

**Faculty of Science Course Syllabus  
Department of Oceanography**

**OCEA4220**

***Numerical Modelling of Atmospheres and Oceans  
Winter Term, 2022/2023***

**Instructor(s):** *Jinyu Sheng, Jinyu.Sheng@Dal.Ca, Office: Room 5676, Oceanography  
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**Lectures:** *10:35-11:25 am, Monday, Wednesday and Friday, LSC-Oceanography  
O3652*

**Laboratories:**

**Tutorials:** *6 hours each week.*

**Course delivery:** *Lectures will be delivered in-person*

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*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*

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*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 completing 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, 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 not 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](mailto:scieasst@dal.ca)) at least 2 weeks prior to the start of classes.*

Component	Weight (% of final grade)	Date
<i>Mid-term</i>	<i>20</i>	
<i>Final exam</i>	<i>35</i>	
<i>Assignments</i>	<i>40</i>	
<i>Class Interaction</i>	<i>5</i>	

**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 Dalhousie Common Grade Scale**

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*

*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*

**Faculty of Science Course Syllabus (Section B)****OCEA4220*****Numerical Modelling of Atmospheres and Oceans******Winter Term, 2021/2022***

Please ensure that the following information on University Policies and Student Resources is available to all students in your course. This document may be posted on your Brightspace course site, or elements may be copied into your **Course Syllabus, Section A**.

**University Policies and Statements**

**This course is governed by the academic rules and regulations set forth in the University Calendar and by Senate**

**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.

**Information:** [https://www.dal.ca/dept/university\\_secretariat/academic-integrity.html](https://www.dal.ca/dept/university_secretariat/academic-integrity.html)

**Accessibility**

The Advising and Access Services Centre is Dalhousie's centre of expertise for student accessibility and accommodation. The advising team works with students who request accommodation as a result of a disability, religious obligation, or any barrier related to any other characteristic protected under Human Rights legislation (Canada and Nova Scotia).

**Information:** [https://www.dal.ca/campus\\_life/academic-support/accessibility.html](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—perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution.

**Code:** [https://www.dal.ca/dept/university\\_secretariat/policies/student-life/code-of-student-conduct.html](https://www.dal.ca/dept/university_secretariat/policies/student-life/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, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness

**Statement:** <http://www.dal.ca/cultureofrespect.html>

**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 (1321 Edward St) ([elders@dal.ca](mailto:elders@dal.ca)).

**Information:** [https://www.dal.ca/campus\\_life/communities/indigenous.html](https://www.dal.ca/campus_life/communities/indigenous.html)

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

[https://www.dal.ca/academics/important\\_dates.html](https://www.dal.ca/academics/important_dates.html)

**University Grading Practices**

[https://www.dal.ca/dept/university\\_secretariat/policies/academic/grading-practices-policy.html](https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html)

## **Student Resources and Support**

### **Advising**

**General Advising** [https://www.dal.ca/campus\\_life/academic-support/advising.html](https://www.dal.ca/campus_life/academic-support/advising.html)

**Science Program Advisors:** <https://www.dal.ca/faculty/science/current-students/academic-advising.html>

**Indigenous Student Centre:** [https://www.dal.ca/campus\\_life/communities/indigenous.html](https://www.dal.ca/campus_life/communities/indigenous.html)

**Black Students Advising Centre:** [https://www.dal.ca/campus\\_life/communities/black-student-advising.html](https://www.dal.ca/campus_life/communities/black-student-advising.html)

**International Centre:** [https://www.dal.ca/campus\\_life/international-centre/current-students.html](https://www.dal.ca/campus_life/international-centre/current-students.html)

### **Academic supports**

**Library:** <https://libraries.dal.ca/>

**Writing Centre:** [https://www.dal.ca/campus\\_life/academic-support/writing-and-study-skills.html](https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html)

**Studying for Success:** [https://www.dal.ca/campus\\_life/academic-support/study-skills-and-tutoring.html](https://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html)

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

**Fair Dealing Guidelines** <https://libraries.dal.ca/services/copyright-office/fair-dealing.html>

### **Other supports and services**

**Student Health & Wellness Centre:** [https://www.dal.ca/campus\\_life/health-and-wellness/services-support/student-health-and-wellness.html](https://www.dal.ca/campus_life/health-and-wellness/services-support/student-health-and-wellness.html)

**Student Advocacy:** <https://dsu.ca/dsas>

**Ombudsperson:** [https://www.dal.ca/campus\\_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html](https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html)

### **Safety**

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

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

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

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

**Dalhousie COVID-19 information and updates:** <https://www.dal.ca/covid-19-information-and-updates.html>