DALHOUSIE
UNIVERSITY

Faculty of Science Course Syllabus
Department of Oceanography
OCEA4220
Numerical Modelling of Atmospheres and Oceans
Winter Term, 2023/2024

Instructor(s): *Jinyu Sheng,* Jinyu.Sheng@Dal.Ca*, Office: Room 5676, Oceanography*
Hal Ritchie, hal.ritchie@canada.ca, Office: Room 5663, Oceanography

Lectures: 10:35-11:25 pm, Monday, Wednesday, and Friday

Laboratories:

Tutorials: *6 hours each week.*

Submit course syllabus to your Department office for posting on the Dept website prior to the start of term
Submit requests for final exam exemptions (1000, 2000 and 3000 level courses only) to the Dean's office at least 2 weeks prior to the start of term

The following information should be included, as a minimum, in every course syllabus.

Course Description

This course discusses numerical modelling techniques for simulating atmospheric and oceanic circulations. Material includes: review of governing equations; finite difference, finite element, and spectral methods; Eulerian, semi-implicit and semi-Lagrangian time integration techniques; accuracy and stability analyses; data assimilation and ensemble prediction methods; and boundary treatment for ocean models.

Course Prerequisites

1000-level calculus course and instructor's consent. An introductory class in fluid mechanics is also helpful.

Course Objectives/Learning Outcomes

The main objective of this course is to teach students on methodologies of transforming a set of differential equations that describe motion in atmospheres and oceans into a set of algebraic statements that can be calculated in an electronic computer.

Students will gain in depth knowledge of numerical modelling for simulating atmospheric and oceanic circulations after competing the course.

Course Materials

- *Haltiner, G. and Williams, R., Numerical Prediction and Dynamic Meteorology, John Wiley & Sons.*

- *Haidvogel, D. B., and Aike Beckmann, A., Numerical Ocean Circulation Modeling. Imperial College Press, 1999.*

- *Mesinger, F., and Arakawa, A., Numerical Methods Used in Atmospheric Models. Global Atmospheric Research Programme (GARP), WMO-ICSU Organizing Committee, GARP Publications Series No. 17, World Meteorological Organization. August 1976*

- *Course website, lecture recordings (if available)*

Course Assessment

- *The course evaluation is based on periodic assignments, tests, computer laboratory exercises, term project and final exam.*

- *There will be no supplementary exam.*

- *There is no need for the Registrar's Office to schedule the final exam since graduate students are required to present their term projects during the final exam period.*

NOTE: *An exemption is required for 1000 to 3000 level courses if you are <u>not</u> planning to hold a final exam scheduled by the Registrar's Office. Submit your syllabus along with your request (**and reason for the request**) to the Assistant Dean (scieasst@dal.ca) <u>at least 2 weeks</u> prior to the start of classes.*

Component	Weight (% of final grade)	Date
Mid-term	***20***	
Assignments	***40***	
Class Interaction	***5***	
Final Exam	***35***	

Other course requirements

List all (e.g., attendance, completion of all labs, non-graded presentation)

Conversion of numerical grades to Final Letter Grades follows the <u>Dalhousie Common Grade Scale</u>

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

Course Policies

- *For each or any part of a day that the assignment is late, including weekends and statutory holidays and other days when the University is closed, the student will lose 5% of the maximum* *possible value of the assignment for the first day or part of a day that the assignment is late and an additional 2% for each subsequent day or part of a day.*

- *The pdf files of our lecture notes will be distributed to students during the distance course continuation period.*

- *The final exam will be an open-book exam. There will be no supplementary exam.*

Course Content

Chapter 1: Introduction
- *1.1 Numerical Weather Prediction*
- *1.2 Ocean Modelling and Prediction*

Chapter 2: Differential Equations Governing Atmospheric and Ocean Circulation
- *2. 1 Basic Equations*
  - *2.1.1 Momentum Motions*
  - *2.1.2 Continuity Equation*
  - *2.1.3 Equation of State*
- *2.2 Geostrophy and Ekman Theory*
  - *2.2.1 Geostrophic Currents*
  - *2.2.2 Wind-Driven Ekman Currents*

Chapter 3: Space-Differencing
- *3.1 Finite-difference method*
  - *3.1.1 Finite Difference Formulation*
  - *3.1.2 First and Second Derivatives*
  - *3.1.3 Laplacian and Jacobian Operators*
  - *3.1.4 Staggered Grid Systems*
- *3.2 Spectral and Finite-Element Method*

Chapter 4: Time-Differencing
- *4.1 Euler, Backward and Trapezoidal Schemes*
  - *4.1.1 Euler Scheme*
  - *4.1.2 Backward Scheme*
  - *4.1.3 Trapezoidal Scheme*
- *4.2 Matsuno and Heun's Schemes*
  - *4.2.1 Matsuno Scheme*
  - *4.2.2 Heun's Scheme*
- *4.3 Adams-Bashforth Scheme*
- *4.4 Leap-Frog Scheme*
- *4.5 Implicit Schemes*
- *4.6 Semi-Lagrangian Method*

DALHOUSIE UNIVERSITY

Chapter 5: Computational Accuracy and Stability Analysis
- *5.1 Accuracy and Consistency*
- *5.2 Stability and Convergence*
  - *5.2.1 Energy Method*
  - *5.2.2 Von Neumann's Method*
  - *5.2.3 Courant-Friedrichs-Lewy Condition*

Chapter 6. Combined Time- and Space-Differencing
- *6.1 Linear Barotropic Model*
- *6.2 Quasi-Geostrophic Baroclinic Model*
- *6.3 Primitive Equation Model*

Chapter 7: Data Assimilation and Ensemble Prediction Methods
- *7.1 Data Assimilation*
  - *7.1.1 Sequential Method*
  - *7.1.2 Variational Method*
- *7.2 Ensemble Prediction Method*

Chapter 8: Lateral Boundary Treatment for Ocean Modeling

Chapter 9: Surface Boundary Treatment for Ocean Modeling