



McGill

Graduate Student Handbook

Department of Atmospheric and Oceanic Sciences

Your ultimate guide on *HOW2GAMAOS!*
(How to get around McGill's AOS department)

September 2021

Department of Atmospheric & Oceanic Sciences

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DESCRIPTION OF THE DEPARTMENT

History

The history of meteorology at McGill dates back to the middle of the nineteenth century when the McGill Weather Observatory was established. It has made continuous measurements of meteorological variables for over a century. Following the Second World War, two active atmospheric sciences research groups emerged at McGill. Dr. J. Stewart Marshall led a radar meteorology group in the Physics Department, and Dr. F. Kenneth Hare directed an arctic meteorology program in the Department of Geography. These two groups united in 1959 to form the Department of Meteorology. Since its creation, the Department has been a Canadian and international leader in the training of many distinguished atmospheric scientists. McGill has awarded over 400 M.Sc. degrees and more than 200 Ph.D. degrees in this field.

The history of oceanographic research at McGill also dates from the 1850's and was brought into focus in 1963 with the establishment of the Marine Sciences Centre (later the Institute of Oceanography). Under the directorship of Dr. Max J. Dunbar, the Institute offered M.Sc. and Ph.D. degree programs in the areas of physical, geological and biological oceanography. In 1987, the Institute was closed, and a Graduate Program in Oceanography was established to coordinate teaching and research in the marine sciences carried out by faculty members in the Departments of Meteorology, Earth and Planetary Sciences and Biology. In 1992, the Department of Meteorology became the Department of Atmospheric and Oceanic Sciences (AOS), to demonstrate the broad range of research activities in the atmospheric sciences, physical oceanography and climate studies.

Mission

The Department of Atmospheric and Oceanic Sciences continues to strengthen its leadership in teaching, research, and service on the Canadian and international scene. Graduate students in the field move on to successful careers such as environmental research and consulting, weather and climate forecasting and analysis for government or private industry and teaching at the college and university level. Our research areas include:

- Atmospheric Chemistry
- Geophysical Fluid Dynamics
- Cloud Physics and Dynamics
- Atmospheric Radiation
- Mesoscale Meteorology
- Physical Meteorology
- Sea Ice
- Ocean Dynamics
- Remote Sensing
- Physical Oceanography
- Air-snow/ ice-ocean Biogeochemistry
- Stratospheric Dynamics and Chemistry
- Dynamical Meteorology and Climatology
- Global Climate Change and Variability
- Radar Meteorology
- Synoptic Meteorology
- Air-Sea Interactions
- Development of technology for atmospheric observation, pollution remediation

Faculty Members

Faculty Professors

Parisa Ariya

Professor, Ph.D. (York)
(Joint with Chemistry; James McGill Professor)

Peter Bartello

Professor, Ph.D. (McGill)
(Joint with Mathematics and Statistics)

Carolina Dufour

Assistant Professor, Ph.D. (Grenoble); Undergraduate Program Director

Frédéric Fabry

Associate Professor, Ph.D. (McGill)
(Joint with McGill School of Environment; Director, J. Stewart Marshall Radar Observatory)

John R. Gyakum

Professor, Ph.D. (M.I.T.)
(Canada Steamship Lines Professor)

Yi Huang

Associate Professor, Ph.D. (Princeton)

Daniel Kirshbaum

Associate Professor, Ph.D. (U.
Washington) (Chair)

Timothy Merlis

Associate Professor, Ph.D. (Caltech)
(Canada Research Chair, Tier 2;)

Thomas Preston

Assistant Professor, Ph.D.
(U.B.C.) (Joint with Chemistry)

Djordje Romanic

Assistant Professor, Ph.D. (Western Ontario)

David N. Straub

Associate Professor, Ph.D. (U.
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Ivy Tan

Assistant Professor, Ph.D. (Yale)

Bruno Tremblay

Professor, Ph.D. (McGill)

Andreas Zuend

Associate Professor, Ph.D. (ETH Zurich); Graduate Program Director

Adjunct Professors

Leonard Barrie

Adjunct Professor
Stockholm University

Mark Buehner

Adjunct Professor
Meteorological Research Division of Environment and Climate Change Canada

Pavlos Kollias

Adjunct Professor
Stony Brook University

Hai Lin

Adjunct Professor, Ph.D. (McGill)
Research Scientist, Meteorological Service of Canada

Louis-Phillippe Nadeau

Adjunct Professor, Ph.D. (McGill)
Université du Québec à Rimouski

Emeritus Professors

Jacques Derome

Emeritus Professor, F.R.S.C., Ph.D. (Michigan)

Henry G. Leighton

Emeritus Professor, Ph.D. (Alberta)

Lawrence A. Mysak

Emeritus Professor, C.M., F.R.S.C., Ph.D. (Harvard)
(Canada Steamship Lines Professor)

Isztar Zawadzki

Emeritus Professor, F.R.S.C., Ph.D. (McGill)

Man K. (Peter) Yau

Emeritus Professor, Ph.D. (M.I.T.)

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GRADUATE STUDIES

Admission Requirements

Applicants for the **M.Sc. program** must meet the general requirements of McGill's Graduate and Postdoctoral Studies (GPS) and hold a Bachelor's degree with high standing in Meteorology, Physical Oceanography, Physics, Mathematics, Engineering, or other related subjects. The minimum academic standard for admission to the M.Sc. and Ph.D. degree programs is normally a high second-class standing, i.e. Cumulative Grade Point Average (CGPA) > 3.5. Normally the Department sets a significantly higher level of CGPA for admission. In addition, higher grades are expected in courses considered preparatory for the Department's graduate program.

Students registered in the M.Sc. program who perform especially well may be considered for a transfer to the Ph.D. program before the completion of their M.Sc. program. The normal requirement for admission to the **Ph.D. program** is a Master's degree in Atmospheric Science, Physical Oceanography, or a related discipline, with **high standing**. In addition, a Faculty member in the Department must agree to supervise the thesis of an incoming Ph.D. student before an offer of admission is made. Other requirements that may apply are:

Non-Canadian applicants whose mother tongue is not English and who have not completed an undergraduate or graduate degree using the English language are required to submit documented proof of competency in oral and written English. Accepted placement tests include:

- **TOEFL** Internet-Based Test (IBT): minimum overall score of 86 with each component score not less than 20
- **IELTS**: a band score of 6.5 or greater

Please refer to the following website for a comprehensive listing of accepted options to provide proof of English proficiency:

<http://www.mcgill.ca/gradapplicants/international/apply/proficiency>

Financial Support

The Department normally provides financial support to all graduate students in the form of a graduate stipend. The value of the stipend varies according to the amount of external support received by the student and the fees to be paid. For example, out-of-province and international students who pay a higher tuition receive additional support from the Department to partially or fully offset this additional expense. Students with external funding (scholarships, etc.) normally receive a top-up to their scholarship, such that the total is above the typical stipend received by non-scholarship students. A number of Teaching Assistantships are also available.

Students accepting employment outside the University while still receiving a graduate stipend from the Department must immediately notify the Department's Graduate Program Director, in writing. Please note that acceptance of employment could lead to a reduction or termination of Departmental financial support.

All students are encouraged to apply for postgraduate fellowships from government and non-profit funding agencies such as Le Fonds de recherche du Quebec - Nature et technologies (FRQNT) and Mitacs. Canadians and Permanent Residents of Canada are also strongly encouraged to apply for

postgraduate fellowships offered by federal government agencies such as the Natural Sciences and Engineering Research Council (NSERC) and the Meteorological Service of Canada (MSC). For **additional information**, please contact the **Administrative and Student Affairs Coordinator**: graduateinfo.aos@mcgill.ca. Information can also be found at <https://www.mcgill.ca/gradapplicants/funding> and <https://www.mcgill.ca/gps/funding>.

Departmental Fellowships and Awards

The **Stephen and Anastasia Mysak Graduate Fellowship** was established in 2006 by Professor Lawrence A. Mysak, an Emeritus Professor in the Department, in honour of his father, Stephen Mysak (1906–2007), and in memory of his mother, Anastasia Mysak (1907–1978). It is to be awarded by Graduate and Postdoctoral Studies upon recommendation of the Department of Atmospheric and Oceanic Sciences, to a full-time graduate student pursuing research in one or more fields of air-sea interaction, oceanography or climate. The Fellowship is awarded on the basis of academic excellence. The estimated value of this fellowship is \$15,000 per year, renewable once at the Master’s level, and twice at the Doctoral level. The Mysak Fellowship may not be held in conjunction with other McGill or major granting agency awards.

The **Max Dunbar Award** was established in 1985 by former students of Professor M.J. Dunbar in recognition of his teaching and research career at McGill. Formerly administered by the Institute of Oceanography, the Dunbar Award is now awarded by the Departments of Atmospheric and Oceanic Sciences, Biology, and Earth and Planetary Sciences, upon recommendation of the departments’ award committees, to a graduate student in any marine field of study with an outstanding academic record. The award value varies, but is normally approximately \$1,000.

Student Rights and Responsibilities

Students have the responsibility of informing themselves of the University’s regulations, program requirements, fellowship opportunities and deadline dates. Useful sources of information in the Department are the Administrative and Student Affairs Coordinator, the Graduate Program Director, the Departmental website (www.mcgill.ca/meteo), and the Graduate and Postdoctoral Studies website (www.mcgill.ca/gps). The **Handbook of Student Rights and Responsibilities** is available on the web (<https://www.mcgill.ca/students/srr/>).

Academic Integrity

McGill University values academic integrity, which is fundamental to achieving our mission of the advancement of learning. To learn more about academic integrity at McGill, please visit <https://www.mcgill.ca/deanofstudents/plagiarism>. The website contains information concerning the

meaning of integrity, how to foster it, and the consequences of breaching it. There is specific information about requirements for citing the work of others, from both print and electronic sources. Students have the responsibility of informing themselves about these matters.

Academic Standing and Failure Policies

Students must obtain grades of **B- or better** in courses used to fulfil program requirements. See [University Regulations & Resources > Graduate > Regulations > Student Records > Grading and Grade Point Averages \(GPA\)](#)

The following grade scale is used for graduate studies at McGill:

Grading and Grade Point Averages (GPA)		
Grades	Grade Points	Numerical Scale of Grades
A	4.0	85–100%
A-	3.7	80–84%
B+	3.3	75–79%
B	3.0	70–74%
B-	2.7	65–69%
F (Fail)	0	0–64%

The failure policy specifies conditions under which graduate students will be withdrawn from the University due to unsatisfactory standing, resulting from failed courses and/or unsatisfactory Graduate Student Research Progress Tracking Reports.

A student who has **failed one course** which counts for credit toward the student’s degree may automatically write one **supplemental examination** or, with the permission of the Graduate Program Director, may **retake that course** or **substitute an equivalent course**. A student with any further failures in that course, including the supplemental, or a failure in any other course, will be required to withdraw from the University.

A student who fails one course and obtains an unsatisfactory Graduate Student Research Progress Tracking Report may be asked to withdraw from the University.

A student who obtains two unsatisfactory Graduate Student Research Progress Tracking Reports may be asked to withdraw from the University.

For additional information, please see [University Regulations & Resources > Graduate > Guidelines & Policies > Failure Policy](#).

Vacation Policy

Graduate students are normally entitled to vacation leave equivalent to university holidays and an additional total of fifteen (15) working days in the year. Funded students with fellowships and research grant stipends taking additional vacation leave may have their funding reduced accordingly. See [Graduate and Postdoctoral Studies > Graduate Students > Degree Progress > Leave of Absence & Vacation Policy](#).

Leave of Absence Policy

All graduate students are eligible to request a leave of absence from Graduate and Postdoctoral Studies for reasons relating to maternity or parenting, personal or family health, professional development, required military service, and employment that precludes progress towards the degree. Leaves must be requested on a term-by-term basis by completing the appropriate [web form](#) and by submitting to the Department the required documentation justifying the leave. The request will be evaluated by the Department and, if appropriate, will be forwarded for approval to Enrolment Services.

For additional information, please see [University Regulations & Resources > Graduate > Guidelines & Policies > Leave of Absence Status](#).

GRADUATE PROGRAMS

Master's Curriculum

The M.Sc. degree requires a minimum of 45 credits, up to a maximum of 51 credits. The program includes from 9 to 27 credits of coursework (depending on the student's background) and the remainder are thesis credits. Master's students with no previous background in atmospheric or oceanic sciences or related fields generally take 21 course credits spread over two semesters (September–December and January–April). For students with a strong background in atmospheric or oceanic science, or a Diploma in Meteorology, the course load may be reduced in consultation with the Graduate Program Director and the supervisor. Such students may register for additional thesis courses (ATOC 693 – 6 credits and/or ATOC 695 – 6 credits) if needed to complete the 45 credits required for the program. **Approval of the Graduate Program Director is required in all such cases.**

Students can be admitted to the M.Sc. program with or without having chosen an advisor or project. Students admitted without a pre-arranged advisor are required to meet with a large cross section of professors in the department during the Fall term in their first year, to discuss possible projects, and are encouraged to keep an open mind throughout this consultation. Near the end of the Fall term, students are assigned advisors and projects. Typically most or all students get their first choice of research projects; however other factors may also be taken into account, so as to prevent too many students from working with the same advisor or in the case where two or more students wish to work on the same project.

If an entering M.Sc. student already has an agreement to work with a particular supervisor on a topic of mutual interest, the student would not participate in the formal selection process, and may begin research with their supervisor prior to May of their first year (if they have the appropriate background).

Seminar Participation

Students registered in M.Sc. programs are expected to regularly attend the Department seminar series during their second year in the program.

All M.Sc. 2 students are also required to attend one of the Student Seminar series, ATOC 751 or ATOC 752, even though they are not registered for these seminar courses. M.Sc. 2 students are required to register for ATOC 694 (Master's Thesis Progress Report and Seminar) in either the Fall or Winter, and **must present a seminar for the Student Seminar series in order to satisfy the seminar component of ATOC 694.**

M.Sc. Curriculum – (45 credits)

REQUIRED COURSES		
<i>Thesis Component (24 credits)</i>		
ATOC 691	Master's Thesis Literature Review	3 cr.
ATOC 692	Master's Thesis Research 1	6 cr.
ATOC 694	Master's Thesis Progress Report and Seminar	3 cr.
ATOC 699	Master's Thesis	12 cr.
COMPLEMENTARY COURSES (21 credits)		
Must complete or have completed the following courses or equivalent:		
ATOC 512	Atmospheric and Oceanic Dynamics	3 cr.
ATOC 513	Waves and Stability	3 cr.
ATOC 515	Turbulence in Atmosphere and Oceans	3 cr.
ATOC 519/ CHEM 519	Advances in Chemistry of Atmosphere	3 cr.
ATOC 521	Cloud Physics	3 cr.
ATOC 525	Atmospheric Radiation	3 cr.
ATOC 530	Paleoclimate Dynamics	3 cr.
ATOC 531	Dynamics of Current Climates	3 cr.
ATOC 540	Synoptic Meteorology 1	3 cr.
ATOC 541	Synoptic Meteorology 2	3 cr.
ATOC 548	Mesoscale Meteorology	3 cr.
ATOC 557	Research Methods: Atmospheric and Oceanic Sciences	3 cr.
ATOC 568	Ocean Physics	3 cr.
ATOC 626	Atmospheric/Oceanic Remote Sensing	3 cr.
<ul style="list-style-type: none"> ▪ Students may select either ATOC 519 or CHEM 519 ▪ Other courses at the 500 level or higher may be taken at the recommendation of the Department's Graduate Program Director. 		
<p>Students with a strong background in atmospheric or oceanic science, or a Diploma in Meteorology, will take at least the 9-credit minimum. <i>Students with no previous background in atmospheric or oceanic science must take at least 21 credits of coursework.</i></p>		

Guidelines on the Completion of the M.Sc. Thesis

Refer to the "[Regulations Concerning Theses](#)" section of the McGill University eCalendar.

Purpose of the Thesis

- A thesis for the master's degree, while not necessarily requiring an exhaustive review of work in the particular field of study, or a great deal of original scholarship, must show familiarity with previous work in the field and must demonstrate the ability to carry out research and to organize results, all of which must be presented using appropriate scientific writing.

Scope

- The thesis should demonstrate a thorough understanding of the subject matter. It should define the problem clearly, give an adequate summary of previous work, explain the methods used, and present the results. Details should be sufficient to enable a researcher outside the particular area of specialization to comprehend the approach and the significance of the work, and to reproduce it if desired. The thesis should normally not exceed 100 pages.

Originality

- Although it is not required that the M.Sc. thesis contains a great deal of original scholarship, some originality is expected. This might consist of extending the application of an existing method or theory, of comparing several such methods or theories, or of giving a new interpretation to concepts already established. While it is not a degree requirement that the thesis be of publishable quality, it is very much in the student's and the supervisor's interest to strive, after the thesis is submitted, to prepare a paper based on the thesis for submission to a refereed journal.

Research Schedule

- For students who have completed their course requirements, the total time devoted to the thesis work should be about 12 to 14 months, two or three of which are needed to write the thesis and have it read and commented on by the supervisor. For example, students completing the course requirements at the end of April of the M.Sc. 1 year, and starting their research in early May, should submit their theses preferably by the end of April, and no later than the end of June of the M.Sc. 2 year.

Tracking Research Progress

AOS does not require research progress tracking for M.Sc. students. It is only required if the supervisor requests it.

Ph.D. Curriculum

A student who has obtained a Master's degree at McGill University or at an approved institution in Atmospheric Science (Meteorology), Physical Oceanography, or a related physical science field, and is proceeding to a Ph.D. degree, will, on the recommendation of the department, be admitted at the Ph.D. 2 level. In this case, the residency requirement for the program is two years.

Students without a related Master's degree may be admitted to the Ph.D. 1 level. The first year is then devoted mainly to coursework and is usually similar to the M.Sc. 1 year (refer to M.Sc. 1 curriculum). The selection of courses is made in consultation with the Ph.D. research supervisor and is subject to the approval of the GPD. Candidates entering Ph.D. 1 must follow a program of at least three years' residency at the University.

The minimum course requirements are given below.

REQUIRED COURSES (1 credit)		
ATOC 700	Ph.D. Proposal Seminar	1 cr.
ATOC 701	Ph.D. Comprehensive (General)	0 cr.
COMPLEMENTARY COURSES (7 credits)		
ATOC 751 D1/D2	Seminar: Physical Meteorology	1 cr.
OR		
ATOC 752 D1/D2	Atmospheric, Oceanic & Climate Dynamics Seminar	1 cr.
<ul style="list-style-type: none"> ▪ The remaining 6 credits are chosen from the Department of Atmospheric and Oceanic Sciences, at the 500 or 600 level, as approved by the research supervisor and the Graduate Program Director (GPD). This requirement may be waived by the GPD for students whose prior experience or achievements give clear evidence that the additional courses are unnecessary. 		

Ph.D. Comprehensive (General) and Thesis Proposal Examination

Refer to the "[Ph.D. Comprehensives Policy](#)" section of the McGill University eCalendar. Both ATOC 701 and ATOC 700 fall under this comprehensive policy.

Ph.D. candidates are required to take **two examinations**, **ATOC 701** (Ph.D. Comprehensive (General)) and **ATOC 700** (Ph.D. Proposal Seminar), usually during their Ph.D. 2 and Ph.D. 3 years, respectively. The results of these examinations determine whether students will be permitted to continue in their programs. The methods adopted for examination and evaluation and the areas to be examined, are specified by departmental regulations and approved by Graduate and Postdoctoral Studies. It is the responsibility of students to inform themselves of these details. For more information, see [University Regulations & Resources > Graduate > Guidelines and Policies > Ph.D. Comprehensives Policy](#).

ATOC 701 – Ph.D. Comprehensive (General)

- ATOC 701 is an **oral examination** conducted by a committee ordinarily consisting of three examiners, one of whom is the student's supervisor. This examination is intended to determine whether the candidate has a sufficiently broad understanding of topics in atmospheric sciences, climate dynamics and/or physical oceanography to proceed in the Ph.D. program. The level of knowledge should be

sufficient, for example, to allow the candidate to teach at the undergraduate level. The candidate will be **examined on three topics** of atmospheric and oceanic sciences:

Topics	Associated Courses
Atmospheric Chemistry	ATOC/CHEM 519
Atmospheric Radiation	ATOC 525
Climate Dynamics	ATOC 531
Cloud Physics	ATOC 521
Geophysical Fluid Dynamics	ATOC 512, 513
Mesoscale Meteorology	ATOC 548
Numerical Methods	ATOC 558
Physical Oceanography	ATOC 568
Remote Sensing	ATOC 626
Synoptic Meteorology	ATOC 540, 541
Turbulence	ATOC 515
Notes:	
¹ Another topic of direct relevance to atmospheric and oceanic sciences may be substituted for one of the above only in special cases and only with the approval of the Graduate Program Director or Chair.	
² The listed associated courses provide guidance on the material covered and the level of knowledge expected. While having taken an associated course may be beneficial, it is not a requirement for selecting a certain topic (e.g. a student may already possess equivalent knowledge). Students are advised to discuss expectations for their selection of topics with their exam committee sufficiently in advance of the comprehensive exam.	

- The student selects the three topics, subject to the approval of his/her Ph.D. supervisor and must inform the departmental Chair of these choices. The student may consult the members of the examining committee for advice on how to best prepare for the examination. **The examination will take place in the last four months of the Ph.D. 2 year.** Questions will not only test knowledge of the material in a particular book or books but will also test the candidate's ability to reason and to synthesize ideas from different areas. After the examination, whether a student passes or fails, feedback will be given to the candidate by his or her supervisor. If the candidate **fails the examination**, a grade of **HH (which designates "Continuing")** is assigned and s/he may **take** the Comprehensive (General) examination a **second time**, within a minimum of four months and a maximum of six months. **A second failure, however, requires withdrawal from the Ph.D. program.**

ATOC 700 – Ph.D. Proposal Seminar

- ATOC 700 consists of a **written proposal and an oral presentation (approximately 30 minutes in length)** followed by an examination before a committee of at least three professors (four if the student is co-supervised), consisting of the student's supervisor(s) as well as at least two other full-time AOS faculty members designated by the Department's Chair. This examination is intended to assess the candidate's preparedness for undertaking original research in a particular subject area,

and it should be **taken 6 to 12 months after passing ATOC 701.**

- The student must submit a **written thesis proposal** of about **20 pages** (typewritten, double-spaced) to the ATOC 700 examination committee at least one week before the date of the oral presentation. This proposal should define the problem to be discussed, demonstrate that the candidate is familiar with the literature, describe the methodology to be used, present some preliminary results, and outline future work. The oral presentation can be given as part of the ATOC 751 or 752 seminar series, or at a specially scheduled seminar open to the students and faculty of AOS. Following the question period after the presentation, the candidate will be questioned further by the examination committee in absence of an audience.
- A grade of **Passed** is reported to the Graduate and Postdoctoral Studies office if the committee is satisfied that the candidate is adequately prepared to undertake the proposed research. If the examining committee is not satisfied and the candidate **fails** the examination, a grade of **HH (which designates “Continuing”)** is assigned. In this case, after receiving appropriate feedback from the examination committee, the candidate is allowed to take the thesis proposal examination a second time in the presence of the same committee, within a minimum of four months and a maximum of six months. **A second failure of ATOC 700, however, requires withdrawal from the Ph.D. program.**

Ph.D. Supervisory Committee

Purpose

- The role of the Supervisory Committee is to assist the Ph.D. student in the advancement of his/her research and thesis, and to evaluate and report on progress.
- The primary responsibility for carrying out the research project rests with the student.
- The responsibility for day-to-day evaluation of work, providing suggestions and constructive criticism, and the overall guidance of the research belongs to the supervisor. Additional perspective provided by other members of the committee can be helpful to both student and supervisor. The committee may consider issues such as the validity of the approach, technical problems, the significance of results, directions to be taken in the future, and complementary course work. The Supervisory Committee participates actively in the setting of research goals and evaluating progress as detailed below.

Appointment of Members

- A Supervisory Committee will be selected after the Ph.D. Comprehensive (General) examination, usually on the basis of consultations between the student, the supervisor, prospective members of the committee and the Department Chair.
- This Committee should consist of a minimum of two faculty members (including the supervisor). Committee members are typically professors in the Atmospheric and Oceanic Sciences; however, professors in other McGill departments may also be appropriate in some cases. A minimum of two committee members must be full-time at McGill.

Graduate Student Research Progress Tracking

- McGill requires annual tracking of doctoral students' progress toward the degree. The [Graduate Student Research Progress Tracking Form](#) is to be used during face-to-face meetings between the doctoral student, supervisor, and at least one other departmental representative. Having written agreed-upon expectations and clearly defined requirements aids in reducing times to completion and leads to fewer supervisor-supervisee misunderstandings.
- At least annually, there must be a progress tracking meeting at which objectives for the upcoming year are established and prior progress recorded and evaluated. For doctoral students whose committees have already been formed, a member of the supervisory committee or a representative from the academic unit must also attend.
- Students should be informed of the phases through which they must pass towards the achievement of the graduate degree, the approximate amount of time each phase should take, the criteria for successful completion, and any deadlines relating to these phases.

Procedure:

- At the first annual progress reporting meeting (to be held shortly after doctoral students begin their programs), written objectives/expectations for the year must be recorded in the OBJECTIVES box on page 1 of the form. Those attending the meeting—the student, the supervisor, and, in the case of Ph.D. students whose committees have been formed, a member of the supervisory committee or a representative from the academic unit—must sign the form on page 3.
- Subsequently, the student and supervisor(s), and a member of the supervisory committee or a representative from the academic unit, must meet annually to review the progress that has been achieved toward the recorded objectives. Prior to these meetings, the student should record his/her accomplishments and progress for the year by completing the PROGRESS box on page 1 of the form. This completed form is then evaluated by the committee (i.e., supervisor and the member of the supervisory committee or a representative from the academic unit) on page 2 of the form. All parties sign the form on page 3. At this same meeting, objectives for the following year should be recorded in the OBJECTIVES box on page 1 of the same form.
- This form may also be supplemented with unit-specific details or documents (see page 2 of the form).
- If progress is judged unsatisfactory, a follow-up progress tracking meeting must occur not sooner than 4 months and not later than 6 months after the first report. A deadline for the follow-up meeting must be indicated on page 2 of the form.
- Two unsatisfactory reports (not necessarily successive) constitute unsatisfactory progress towards the degree and, if recommended by the academic unit, the student will be withdrawn from the University.
- A student or faculty member who refuses to sign the form must write a statement detailing their reasons for not signing.
- In cases where the student has missed an established progress report deadline and has not responded to the unit within 4 weeks after being contacted by the academic unit, the report may be completed in the student's absence, and progress may be judged unsatisfactory.
- The Graduate Program Director must review and sign all Progress Tracking Reports. If the Graduate Program Director is the supervisor, the Chair's signature is required.

- It is the **graduate student's responsibility** to properly **complete these forms** throughout the duration of their Ph.D. degree. Original copies of all the tracking forms are kept in the student's file in the departmental office. Ideally, copies of these forms should also be retained by the student and her/his supervisor.

GRADUATE COURSES – Descriptions

ATOC 512 Atmospheric and Oceanic Dynamics (3 credits)

Introduction to the fluid dynamics of large-scale flows of the atmosphere and oceans. Stratification of atmosphere and oceans. Equations of state, thermodynamics and momentum. Kinematics, circulation, and vorticity. Hydrostatic and quasi-geostrophic flows. Brief introduction to wave motions, flow over topography, Ekman boundary layers, turbulence.

Offered in Fall 2021

ATOC 513 Waves and Stability (3 credits)

Linear theory of waves in rotating and stratified media. Geostrophic adjustment and model initialization. Wave propagation in slowly varying media. Mountain waves; waves in shear flows. Barotropic, baroclinic, symmetric, and Kelvin-Helmholtz instability. Wave-mean flow interaction. Equatorially trapped waves.

Offered in Winter 2022

ATOC 515 Turbulence in the Atmosphere and Oceans (3 credits)

Application of statistical and semi-empirical methods to the study of geophysical turbulence. Reynolds' equations, dimensional analysis, and similarity. The surface and planetary boundary layers. Oceanic mixed layer. Theories of isotropic two- and three-dimensional turbulence: energy and enstrophy inertial ranges. Beta turbulence.

Not offered 2021–2022

ATOC 519 Advances in Chemistry of Atmosphere (3 credits)

Selected areas of atmospheric chemistry from field and laboratory to theoretical modelling are examined. The principles of atmospheric reactions (gas, liquid and heterogeneous phases in aerosols and clouds) and issues related to chemical global change will be explored.

Not offered 2021–2022

ATOC 521 Cloud Physics (3 credits)

Review of dry and moist atmospheric thermodynamics concepts. Atmospheric aerosols, nucleation of water and ice. Formation and growth of cloud droplets and ice crystals. Initiation of precipitation. Severe storms and hail. Weather modification. Numerical cloud models.

Offered in Winter 2022

ATOC 525 Atmospheric Radiation (3 credits)

Solar and terrestrial radiation. Interactions of molecules, aerosols, clouds, and precipitation with radiation of various wavelengths. Radiative transfer through the clear and cloudy atmosphere. Radiation budgets. Satellite and ground-based measurements. Climate implications.

Offered in Fall 2021

ATOC 530 Paleoclimate Dynamics (3 credits)

Introduction to the components of the climate system. Review of paleoclimates. Physical processes and models of climate and climate change.

Not offered 2021–2022

ATOC 531 Dynamics of Current Climates (3 credits)

The general circulation of the atmosphere and oceans. Atmospheric and oceanic general circulation models. Observations and models of the El Niño and Southern Oscillation phenomena.

Offered in Fall 2021

ATOC 540 Synoptic Meteorology 1 (3 credits)

Analysis of current meteorological data. Description of a geostrophic, hydrostatic atmosphere. Ageostrophic circulations and hydrostatic instabilities. Kinematic and thermodynamic methods of computing vertical motions. Tropical and extratropical condensation rates. Barotropic and equivalent barotropic atmospheres.

Offered in Fall 2021

ATOC 541 Synoptic Meteorology 2 (3 credits)

Analysis of current meteorological data. Quasi-geostrophic theory, including the omega equation, as it relates to extratropical cyclone and anticyclone development. Frontogenesis and frontal circulations in the lower and upper troposphere. Cumulus convection and its relationship to tropical and extratropical circulations. Diagnostic case study work.

Offered in Winter 2022

ATOC 548 Mesoscale Meteorology (3 credits)

Theory of meteorologically important mesoscale phenomena including mesoscale instabilities, cumulus convection and its organization (including thunderstorms, squall lines, and other forms of severe weather), internal gravity waves, and topographically forced flows. Application of theory to the physical interpretation of observations and numerical simulations.

Offered in Winter 2022

ATOC 551 Selected Topics 1 (3 credits)

Topics in atmospheric and oceanic sciences.

Not offered 2021–2022

ATOC 552 Selected Topics 2 (3 credits)

Topics in atmospheric and oceanic sciences.

Not offered 2021–2022

ATOC 555 Field Course 1 (3 credits)

Field studies in selected topics of the atmospheric and oceanic sciences.

TBD; may be offered in Summer 2022

ATOC 556 Field Course 2 (3 credits)

Field studies in selected topics of the atmospheric and oceanic sciences.

Not offered 2021–2022

ATOC 557 Research Methods: Atmospheric and Oceanic Science (3 credits)

This course is focused on the analysis of observational and modeling data, and the advantages and limitations of different data are discussed. The course covers several analysis methods (regression, principal component analysis, optimal estimation) commonly used in the atmospheric and oceanic sciences. In addition to the theory underlying these methods, there will be hands-on applications to observations of Earth.

Offered in Fall 2021

ATOC 558 Numerical Methods and Laboratory (3 credits)

Numerical simulation of atmospheric and oceanic processes. Finite difference, finite element, and spectral modelling techniques. Term project including computer modelling of convection or large-scale flows in the atmosphere or ocean.

Not offered 2021–2022

ATOC 568 Ocean Physics (3 credits)

Research methods in physical oceanography including data analysis and literature review. Course will be divided into five separate modules focusing on temperature-salinity patterns, ocean circulation, boundary layers, wave phenomena and tides.

Not offered 2021–2022

ATOC 616 Topics in Geophysical Fluid Dynamics (3 credits)

Advanced topics in the dynamics of oceanic and atmospheric flows.

Not offered 2021–2022

ATOC 626 Atmospheric/Oceanic Remote Sensing (3 credits)

Principles of radiative transfer applied to observing the atmosphere and oceans by satellite, radar, and other methods of remote sensing. Applications to cloud physics and climate research.

Not offered 2021–2022

ATOC 642 D1/D2 Weather Briefing (1 credit)

Not offered 2021–2022

ATOC 670 Reading Course: Meteorology 1 (3 credits)

Assigned reading of a specialized topic in meteorology with formal evaluation.

Offered every Fall and Winter

ATOC 671 Reading Course: Meteorology 2 (3 credits)

Assigned reading of a specialized topic in meteorology with formal evaluation.

Offered every Fall and Winter

ATOC 672 Reading Course: Oceanography 1 (3 credits)

Assigned reading of a specialized topic in oceanography with formal evaluation.

Offered every Fall and Winter

ATOC 673 Reading Course: Oceanography 2 (3 credits)

Assigned reading of a specialized topic in oceanography with formal evaluation.

Not offered 2021–2022

ATOC 681 Adv. in Meteorology and Physical Oceanography (3 credits)

Not offered 2021–2022

ATOC 691 Master's Thesis Literature Review (3 credits)

Review of the relevant literature in preparation for the M.Sc. research.

Offered every Fall and Winter

ATOC 692 Master's Thesis Research 1 (6 credits)

Independent research under the supervision of the student's M.Sc. supervisor.

Offered every Fall and Winter

ATOC 693 Master's Thesis Research 2 (6 credits)

Independent research under the supervision of the student's M.Sc. supervisor.

Offered every Fall and Winter

ATOC 694 Master's Thesis Progress Report and Seminar (3 credits)

Written report on the M.Sc. research progress and oral presentation of the report in seminar form to staff and students.

Offered every Fall and Winter

ATOC 695 Master's Thesis Research 3 (6 credits)

Independent research under the supervision of the student's M.Sc. supervisor.

Offered every Fall and Winter

ATOC 696 Master's Thesis Research 4 (6 credits)

Independent research under the supervision of the student's M.Sc. supervisor.

Not offered 2021–2022

ATOC 698 Thesis Research 1 (16 credits)

Not offered 2021–2022

ATOC 699 Master's Thesis (12 credits)

Independent research under the supervision of the student's M.Sc. supervisor leading to the M.Sc. thesis.

Offered every Fall and Winter

ATOC 700 Ph.D. Proposal Seminar (refer to p. 15)

Offered every Fall, Winter, and Summer

ATOC 701 Ph.D. Comprehensive (General) (refer to p. 14)

Offered every Fall, Winter, and Summer

ATOC 751 D1/D2 Seminar: Physical Meteorology (1 credit)

Seminars on topics in physical meteorology. Students are required to present one or more seminars during the year on their thesis research and to participate actively in the seminars given by others. Offered every Fall and Winter

ATOC 752 D1/D2 Atmospheric, Oceanic & Climate Dynamics Seminar (1 credit)

Seminars on topics in atmospheric, oceanic and climate dynamics. Students are required to present one or more seminars during the year on their thesis research and to participate actively in the seminars given by others. Offered every Fall and Winter

STUDENT SERVICES – DOWNTOWN CAMPUS

Unless otherwise indicated, all Student Services on the Downtown Campus are located in the William and Mary Brown Student Services Building, 3600 McTavish Street, Montreal, Quebec, H3A 1Y2. Below is a list of some services available in that building. For further information, consult: <https://www.mcgill.ca/studentservices/>.

Campus Life and Engagement

To ensure that your transition into the academic and social life at McGill University is as smooth as possible, the Campus life and Engagement office helps newly admitted students prepare for the course registration period on Minerva. The CL&E staff is always available to provide advice and referrals to the many support mechanisms at McGill.

Telephone	(514) 398–6913
Email	graduatefunding.gps@mcgill.ca
Website	https://www.mcgill.ca/gps/

Student Wellness Hub

The Student Wellness Hub is a renovated space that has consolidated and expanded Health Services, Counselling and Psychiatric Services. It features staff, clinicians and medical professionals, for any and all health and wellness needs that a student may have. It is located on the third, fourth and fifth floors of the Brown Building.

All full- and part-time students who have paid student service fees are eligible for services free of charge. 30-minute drop-in counselling appointments are available if you do not have a regular counsellor at the Hub and have a single mental health issue that you think could be addressed in 1 session. Drop-ins with a doctor or nurse are available to anyone. They can provide emergency care, prescription renewals, referrals and other services. Owing to the COVID-19 pandemic, many of the student services offered by the Wellness Hub may be by remote delivery. For details, click visit the "[How to Access Student Services](#)" page.

Address	3600 McTavish Street Brown Student Services Building, 3 rd Floor Montreal, Quebec H3A 1Y2 Canada
Telephone	(514) 398–3601
Email	wellness.hub@mcgill.ca
Website	https://www.mcgill.ca/wellness-hub/

Keep.meSafe

Keep.meSAFE is a mental health counselling service that specializes in student mental health support and provides access to:

- In-person counselling appointments with hundreds of licensed counsellors in the City of Montreal, with minimal wait times.
- 24/7/365 immediate and unlimited access to licensed counsellors through telephone and mobile chat, even when travelling abroad.
- Mental health care in over 60 languages.

The website is: <https://ssmu.ca/blog/2020/03/mental-health-resource-available-keep-mesafe/>

Never Alone

What is Never Alone?

Never Alone is an information and referral service created to support youth in Montreal during the COVID-19 outbreak. We operate by phone, text, and live chat. Chatline operators can provide answers to common questions and point you to resources for other kinds of support. We cannot provide medical or other advice.

Who can use the chatline?

Anyone in need of information or Montreal-based resources can access the chatline by call, text, or instant message. Currently their hours of operation are Monday-Friday, 4 PM-7 PM. If you need support outside these hours, send them a message and a volunteer will get back to you when they're online.

The website is:

<https://www.covidchatmtl.com/?fbclid=IwAR3x3IPDPRkkGgfDnwJTHHLaiLoF9Zcnl5XvNS7Lt2FJySSWG3wSH0GKCoQ>

The Office for Students with Disabilities (OSD)

The OSD works with students who have documented disabilities, mental health issues, chronic health conditions, or other impairments. These may be temporary, permanent, or episodic. Students must book an appointment with an Access Services Advisor to discuss their barriers and to determine what resources or accommodations will help to make their time at McGill a success. For more information, visit <https://mcgill.ca/osd/>.

Address	Office for Students with Disabilities (OSD) 1010 Sherbrooke Ouest Suite 410 Montreal, Quebec H3A 2R7 Canada
Telephone	(514) 398-6009
Email	disabilities.students@mcgill.ca.

Website <https://www.mcgill.ca/osd/>

Career Planning Service (CAPS)

The Career Planning Service (CAPS) is principally funded by McGill student services fees and receives support from corporate and alumni sponsorships. CAPS assists students in their career development and search for permanent, part-time, and summer jobs, as well as internships, by providing workshops, individual advising, a comprehensive job posting service, and an extensive Career Resource Centre. We serve all full-time students, including graduates, up to three years after the end of their studies.

Employers come to CAPS to look for talented students and graduates with skills that they need for their businesses and organizations. CAPS can provide employers with many services to help them find the best students for their employment needs. Our recruitment services are provided to employers free of charge and are offered year-round.

Address	3600 McTavish Street Brown Student Services Building, suite 2200 Montreal, Quebec H3A 1Y2 Canada
Telephone	(514) 398-3304
Email	careers.caps@mcgill.ca
Website	https://www.mcgill.ca/caps/

Scholarships and Student (Financial) Aid Office

McGill offers financial aid in the form of loans (money that needs to eventually be repaid) and bursaries (money that does not need to be repaid) to eligible students who demonstrate financial need. The assistance provided by the Scholarships and Student (Financial) Aid Office is meant to supplement other sources of core funding such as government aid, parental support, part-time work and, in some cases, a student line of credit from the bank. Their mission is to promote accessibility, support retention and encourage scholarship through financial awards for needy and deserving students in any degree program from any geographic origin.

They also administer The Work Study Program. Work study offers students with financial need access to clerical, research, technical, library or other jobs on campus or in some of the McGill-affiliated hospitals and organizations. The program not only helps students financially but can develop career-related skills and experience. A student's acceptance to the program is based primarily on financial need. If you are interested, you can check the eligibility requirements and apply to participate in the program on Minerva. If you are accepted to participate in the Work Study program, you can apply for the Work Study jobs listed on the job postings page online. You apply directly to the employers and get paid by the employers for your work. For more information, visit: <https://www.mcgill.ca/studentaid/work-study>.

McGill University has a comprehensive scholarship and award program to recognize honour and

encourage the outstanding achievements of its undergraduate students at different levels of study. For a comprehensive list of all scholarships and awards with detailed descriptions and eligibility requirements, please consult the Undergraduate Scholarships and Awards Calendar: <https://www.mcgill.ca/studentawards/undergraduate-scholarships-and-awards>

Address	3600 McTavish Street Brown Student Services Building, suite 3200 Montreal, Quebec H3A 1Y2 Canada
Telephone	(514) 398-6013
Emails	scholarships@mcgill.ca ; student.aid@mcgill.ca
Website	www.mcgill.ca/studentaid
Opening Hours	Monday to Friday: 10-00 am – 4:30 pm

The Student Society of McGill University (PGSS)

Every graduate at McGill is a member of the PGSS. They are there to speak out for you and advocate for your interests. On the local university levels, this means being your representation to the McGill administration. Operating within the University Centre, the PGSS oversees a wide array of clubs, services and events. For more information, visit their website at <https://pgss.mcgill.ca/en/home>

RESEARCH INTERESTS OF FACULTY MEMBERS

Parisa Ariya – Atmospheric and Interfacial (Atmosphere-Ocean) Chemistry

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Research interests

Our laboratory's mission is to explore major fundamental, and applied research questions on chemical and physical processes involving aerosols, as well as organic and metal pollutants of relevance to the Earth's atmosphere and its interfaces. Our direct research contributions are to the fields of atmospheric sciences and climate change, specifically aerosol-cloud interaction, air pollution, atmosphere-ocean interactions, physical and analytical chemistry, sustainable chemistry and technology, nanoscience, environmental health, and medicine.

The IPCC (2013) points to the importance of aerosol-cloud processes due to their impact on the absorption and scattering of radiation and altering the Earth's climate, whereas the WHO (2015) predominantly considers aerosols to be health hazards. It has become increasingly clear that both the climate and toxicity-health impact of nanoparticles are significantly affected by physical and chemical processes such as size, gas-particle partitioning, hygroscopicity, liquid-liquid phase separation, redox kinetics, surface tension, viscosity, molecular configuration, active sites, surface properties, and chemical composition. We have established expertise and infrastructure to perform aerosol research, including nanoparticles in air and air/snow/water surfaces, by contributing to address key uncertainties described above, and pioneering novel questions and solutions, with which affect climate and health challenges.

Our research is performed through complementary field (from Arctic to urban), laboratory and modeling research. Our state-of-the-art kinetic, surface and photochemical laboratory investigations are performed using ultra-fast and sensitive detection using various high-resolution lasers, second harmonic generation, long path FTIR, FT-Raman, various mass spectrometry, microscopy, surface sciences, air pollution and aerosols analyzers. We develop techniques and perform highly sensitive measurements of trace gaseous and particulate compounds. Complementary computational and atmospheric chemical modelling of the reaction intermediates in the atmosphere to simulate the complex physical-bio-chemical interactions. During the last decade, we have developed novel sustainable technology in air and water pollution remediation and smart sensors, which are efficient, energy neutral, recyclable with no

waste, and their life cycle analysis have been considered prior to their design and development. Our active research themes in our laboratories are:

- Aerosol-cloud interactions: Microphysics, ultra-trace characterization, ice nucleation
- Metals (namely Hg) in atmosphere and air/snow/water interface.
- Bioaerosols: Impact on Chemistry and Physics of the atmosphere.
- Development novel techniques for sustainable technology: Natural material, recyclable, energy neutral, efficient, with detailed studies of life cycle analysis
- Urban & Arctic air pollution
- Nanoparticles in atmosphere and in air/snow/water interfaces
- Development of real-time and in-situ technology for atmospheric observations of gases, radicals and aerosol
- Development of pollution remediation technology

Peter Bartello – Geophysical Fluid Dynamics

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Research interests

My research employs both theoretical and numerical techniques to study fluid turbulence in the atmosphere and oceans. A major thrust has been the study of the statistical nature of the flow as a function of rotation and stratification. The simplifying assumptions employed at larger scales, that rotation and stratification terms in the governing equations are predominant and approximately balanced by other terms, become invalid at smaller scales. The interactions between large-scale vortices and more general turbulent and wave motions are therefore the subject of these studies, as is the effect on the turbulent transport of passive scalars such as pollutants or ozone. A simple example is whether turbulent motions preferentially send energy downscale (as in a breaking wave at the shore) or upscale (as in the merging of two eddies to make a larger one). Both are known to occur, depending on the relative strengths of rotation and stratification. Both must be accounted for in coarse-resolution models, such as the ones used for weather and climate studies, but clearly in a different way.

In the large-scale limit wave motion is dissipated via downscale transfer to molecular scales. In this environment attention is naturally directed to the vortices, as they dominate the flow. They have often been considered as isolated, both from each other and from the rest of the motion. However, examinations of large-scale balanced turbulence without waves were able to formalize

the separation between isolated eddies and a low-level background of vorticity filaments. It remains to be seen whether these results extend to more complete models of geophysical flows.

Since there is a reliance on numerical simulation, research on numerics is undertaken in parallel. At the expense of accuracy, weather and climate models are forced to use numerical methods that allow for an enormous reduction in the true range of time and length scales. Minimizing the numerical damage as a function of the true flow's statistics is another research priority. I am also a member of the Applied Math group in the Department of Mathematics and Statistics.

Carolina Dufour – Physical Oceanography of Polar regions

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Research interests

We are interested in identifying and quantifying the physical processes that drive the response of polar oceans to climate change.

Polar oceans play a crucial role in the climate system by taking up and redistributing heat and carbon at global scale, thus greatly reducing the pace of climate warming. Among all the regions of the ocean, the Southern Ocean and North Atlantic are the largest anthropogenic carbon sinks. In addition, the Southern Ocean is thought to be the largest sink for excess heat from the atmosphere in the global ocean. Over recent decades, polar oceans have experienced significant changes, including increases in air temperature, glacial melt, and winds, that are expected to further intensify over the 21st century. These changes have the potential to greatly impact the ability of polar oceans to continue taking up large amounts of heat and carbon dioxide from the atmosphere with important implications for climate warming.

Our current research activities focus on addressing the following questions:

1. How are excess heat and anthropogenic carbon taken up in polar ocean regions, and will these sinks persist in the future?
2. How is heat transported towards high-latitudes and how does that affect sea ice, ice-shelf melting and sea level?

3. What drives the current sea ice variability and its response to climate change, and what impact will this response have on the regional and global climate?

To investigate these questions, we mainly use realistic models of the ocean-sea ice system or of the whole climate system. Though mainly focused on physical oceanography, our research has close connection with marine biogeochemistry (carbon cycle) and the cryosphere (sea ice and ice-shelves).

Frédéric Fabry – Radio Meteorology and Precipitation Physics

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Research interests

Short-term (0-3 hr) prediction of disrupting atmospheric phenomena is one of the rare areas of meteorology that has not seen any significant progress in the past few decades. As a result, the most publicly visible forecast busts in recent years occurred from missed warnings of severe weather. Short-term prediction is also a task where we do not yet largely rely on numerical forecasting. There are many reasons for this: severe atmospheric phenomena evolve quickly; their numerical prediction requires considerable processing as well as proper initial conditions at high resolution; these initial conditions, coming largely from remote sensing, remain currently incomplete especially on properties that drive storm evolution such as temperature, humidity, and winds.

To overcome these problems, progress must occur on many fronts. We must improve the quantity and quality of the data to be assimilated in models. Radar data assimilation is also more complex than that of other data, and radar-specific ideas should be explored. It is also possible that direct detection and non-numerical forecasting may remain the only practical prediction approach in the foreseeable future, and we need to develop new ideas on that front too.

My research interests hence include:

Improving the remote sensing of atmospheric properties

On the technical side, we must improve the quantity, quality, and variety of data available to initialize models properly. This includes:

- The improved exploitation of a radar-based technique to estimate the index of refraction

of air near the surface (Fabry et al. 1997; Feng et al. 2016). This provides valuable information especially on near-surface humidity at both small scales around a radar and at larger scales when considering constraints from many radars (Feng and Fabry 2018);

- The development of new signal processing techniques to extend the coverage of radar data and provide more constraints to initialize numerical models, or to understand problems with existing approaches (Fabry et al. 2013);
- Experimentation with new remote sensing techniques such as a scanning microwave radiometer to constrain humidity over larger areas than traditional instruments (Fabry and Meunier 2009; Themens and Fabry 2014);
- The meteorological analysis of data from our sensors. We operate a variety of instruments that we use to study atmospheric processes and their radar signatures such as riming (Vogel and Fabry 2018) or that we combine with other sensors to extract more information and evaluate model performance (e.g., Radhakrishna et al. 2015).

Data assimilation at the convective scale

Data assimilation is a well-established yet evolving technique to combine optimally the information from past forecasts and the constraints from new measurements to obtain the best estimate of initial conditions for generating useful forecasts. But radar data assimilation proves difficult: information is better on the storms' consequences (precipitation, storm flows) than on its causes (temperature, humidity, environmental winds); it is also limited about fields that will affect the storms' future (e.g., inflow properties). Extracting and properly constraining those properties is critical yet currently poorly done; we are hence investigating approaches to improve that task.

Nowcasting of precipitation and severe weather

Until now, for very short-term forecasts (known as "nowcasts"), nothing performs better than using radar data and extrapolating them in time. These short-term forecasts, are used for a variety of applications such as aviation weather and flood forecasting. Most approaches rely on decade-old ideas. We seek to improve these approaches by better exploiting the large radar data sets now available (Fabry et al. 2017) as well as the newly available frequent satellite information and model guidance.

John R. Gyakum – Synoptic and Dynamic Meteorology

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Research interests

Our research group conducts research on synoptic-dynamic analyses and forecasting of extreme

weather in the context of climate variability. The extreme weather research involves comprehensive analyses of dynamic and thermodynamic environments (and their variability in a changing climate) facilitating such phenomena as freezing rain storms, arctic air mass generation, extreme precipitation events in extratropical latitudes, and extreme extratropical cyclogenesis. We are also studying mesoscale processes in the Saint Lawrence River Valley (SLRV, where Montreal is located), with a focus on orographic modulation of wind, precipitation, and temperature. An example of the SLRV's impact on sensible weather is the channelling of winds that are associated with enhancing precipitation amounts beyond what can be expected for similar weather systems in level terrain.

Current projects

- Radiative processes in the generation of arctic air masses
- The identification and analysis of atmospheric circulation and weather regimes
- Baroclinic conditioning of environments facilitating extreme extratropical oceanic cyclogenesis
- Synoptic-dynamic analyses of long-duration freezing rain storms

Yi Huang – Atmospheric Radiation and Physical Climatology

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Research interests

We strive to improve the understanding of climate and weather from a radiation perspective. We use satellite observations, global climate models and radiative transfer models to gain fundamental understanding of the physical factors that control the radiation energy budget of the climate system. The topics of the problems that we address include:

- Radiative transfer theories,
- Atmospheric radiation and its variation in relation to other climatic variables,
- Remote sensing: using radiative measurements as a tool to infer atmospheric states and monitor weather and climate changes.

Current projects

- Variability of Earth radiation energy budget
- Role of radiation in global and regional climate changes, e.g., concerning Arctic sea ice
- Satellite and ground-based remote sensing of atmospheric temperature and constituents

Daniel Kirshbaum – Mesoscale Meteorology – Department Chair

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Research interests

Mesoscale dynamics and moist convection: cumulus convection is capable of producing severe local weather and plays a key role in the climate system. Because cumuli form at very small spatiotemporal scales and are inherently turbulent and chaotic, they are poorly resolved in weather and climate models and challenging to physically interpret. These challenges render cumulus convection and its collective effects highly uncertain in forecast models. Such uncertainty can be partially mitigated by ensemble methods (for convection-permitting regional weather models) or well-formulated physical parameterization schemes (for global weather and climate models).

The initiation of cumulus clouds in a conditionally unstable atmosphere is often decided by mesoscale processes that lift air to its level of free convection (LFC). The dynamics of such processes (e.g., mountain flows, fronts, drylines, and outflow boundaries) are thus another topic of intensive study. However, lifting to the LFC is only a necessary condition for convection initiation—other dynamical and microphysical processes (e.g., vertical wind shear, entrainment of dry environmental air, and the formation of ice) control whether such a cloud will ascend sufficiently deep to produce precipitation. My research uses a combination of observations and models of varying complexity to investigate the dynamics, cloud microphysics, and predictability of moist convection. It aims to quantify key related processes using simple mathematical models, which facilitate conceptual understanding and may be used to improve cumulus parameterization schemes in large-scale models.

Current projects

- Initiation of deep convection
- Cumulus entrainment
- Dynamics of mesoscale circulations
- Orographic precipitation: morphology, sensitivities, and prediction.
- Parameterization of shallow and deep convection in large-scale models.
- Predictability of convective precipitation in convection-permitting weather forecast models.

Timothy M. Merlis – Canada Research Chair in Atmospheric and Climate Dynamics

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Research interests

We research atmospheric circulations and their role in climate changes.

Our goal is to elucidate physical mechanisms underlying the response of atmospheric circulations, surface temperature and precipitation, and tropical cyclones to changes in radiative forcing. Systematic experimentation with numerical climate models allows us to develop climate theories that encompass not only Earth's current and future climate, but also the broader range of possible climates.

For more information, visit the group website: www.meteo.mcgill.ca/~tmerlis.

Thomas Preston – Atmospheric Chemistry

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Research interests

Our research group is focused on developing methods for the study of microphysical and chemical processes in atmospheric aerosol particles. Some topics of interest include: hygroscopicity and water transport, efflorescence and deliquescence, oxidative aging, and liquid-liquid phase separation.

The primary experimental method used by our group is optical trapping. This allows aerosols to be studied at the single particle level where physical parameters can then be determined with high precision and accuracy. Elastic and inelastic light scattering measurements from single particles are taken over time and are used to determine size and composition. We are also interested in the modelling of the interaction of electromagnetic radiation with particles as this

is necessary for the interpretation of measurements and important for the development of future instrumentation.

In summary, our lab uses single particle spectroscopy and modelling to understand fundamental thermodynamic and kinetic processes in atmospheric aerosols.

Djordje Romanic – Boundary-Layer, Applied and Dynamic Meteorology

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Website	https://www.mcgill.ca/meteo/facultystaff/djordje-romanic

Research interests

- Thunderstorm dynamics and thunderstorm winds
- Downbursts: Formation and dynamics of the near-surface outflow
- Tornadoes: Formation and evolution
- Urban boundary-layer processes and their links to sustainability & resilience
- Dynamics and climatology of local winds
- Applications of atmospheric sciences in wind engineering and the wind energy sector

Globally, there are around 2000 thunderstorms in progress at any given moment. Thunderstorms are associated with high-impact weather, such as tornadoes, downbursts, hail, lightning, and heavy precipitation. Severe thunderstorm winds and tornadoes cause major damages to the built environment across North America and in many other regions around the world. Our research group is particularly interested in the formation, dynamics, and evolution of tornadoes and downbursts. We use field measurements, numerical models, and physical experiments in a wind chamber to analyze these non-synoptic wind phenomena. The applications of our research are in the fields of wind engineering and urban sustainability & resilience. Modifications to downburst outflows caused by urban environments and the influence of roughness changes on the outflow dynamics are some of the open questions that we are trying to answer. Moreover, we are also actively investigating the interaction between downburst outflows and ambient atmospheric boundary layer winds.

In addition to thunderstorm winds and tornadoes, our research is also focused on the dynamics and climatology of local winds. Local winds are sub-synoptic scale wind systems whose dynamics and climatology are driven by the local orography, proximity to the large bodies of water, local

changes in surface roughness and land use, and other local-scale factors. By quantifying the local wind resources (in Canada) and their long-term trends, the research is directly contributing to the wind energy sector and the clean energy initiative. Furthermore, the interaction between local winds and urban environments is investigated in the context of urban sustainability.

David N. Straub – Physical Oceanography

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Research interests

My research uses geophysical fluid dynamics (GFD) and numerical modelling to study a variety of atmospheric and oceanic flows and flow regimes. Geophysical fluid flows are strongly influenced by buoyancy and by the earth's rotation (through the Coriolis force), both of which can act to make atmospheric and oceanic flows behave in counter-intuitive ways. For example, inertia-gravity waves have frequencies that depend on wave vector orientation, but not on wavelength and geostrophic turbulence does not cascade energy to small scales. The latter point implies that the dynamics of eddying ocean climate models, for example, dissipate energy only in associated with ad hoc parameterizations included in the models essentially for this purpose. Most of the work in my group centers on applications to the ocean or climate. Recent and ongoing projects include:

- Energetics of ocean circulation: Because geostrophic turbulence does not cascade mechanical energy towards dissipation length scales, it is not obvious how the energy budget of wind and buoyancy circulation is closed. The three principal mechanisms appear to be i) bottom drag, ii) a modulation of wind power input to the ocean via surface current and wave modulations of air-sea momentum transfer and iii) a transfer of energy from geostrophic to ageostrophic modes (which do transfer energy forward towards dissipation length scales). The first of these was long assumed to be dominant. Our work has shown the 2nd to be comparable in magnitude and has suggested the third as a dynamically interesting and plausible possibility. We are continuing work in these areas.
- Surface wave effects on air-sea interaction. Ocean circulation models take the wind stress to drive an interior ocean circulation. Anyone who has been to sea knows that this same wind stress also excites surface gravity waves. How these waves interact with the interior circulation has been extensively studied at small scales (e.g., Langmuir turbulence) and on global scales, but has not been extensively studied in flow regimes corresponding to the ocean's mesoscale current (such as the Gulf Stream) and eddy fields. Since the waves are refracted by these currents, there are clear signatures in the currents and eddies in the wave field. We are interested in how accounting for this mesoscale structure in the wave field impacts the currents and eddies, which in turn, act to shape large scale ocean

circulation.

- Signatures in sea surface height of different dynamical modes. Satellite altimetry is entering a new age in which sea surface height can be observed from space at horizontal length scales of a few kilometers. At these scales, geostrophically balanced modes no longer dominate the flow. It is therefore interesting to characterize how other flow regimes (quasi-linear waves, sub-mesoscale turbulence) are reflected in this signal. Understanding this is, in part, directly related to the two projects listed above.
- Other recent and ongoing projects include i) dynamics and transport of the Antarctic Circumpolar Current, ii) tropopause effects on rotating stratified turbulence, iii) effects of near-discontinuities in ice-ocean stress (e.g. related to sea ice leads) on upper ocean dynamics, iv) impacts of moisture and latent heat release in idealized models of atmospheric circulation in current and future climatic conditions, and v) quasi-zonal jets in ocean circulation models. More generally, I enjoy working in collaboration with students and colleagues on a wide range of topics with the aim of examining topics of current interest to the ocean and climate communities from the perspective of geophysical fluid dynamics.

Ivy Tan – Atmospheric Remote Sensing

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Research interests

We use a combination of remote sensing observations and global climate models to better understand and predict how clouds change in response to global warming. Our research is motivated by the fact that clouds contribute the largest uncertainty to climate projections in climate models. Some questions we strive to answer are:

1. How does cloud optical depth change in response to global warming? What are the dominant physical mechanisms responsible for these changes?
2. How does the unique environment of the Arctic influence mixed-phase clouds? How do these clouds in turn impact Arctic climate?
3. How can mixed-phase clouds be more realistically represented in large-scale climate models? Do more realistic representations of these clouds impact climate sensitivity?

Bruno Tremblay – High Latitude Climate and Climate Variability

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Research interests

I am interested in the high latitudes and their effect on global climate, local climate and lower latitudes. My research is centered on sea ice at the interface between the ocean and the atmosphere. The Arctic is transitioning from a perennial to a seasonal ice cover; this is often referred to as the Antarcticification of the Arctic Ocean. In my group, we study the impact of lateral and vertical ocean heat flux, surface radiative and turbulent fluxes, meridional moisture and heat transport and cloud type on the observed decline of sea ice. In addition to decadal projections of Arctic sea ice, I am interested in seasonal and sub-seasonal forecast of sea ice conditions. To this end, we use Global Climate Models (GCMs), coupled primitive equations ice-ocean models, and stand alone sea ice models. I also do field work in the Canadian Arctic and Labrador coast to study the sea ice mass balance and internal sea ice stresses. Finally, I am interested in the development of new sea ice rheological model (stress strain relationship) and the applications of new numerical techniques to solve for the highly non-linear momentum equation of sea ice.

Outstanding questions

- What is responsible for rapid sea ice decline in the Arctic Ocean?
- How will these changes impact the fresh water and heat budget of the Arctic? The fresh water exchange between the Arctic and the northern North Atlantic where deep convection is present? And vertical mixing of heat, salt and nutrient in the Arctic?
- What are potential sources of predictability of Arctic sea ice on sub-seasonal, seasonal and decadal time scale?
- How will negative feedbacks associated (for instance) with the potential increase in summer cloud cover and fresh water flux to the northern North Atlantic affect the response of the high latitude to this warming?
- What are the geophysical mechanical strength properties of sea ice?

Current projects

- The study of the fresh water and heat budget of the Arctic Ocean and its effect on the density driven ocean circulation and meridional ocean heat fluxes in the Arctic Ocean. This work is done using the Community Earth System Model Large Ensemble, in collaborations with Alexandra Jahn (Colorado State University) and Marika Holland

(NCAR) on the modelling side, and Peter Schlosser and Robert Newton from the Lamont Doherty Earth Observatory (LDEO) of Columbia University (CU) on the observational side.

- We use the paleo-record to constrain future projections of Arctic Climate Change. To this end, we consider the Mid Holocene Climatic Optimum as a proxy for future climate change in the Arctic. We identify GCMs that are sensitive to the increase summer solar insolation during the Mid Holocene Climate Optimum as suggested by paleo-proxy data and assess whether those same models are more sensitive to increase longwave radiative forcing associated with greenhouse gas.
- Development of new sea ice rheological models and the energetics of sea ice. This work is done in collaboration with Martin Losch from the Alfred Wegener Institute and Jean-François Lemieux from Environment and Climate Change Canada (ECCC).
- Development of new numerical solver using preconditioned Krylov methods.
- Rapid sea ice decline in the Arctic Ocean and its relationship with lateral ocean heat fluxes through the Bering Strait, Fram Strait and the Barents Sea Opening, vertical ocean heat flux associated with Ekman pumping along active sea ice leads, and surface turbulent and radiative fluxes at the ice surface.
- The effects of inertial oscillations on air-sea interactions, internal wave generation and vertical ocean mixing in ice-covered seas. This work is done in collaboration David Straub and Luc Rainville from the Applied Physics Laboratory – UW.
- Lagrangian study of pollutant, sediment and nutrients transport by Arctic sea ice. This work is done in collaboration with Stephanie Pfirman (University of Arizona) and Robert Newton (LDEO).
- Seasonal forecasting of sea ice using a Lagrangian Trajectory model. This work is done in collaboration with Bill Merryfield and Bertrand Denis (ECCC), Robert Newton (LDEO) and Stephanie Pfirman (University of Arizona).
- The impact of the low-level temperature inversion on the surface radiative balance in the Arctic Ocean. This work is done in collaboration with Jen Kay (Colorado State University).
- Ice stress and ice mass balance data analysis for the development of new sea ice dynamic models including thermal stress. This study is done in collaboration with Adrienne Tivy (Canadian Ice Service) and Jean-François Lemieux (ECCC).
- The study of sea ice arches using a linear elastic solid model. Derivation of sea ice mechanical properties of sea ice using this linear elastic solid model and satellite observations.

Man K. (Peter) Yau – Cloud Physics and Dynamics

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Research interests

1. Improving quantitative precipitation forecasts

NSERC and Hydro-Quebec has been supporting our Industrial Research Chair Program on “Improving short-term forecast of precipitation”. The efficient generation and distribution of hydro-electric power depends on accurate forecast of inflows in reservoirs and drainage basins, which in turn is affected significantly by the quality of the forecast of the type and amount of precipitation. During the first mandate of the Industrial Research Chair program (2009-2014), various tools have been developed to improve the forecast of when, where, how much, and what type of precipitation would occur over a lead time of one to two days. During the second mandate (2014-2019), this forecast lead time will be increased to one week which would be highly beneficial for capacity management of hydroelectric power.

Specific projects during the second mandate include study on condensation and collisional growth of cloud droplets in turbulence using direct numerical simulation (DNS) techniques, the development of a unified aerosol-microphysics multi-moment scheme across model resolutions, the improvement on the representation of upright and slantwise convection in the Canadian computer weather prediction models, and the evaluation of quantitative precipitation and hydrological forecasts as a result of the better representation of convective and cloud/precipitation processes.

2. Studies on hurricanes

Hurricanes are violent vortices in the atmosphere and can contribute significantly to precipitation. For hurricane prediction, two major problems remain. One is to forecast the rapid intensification (RI) of the storm and the other is to forecast when a storm will form.

Convection in the eyewall can affect RI in two ways. First, latent heating released in cloud processes is a main source of energy. Its spatial distribution affects RI especially when bursts of convection occur inside the radius of maximum wind. Second, latent heating in the eyewall produces a hollow tower of potential vorticity (PV) that supports propagating vortex Rossby waves (VRW) which may become unstable to mix eyewall PV into the eye to effect intensity change. Additionally, VRWs in a hurricane vortex can radiate gravity waves leading to another instability known as radiative pumping. The understanding of these instabilities is important to improve hurricane forecasting.

Our current research projects on hurricanes include:

- The role of microphysical processes on hurricane intensity changes and the distribution of precipitation.
- Mechanism for oscillating wobbles in tropical cyclones with concentric eyewalls.
- Kelvin cat’s eye and the genesis of hurricanes.

- The formation of elliptic eyewalls from spontaneous emission of spiral inertial-gravity waves.
- Dynamics of inner eyewall dissipation in hurricane Wilma (2005).

Andreas Zuend – Aerosol Chemistry and Physics

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Research interests

My group works in the field of Atmospheric Chemistry and Physics with a focus on the chemical and microphysical processes governing the formation and transformations of atmospheric aerosols.

Atmospheric aerosols are tiny particles suspended in the air. Despite the small mass contribution of aerosol particles when compared to the major gaseous constituents of a volume of air, this particulate form of matter in the atmosphere is of fundamental importance for urban and regional air quality and the global climate system. Aerosols are among the least understood and quantified climate agents, affecting Earth's radiation balance directly as well as indirectly via their crucial role in the formation of cloud droplets and influence on cloud microphysics. Part of the lack of knowledge is due to the complexity and variety of primary and secondary particle sources, the chemical composition, phases, and physical states of aerosols and the evolution of these properties during the lifetime of aerosols in the troposphere.

Current projects

Our research projects are motivated by the need to understand the chemical thermodynamics, reactions, and mass transfer kinetics of complex mixtures consisting of tens to thousands of oxidized organic compounds, water, and inorganic electrolytes that form and characterize the majority of aerosols in the troposphere. Improvements of the understanding and modeling of coupled processes between aerosols and the surrounding air lead to improvements in the interpretation of laboratory and field observations and predictions of air quality and aerosol–cloud–climate interactions.

We apply existing atmospheric chemical mechanisms, unique thermodynamic models and develop new numerical methods and system analysis tools for the characterization and prediction of aerosol particle composition, phases, viscosity and phase transitions at

environmental conditions. These tools allow us to improve the process-level understanding of atmospheric aerosol formation and evolution and enable the direct comparison to laboratory experiments and field studies performed by various collaborating groups. Recently, we have also contributed to the development of versatile reduced-complexity models of aerosol representations. Those simpler models are targeting applications in air quality and chemistry climate models, which cannot afford a detailed description of particle composition and related relative humidity effects on aerosol growth. In our group, we are also actively developing implementations of improved aerosol schemes into large-scale atmospheric chemistry models (such as GEOS-Chem and CMAQ). On the detailed aerosol modeling level, in a collaboration with an international team, we developed a new approach to model the composition-dependent surface tension of aerosol particles serving as nuclei of cloud droplets. In that study, we designed an extension to our state-of-the-art liquid–liquid phase separation model, so that growing particle size and changes in composition and surface tension were considered in a realistic way. This has shed new light on the role of organic compounds and organic-rich phases in cloud droplet formation – and opened new possibilities for addressing key questions about aerosol–cloud interactions in future research. Ongoing projects are further developing detailed, particle-size-dependent models, since on the sub-micrometer scale, the surface-to-volume ratio of droplets and particles becomes important.

Current projects include the development of theory and reliable numerical algorithms for the calculation of liquid–liquid phase separation, liquid–solid equilibria, water content and acidity of complex chemical mixtures representing ambient and laboratory aerosols. We also work on coupled gas–particle partitioning schemes ranging from high to low complexity for applications in chemical box models (0-D) and implementation in 3-D atmospheric chemistry transport and climate models. For such models we make use of existing cheminformatics tools as well as machine learning approaches – customized to our needs. Box models are, for example, applied to study the formation of so-called secondary organic aerosols from emissions and photochemical processing of volatile organic compounds due to incomplete combustion of jet fuel by passenger aircrafts during different phases of cruise flight/take-off/idling on ground. Ongoing work also focuses on the modeling of highly viscous phases of organic aerosols, their role in dynamic mass transfer in the atmosphere, and on how we can predict such particle properties in a feasible way.

Visit our group website for more information.

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