dalhousie University's Grading Practices Policy https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html
- Scent-Free Program http://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html
- Faculty Information: Student Self-Declaration of Absence https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/academic-policies/student-absence/student-absence---for-faculty.html