

Quantitative Methods in Earth and Environmental Sciences Syllabus

Department of Earth and Environmental Sciences

ERTH 6353 Fall 2024

Dalhousie University acknowledges that we are in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq People and pays respect to the Indigenous knowledges held by the Mi'kmaq People, and to the wisdom of their Elders past and present. The Mi'kmaq People signed Peace and Friendship Treaties with the Crown, and section 35 of the Constitution Act, 1982 recognizes and affirms Aboriginal and Treaty rights. We are all Treaty people.

Dalhousie University also acknowledges the histories, contributions, and legacies of African Nova Scotians, who have been here for over 400 years.

Course Instructor(s)

Name	Email	Office Hours
Miao Zhang	miao.zhang@dal.ca	TBD
Fernando Cordoba Ramirez	fr450518@dal.ca	TBD

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/>

Course Structure

Course Delivery: In-person

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

Laboratories/Tutorials: Mondays, 4:35 – 5:25 pm, LSC-BIOL&EARTH B7123

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.

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%)

Conversion of numerical grades to final letter grades follows the

Dalhousie Grade Scale

A+ (90-100)	B+ (77-79)	C+ (65-69)	D (50-54)
A (85-89)	B (73-76)	C (60-64)	F (0-49)
A- (80-84)	B- (70-72)	C- (55-59)	

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 mid-term or final exams. If you must miss an exam due to illness or unavoidable circumstances (please notify the instructor in advance), the missing exam will have its weight redistributed among your assignments. For example, if you missed the final exam, the 20% weight will be equally distributed among your four assignments. Students must use the Student Declaration of Absence form for missed lectures or tutorials (at most twice). If you have absences lasting longer than three consecutive days, you need to contact the instructor and your advisor to explore other accommodations.

Course Policies related to Academic Integrity

Students are not allowed to work together on assignments. The use of AI bots (e.g., ChatGPT) will not be allowed. Anti-plagiarism software will be applied. Additional information is provided in the supplemental syllabus.

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 Content

Lecture#	Lecture Content	Lab
	Unit 1. Review of Prerequisites	(After lecture)
Lecture 1	1.1 Introduction	
Lecture 2	1.2 MATLAB Programming	Lab 1
Lecture 3	1.3 Python Programming	
Lecture 4	1.4 Review of Matrix Algebra	Lab 2
Lecture 5	1.5 Review of Calculus	
	Unit 2. Data Processing and Analysis	
Lecture 6	2.1 Uncertainty and Error	Lab 3
Lecture 7	2.2 Frequency Analysis	
Lecture 8	2.3 Filtering and Correlation	Lab 4
Lecture 9	2.4 Data Distribution and Fitting	
Lecture 10	2.5 Principal Component Analysis and Cluster Analysis	Lab 5
	Unit 3: Numerical Modelling	
Lecture 11	3.1 Partial Differential Equation (PDE)	
Lecture 12	3.2 Examples of Important PDEs	Lab 6
Lecture 13	3.3 First Order Finite-difference Method	
Lecture 14	3.4 High Order Finite-difference Method	Lab 7
Lecture 15	3.5 Hands-on Example with Codes	
Lecture 16	3.6 Accuracy, Stability and Boundary Condition	Lab 8
	Unit 4: Inverse Problem	
Lecture 17	4.1 Least Squares Inversion & Regularization Methods	
Lecture 18	4.2 Deterministic Inversion I: Newton's Method	Lab 9
Lecture 19	4.3 Deterministic Inversion II: Gradient Descent	
Lecture 20	4.4 Guest Lecture: Specific Applications in EES	Lab 10
Lecture 21	4.5 Stochastic Inversion I: Monte Carlo	
Lecture 22	4.6 Stochastic Inversion II: Simulated Annealing	Lab 11

University Policies and Statements

Recognition of Mi'kmaq Territory

Dalhousie University would like to acknowledge that the University is on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit or e-mail the Indigenous Student Centre at 1321 Edward St or elders@dal.ca. Additional information regarding the Indigenous Student Centre can be found at: https://www.dal.ca/campus_life/communities/indigenous.html

Internationalization

At Dalhousie, 'thinking and acting globally' enhances the quality and impact of education, supporting learning that is "interdisciplinary, cross-cultural, global in reach, and orientated toward solving problems that extend across national borders." Additional internationalization information can be found at: <https://www.dal.ca/about-dal/internationalization.html>

Academic Integrity

At Dalhousie University, we are guided in all our work by the values of academic integrity: honesty, trust, fairness, responsibility, and respect. As a student, you are required to demonstrate these values in all 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. Additional academic integrity information can be found at: https://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Student Accessibility Centre is Dalhousie's centre of expertise for matters related to student accessibility and accommodation. If there are aspects of the design, instruction, and/or experiences within this course (online or in-person) that result in barriers to your inclusion, please contact the Student Accessibility Centre (https://www.dal.ca/campus_life/academic-support/accessibility.html) for all courses offered by Dalhousie with the exception of Truro. For courses offered by the Faculty of Agriculture, please contact the Student Success Centre in Truro (<https://www.dal.ca/about-dal/agricultural-campus/student-success-centre.html>)

Conduct in the Classroom – Culture of Respect

Substantial and constructive dialogue on challenging issues is an important part of academic inquiry and exchange. It requires willingness to listen and tolerance of opposing points of view. Consideration of individual differences and alternative viewpoints is required of all class members, towards each other, towards instructors, and towards guest speakers. While expressions of differing perspectives are welcome and encouraged, the words and language used should remain within acceptable bounds of civility and respect.

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, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness (Strategic Priority 5.2). Additional diversity and inclusion information can be found at: <http://www.dal.ca/cultureofrespect.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 - perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. The full Code of Student Conduct can be found at:

https://www.dal.ca/dept/university_secretariat/policies/student-life/code-of-student-conduct.html

Fair Dealing Policy

The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie. Additional information regarding the Fair Dealing Policy can be found at: https://www.dal.ca/dept/university_secretariat/policies/academic/fair-dealing-policy-.html

Originality Checking Software

The course instructor may use Dalhousie's approved originality checking software and Google to check the originality of any work submitted for credit, in accordance with the Student Submission of Assignments and Use of Originality Checking Software Policy. Students are free, without penalty of grade, to choose an alternative method of attesting to the authenticity of their work and must inform the instructor no later than the last day to add/drop classes of their intent to choose an alternate method. Additional information regarding Originality Checking Software can be found at: <https://www.dal.ca/about/leadership-governance/academic-integrity/faculty-resources/ouriginal-plagiarism-detection.html>

Student Use of Course Materials

Course materials are designed for use as part of this course at Dalhousie University and are the property of the instructor unless otherwise stated. Third party copyrighted materials (such as books, journal articles, music, videos, etc.) have either been licensed for use in this course or fall under an exception or limitation in Canadian Copyright law. Copying this course material for distribution (e.g. uploading to a commercial third-party website) may lead to a violation of Copyright law.

Faculty of Science

Student Resources and Support

University Policies and Programs

Important Dates in the Academic Year (including add/drop dates):

http://www.dal.ca/academics/important_dates.html

Classroom Recording Protocol:

https://www.dal.ca/dept/university_secretariat/policies/academic/classroom-recording-protocol.html

Dalhousie Grading Practices Policies:

https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html

Grade Appeal Process: https://www.dal.ca/campus_life/academic-support/grades-and-student-records/appealing-a-grade.html

Sexualized Violence Policy: https://www.dal.ca/dept/university_secretariat/policies/health-and-safety/sexualized-violence-policy.html

Scent-Free Program: <https://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html>

Learning and Support Resources

General Academic Support – Advising (Halifax): https://www.dal.ca/campus_life/academic-support/advising.html

General Academic Support – Advising (Truro): <https://www.dal.ca/about-dal/agricultural-campus/ssc/academic-support/advising.html>

Student Health & Wellness Centre: https://www.dal.ca/campus_life/health-and-wellness.html

On Track (helps you transition into university, and supports you through your first year at Dalhousie and beyond): https://www.dal.ca/campus_life/academic-support/On-track.html

Indigenous Student Centre: https://www.dal.ca/campus_life/communities/indigenous.html

Indigenous Connection: <https://www.dal.ca/about-dal/indigenous-connection.html>

Elders-in-Residence (The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit the office in the Indigenous Student Centre or contact the program at elders@dal.ca or 902-494-6803:

<https://cdn.dal.ca/content/dam/dalhousie/pdf/academics/UG/indigenous-studies/Elder-Protocol-July2018.pdf>

Black Student Advising Centre: https://www.dal.ca/campus_life/communities/black-student-advising.html

International Centre: https://www.dal.ca/campus_life/international-centre.html

LGBTQ2SIA+ Collaborative: <https://www.dal.ca/dept/vpei/edia/education/community-specific-spaces/LGBTQ2SIA-collaborative.html>

Dalhousie Libraries: <http://libraries.dal.ca/>

Copyright Office: <https://libraries.dal.ca/services/copyright-office.html>

Dalhousie Student Advocacy Services: <https://www.dsu.ca/dsas?rq=student%20advocacy>

Dalhousie Ombudsperson: https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html

Human Rights and Equity Services: <https://www.dal.ca/dept/hres.html>

Writing Centre: https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html

Study Skills/Tutoring: http://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html

Faculty of Science Advising Support: <https://www.dal.ca/faculty/science/current-students/undergrad-students/degree-planning.html>

Safety

Biosafety: <http://www.dal.ca/dept/safety/programs-services/biosafety.html>

Chemical Safety: <https://www.dal.ca/dept/safety/programs-services/chemical-safety.html>

Radiation Safety: <http://www.dal.ca/dept/safety/programs-services/radiation-safety.html>

Laser Safety: <https://www.dal.ca/dept/safety/programs-services/radiation-safety/laser-safety.html>