Atmospheric Dynamics I

Department of Physics & Atmospheric Science
PHYC/OCEA 4411/5411 Fall 2025

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

Name	Email	Student Hours
Dr. Sean Hartery	sean.hartery@dal.ca	Tuesdays 10 AM – 1 PM or by appointment Dunn 209

1. Course Description

The basic laws of fluid dynamics are applied to studies of atmospheric motion, including the atmospheric boundary layer and synoptic scale weather disturbances (the familiar highs and lows on weather maps). Emphasis will be placed on the blend of mathematical theory and physical reasoning which leads to the best understanding of the dominant physical mechanisms.

1.1 Course Prerequisites

PHYC 2140.03 or PHYC 2060.03 or permission of the instructor

1.2 Cross-Listing

PHYC 4411.03, OCEA 4411.03, PHYC 5411.03, OCEA 5411.03

2. Student Resources

2.1 Student Hours

I will be available once per week in Dunn 209 (or virtually, by request) as indicated above. This is your opportunity to directly ask questions regarding lecture content and get assistance with assignments.

2.2 Discussion Boards

Outside of student hours and lectures, you can post questions regarding assignments, lecture content, or general course logistics to the Discussion boards on Brightspace. All students are encouraged to reply, but you can expect a reply from me within 24 - 48 hours.

2.3 Instructor Email

Please include the course code in the subject of your email and your banner number in the body. Ideally, keep emails to important course logistics (e.g. requesting an extension, making up a midterm, etc.). For questions regarding course content, you can always chat with me after class – and if it's a small question, just drop by my office. I don't answer emails after 6:00 PM and if you want to remain sane, neither should you.

3. Course Structure

The course will be delivered in-person. Photocopies of my lecture notes will be made available *after* each lecture – my notes are written to guide me while giving the lecture, not necessarily to guide the student, so they are not an ideal replacement for attendance. Lectures will not be recorded by the instructor, but students may request permission to record lectures. Requests won't be unreasonably denied.

3.1 Lectures

Class Days: M, W
Class Times: 1435 – 1555
Classroom: 221C
Building: Sir James Dunn Building
Campus: Studley
Schedule: See Course Content

3.2 Brightspace

Assignments, lecture notes, and other course resources will be available via Brightspace. You can access the Brightspace page for this course by logging in with your Dalhousie netID and password at the following site: https://dal.brightspace.com/d2l/home

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About the Instructor

When I was 15 or so, I found a copy of "*A Brief History of Time*" by Stephen Hawking on the bathroom countertop at home. I found myself so transfixed by the subjects of astronomy and astrophysics that I sat on the bathroom floor reading until my back hurt. As High School was coming to an end, I decided to pursue a BSc in Physics at Dalhousie University. However, somewhere along the way, my focus shifted – from the deep reaches of the universe to the ethereal clouds of our atmosphere. After leaving Dalhousie, I pursued a PhD in Physics at the University of Canterbury, studying aerosol-cloud interactions over the Southern Ocean, specifically the formation of mixed phase cloud. This provided the rare opportunity to conduct atmospheric research near Antarctica aboard the R/V Tangaroa. Soon after, I accepted an instructor position at Augusta University in Georgia. I found great joy working with students as they explored the fundamental concepts of physics – particularly in the lab, where they could see simple electrical and mechanical principles at work. In 2023, I was given the opportunity to bring my love and passion for teaching physics back to Dalhousie – I hope that I get to share some of my joy of physics with you.

Outside of research and teaching, I enjoy biking, baking, playing guitar, drinking coffee, seeing live music, and hanging out with my partner and our two cats. My Dungeons and Dragons character is an Oath of Glory Paladin. My favorite band is Tonstartssbandht. I have trouble hearing sometimes – so I might ask you to repeat yourself. I am also terrible at maintaining eye contact – please don't take it personally, I am listening! If I ever mispronounce your name, you are free to mispronounce mine as siːn (it is pronounced ʃɔːn).

3.3 Announcements

Important announcements will be posted primarily on Brightspace and occasionally sent via e-mail. It is important that you check both Brightspace and your assigned Dalhousie e-mail account regularly.

Where can I get the textbook?
Option 1: Campus bookstore. Physical and e-text available.

Option 2: I have a few copies which I can loan out for the semester. First come, first serve. A deposit of 20$ is required.

4. Course Materials

4.1 Textbook (required)

The following textbook is required:
"*Mid-Latitude Atmospheric Dynamics: A First Course*"
Jonathan E. Martin

If you have access to them, and intend to continue in the field, the following textbooks are also quite useful (but not required): "*An Introduction to Dynamic Meteorology*" by James R. Holton and "A*pplied Atmospheric Dynamics*" by Amanda H. Lynch and John J. Cassano. Holton is often considered the *classic* introductory dynamics textbook, but it is a bit dense – it's the best introductory atmospheric dynamics textbook for someone who has already taken atmospheric dynamics (if that makes any sense). Lynch and Cassano forego some of the conveniences of vector calculus notation, leading to some clunky mathematics, but they make up for it with plenty of worked examples and applications. Both have a distinct advantage over Martin: they introduce linear perturbation theory, which we'll use next semester.

4.2 Calculator (required)

A *non-programmable* scientific calculator is permitted for use during tests and exams.

5. Learning Objectives

Upon successful completion of PHYC4411/5511 OCEA4411/5511, a student will be able to:

Diagnose:	thermal wind from geopotential thickness isopleths; geostrophic wind from geopotential height isopleths; warm and cold air advection from thickness & height maps.
Distinguish Between:	subgeostrophic and supergeostrophic flow; baroclinic and barotropic conditions; fundamental and apparent forces;
Identify:	the physical meaning and canonical name of terms in various differential equations; approximations or assumptions applied in the derivations of equations.
Apply:	the primitive equations of motion to study various systems of interest by applying appropriate scaling arguments and convenient coordinate systems.

6. Course Content

While the following schedule is tentative, topics will proceed in the order below. With some exceptions, we will cover Chapters 1 - 5 in Martin.

NOTE: My guiding principle in modifying the syllabus for this term is that it is better to do a few things well than many things poorly. In that spirit, I have tried to cut material which is not essential. Unfortunately, most material in Dynamics I ***is*** rather essential as it provides the framework for understanding Dynamics II (and also Synoptic I/II). So, for transparency, the following modifications were made:

1. Lectures on the latter half of chapter 5 have been pushed into Atmospheric Dynamics II (winter term), where they would normally have been covered this term.
2. Normally, we would have three in-class quizzes. This semester, there will be one in-class midterm.
3. Dynamics II normally concludes with some discretionary (but interesting) lectures on atmospheric waves (Rossby, Kelvin, and Eady waves) and a study of the global circulation. As linear perturbation theory is not *as* essential as QG-theory for one's understanding of meteorology, global circulation material will be cut, and we will only study Rossby waves.

Week	Lecture	Date	Topic	Reading(s)
1	**NC**	Mon, Sep 22	**No Class**	
	1	Wed, Sep 24	Introduction	
2	2	Mon, Sep 29	Eulerian & Lagrangian Perspectives	1.2, 1.4
	3	Wed, Oct 01	Pressure Gradient, Gravity, Geopotential	2.1.1, 2.1.2, 2.2.1
3	4	Mon, Oct 06	Geopotential Height, Friction, Coriolis	2.1.3, 2.2.2
	5	Wed, Oct 08	More Coriolis	2.2.2, pp58-59
4	**NC**	Mon, Oct 13	**Thanksgiving**	
	6	Wed, Oct 15	Scale Analysis	M3.1.1, pp59-60
5	7	Mon, Oct 20	Geostrophic Balance	pp61-65
	8	Wed, Oct 22	Conservation of Mass	pp65-68
6	9	Mon, Oct 27	Conservation of Energy	pp68-71
	10	Wed, Oct 29	Potential Temperature	pp71-72
7	11	Mon, Nov 03	Atmospheric Stability	pp72
	Q	Wed, Nov 05	**Midterm**	
8	**NC**	Mon, Nov 10	**Reading Week**	
	NC	Wed, Nov 12	**Reading Week**	
9	12	Mon, Nov 17	Pressure Coordinates	4.1
	13	Wed, Nov 19	Vertical Velocity	No reading
10	14	Mon, Nov 24	Thermal Wind Balance	4.3
	15	Wed, Nov 26	Natural Coordinates	pp93-97
11	16	Mon, Dec 01	Balance Conditions	pp97-102
	17	Wed, Dec 03	Gradient Wind Balance	pp103-108
12	18	Mon, Dec 08	Circulation	pp115-120
	19	Wed, Dec 10	Vorticity	pp122-126

7. Assessments

You will automatically get the benefit of the grading method which leads to the highest final grade.

Assessment	Method 1	Method 2
Assignments	25%	25%
Participation	5%	5%
Midterm	25%	15%
Project	10%	10%
Final Exam	35%	45%

Assignment	Due Date
#1	Mon Oct 6
#2	Wed Oct 15
#3	Mon Oct 27
#4	Mon Nov 17
#5	Wed Nov 26
#6	Mon Dec 8

5.1 Assignments

Assignments are all weighted equally. Your lowest scoring assignment will be dropped when computing your final grade.

5.2 Participation

Students are expected to participate in class by asking questions, answering conceptual questions posed throughout lecture, and participating in group activities. Attendance provides a bare minimum credit of 1%. Emailing the instructor or posting on the discussion board is not considered participation.

5.2 Midterm

There will be one (1) in-person midterm which will take place in lieu of lecture. The midterm will cover lectures 1 – 10 (assignments 1 – 4).

	Midterm
Date	Wed. Nov 5th

5.3 Project

Students are expected to:

Project Deadlines	Date
Research Article Selection (5%)	Wed Oct 29th
First Draft of Summary (10%)	Wed Nov 19th
Final Draft of Summary (20%)	Wed Dec 10th
Oral Presentation (65%)	TBD

a. Select a research article which is appropriately connected to the fundamental concepts presented in our course. In a short paragraph (<150 words), the student is expected to explain how the article connects to the course.
b. Provide a substantive summary of the research article, connecting the main points of the article to the fundamental concepts in our course. Summary should not exceed 800 words. The summary will first be submitted as a first draft, for which timely feedback will be provided. The final draft should clearly synthesize criticism and suggestions from the first draft.
c. Present the research article to the class in the form of an oral presentation with accompanying PowerPoint. Presentation will be assessed based on aesthetics (legibility of figures and text), the presenter's ability to communicate technical details, and professionalism (a troubling word, but I simply mean that the student approaches the presentation in a manner that respects the subject, themselves, and the audience). The tone of the presentation should be suitable for an academic conference.

The research article should be peer-reviewed and published in a relevant academic journal (e.g. take a look at any AMS or RMetS journals). Students may not present original research. Please do not use "review articles" which summarize work in a particular sub-discipline. The article should contain concepts relevant to the class but may go beyond the purview of the class provided sufficient background details are presented. If you are scratching your head for ideas, look at the end-of-chapter bibliographies in the textbook. Some cursory literature

searches of those authors should provide an extensive list of articles to choose from. Students will be graded on their ability to present the research at a level appropriate for a 4th year undergraduate student. The presentations will be held outside of class at a mutually agreed upon time. No group work permitted.

Note: If a student isn't comfortable presenting in person, they may record and submit a video presentation instead.

5.4 Final Exam

The final exam will be a cumulative test of all content featured in lectures, with an emphasis on the later, untested parts of the course. The final exam will take place during the formal exam period, but at a time and date decided by consensus. The decision will be made once the Registrar publishes their exam schedule.

5.5 Calculation of Final Grades

Undergraduate

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)	

Please note that your final numerical grade is rounded (e.g. 89.5 → 90, 89.4 → 89) before conversion to letter grade as above.

Graduate

Number to letter conversion is the same for graduates as for undergraduates, except that any grade below B- is considered an F. For grades of F, see FGS calendar for implications on program continuation.

6. Course Policies on Missed or Late Academic Requirements

6.1 Assignments

If you require an extension on an assignment, please give me 24 hours' notice. I can normally grant extensions up to 3 days, but I can offer longer extensions in more serious cases (e.g. prolonged illness). If you *don't* request an extension, an assignment loses ten percentage points per day past due (e.g. an assignment grade of 87% would drop to 77% for one day past due, 67% two days, etc.).

6.2 Midterm

If you know ahead of time that you are going to miss the midterm due to serious illness or personal emergency, please notify me ASAP and we will re-schedule – given my other teaching duties, this is likely to take place during the morning or evening on a weekday. You must contact me and write the midterm within 48 hours of the in-class date. If no plan is made, you will be graded according to Method 2.

6.3 Project Deadlines

If you submit a project element within 48 hours of the due date, it will be considered "on time". Anything past 48 hours must be agreed upon by prior request.

6.3 Final Exam

The final exam will be scheduled based on a mutually agreed upon date once the main exam schedule is released. Students must take the exam on this date except under exceptional circumstances. If there is a conflict, you should contact the course lecturer as soon as possible. You may not use a Student Declaration of Absence for the final exam.

For University-wide deadlines for payment of academic fees, course withdrawals, convocation, etc. please visit: https://www.dal.ca/academics/important_dates.html

7. Course Policies related to Academic Integrity

All coursework submitted for grading must represent your work and your work alone. To be clear:

- × Students are not permitted to access or copy another student's homework assignments, tests, or exams (including those of past students).
- × Students are not permitted to use any device which would enable cheating during a test or final exam.
- × Students are not permitted to use courseware like Chegg, Course Hero, Quizlet, or LLMs or broadly defined "AI" (including, but not limited to) ChatGPT to complete their homework assignments.
- × A student who supplies their coursework to another student (in the present semester and/or a future semester) also commits an act of plagiarism.

If a student commits a serious act of plagiarism or academic dishonesty, it may result in an automatic grade of F for the course. Continued offenses may result in expulsion from Dalhousie. For more information on Dalhousie University's Academic Integrity policies, please consult: https://www.dal.ca/dept/university_secretariat/academic-integrity.html

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What will an average class look like?

Mostly a traditional lecture (*i.e.* I will explain assumptions taken in deriving formulae, show you applications of key formulae, and solve problems related to homework), though I will try to break up the onslaught of information with conceptual questions (which at least someone in class will need to answer) or short group activities. Given the truncated form of this semester, there will be fewer of these than originally planned.

While I will re-create some classic derivations (e.g. the Coriolis force, thermal wind, etc.), I will mostly try to show you how these core dynamical principles are applied to our understanding of the atmosphere. From time to time, I might forego a derivation altogether when there is no substantial physics to be gleaned (*i.e.*, it's just math, baby). In such cases, I strongly recommend reading the relevant sections of the textbook. Martin is comprehensive when it comes to derivations, and his writing is sufficiently compelling to not lull you to sleep.

8. A Note About AI

I strongly recommend reading the following report on *cognitive offloading* by researchers at MIT*:* *https://www.media.mit.edu/publications/your-brain-on-chatgpt/ (Kosmyna et al., 2025).* The findings are grim, showing that users who habitually use AI to perform tasks that require critical thinking gradually accrue a *cognitive deficit*: i.e., over time, researchers have found that an AI user's critical thinking skills degrade.

As a practical point, to enter the field as a forecast meteorologist, you must perform well on Environment Canada's entrance exams. Even if you manage to ace this semester's assignments, you will perform very poorly on this exam if Microsoft's CoPilot has been whispering in your ear like Grima Wormtongue.

Perhaps more philosophically, you should seriously consider the following: if you are already happily handing over your cognitive responsibilities to AI at this stage in your career, then what hope do you have at actually performing well at a job that requires you to exercise critical judgment? Why should you bother training for a career if you already think you can be replaced by AI? Worse still, even if you do land a job, you will spend a lifetime copying and pasting your experiences into AI to make sense of them. Life will be happier and altogether more gratifying if you approach it with curiosity, humility and ambition. I hope that this course will provide you with the deep understanding of atmospheric dynamics that is necessary to be a meteorologist; but acquiring this understanding necessarily requires YOU to do the thinking.

However, you will no doubt eventually use AI in some form in your career. If you look back on the history of meteorology, it is a field that has both benefited from, and been severely impacted by, technological progress. Meteorological field stations around the globe which once housed trained observers, have largely been replaced by remote sensing stations. Many people who used to physically annotate charts and perform calculations in the met office have been replaced by software. And so there will come a time when AI can more reliably synthesise measurements and modelling into accurate forecasts than our best forecasters. So, what will be the role of the future meteorologist? I expect that it will be the same as it has always been. A meteorologist will be someone who truly understands atmospheric processes, can synthesise data from disparate sources (weather balloons, satellites, and now AI), and can expertly communicate the "story" of the day-to-day weather to the public. Being able to leverage AI to enhance the fidelity of your forecasts will simply be another tool in your toolkit. I do not doubt that the careers of meteorologists will "weather the storm" of AI like any other new technology before it. Suffice it to say, if you think meteorology will die on the sword of AI, then you should talk to all of the career meteorologists who thought they would be out of a job once NCEP started running GFS…

Nataliya Kosmyna, Eugene Hauptmann, Ye Tong Yuan, Jessica Situ, Xian-Hao Liao, Ashly Vivian Beresnitzky, Iris Braunstein, and Pattie Maes. "Your brain on chatgpt: Accumulation of cognitive debt when using an ai assistant for essay writing task." arXiv preprint arXiv:2506.08872 (2025).

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.