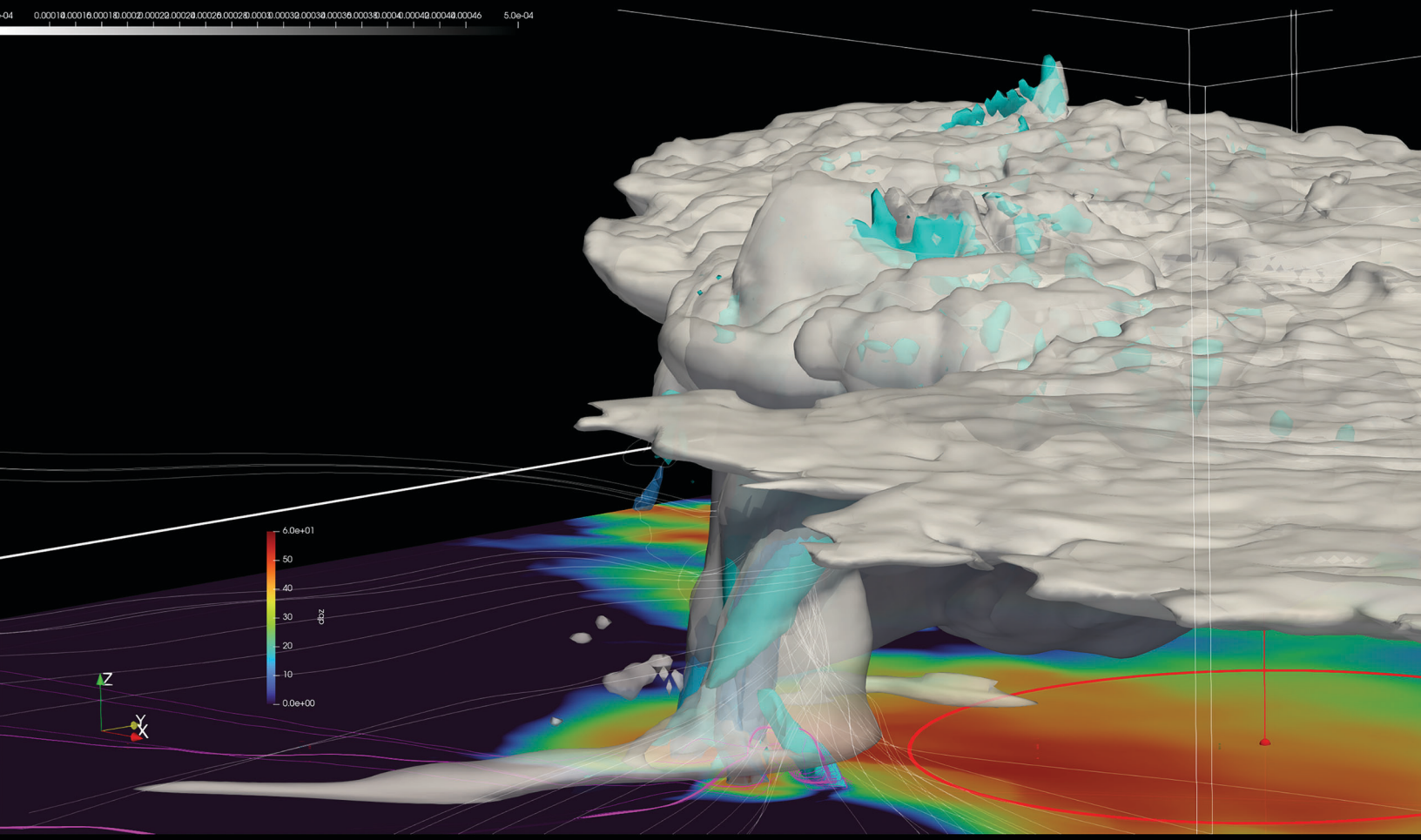
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Volume 82, No. 1
2026

Physics in Canada
La Physique au Canada



2026

Climate and the Environment

Climat et l'environnement

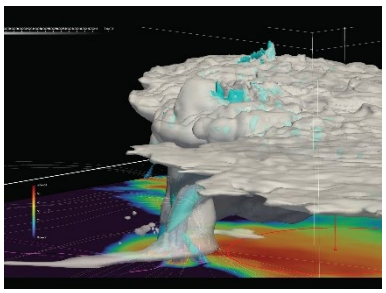
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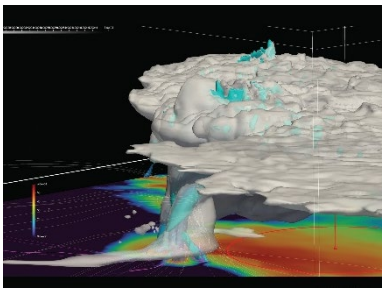
Simulating an extreme weather event



The cover image shows a simulated supercell with a tornado-like vortex: The gray and white surfaces show precipitation particles, with darker blue indicating rain. Cyan highlights areas of strong upward motion and rotation. The colors at the ground show radar reflectivity, which indicates the amount of precipitation-sized particles in the atmosphere. Higher values mean there are more particles or larger particles present. The white and pink lines show airflow paths (streamlines). The white streamlines pass through the middle of the storm and illustrate how air from lower levels feeds the thunderstorm. The pink streamlines start within the simulated tornado. In scientific studies, simulated tornadoes are often called tornado-like vortices because they closely resemble tornadoes but are identified from model simulations rather than direct observations. The pink streamlines highlight the strong rotation within the vortex and remain relatively close to the ground. The simulation is based on the EF4 tornado that occurred near Didsbury, Alberta, on July 1, 2024. Numerical simulations were conducted by undergraduate summer research students Luna Awad and Keya Raval under the supervision of Dr. Lisa Schielicke as part of the NSERC-funded project "Investigating Multiscale Vortex Interactions and their Importance for Extreme Weather in Canada". This research was enabled in part by support provided by SHARCNET (www.sharcnet.ca) and the Digital Research Alliance of Canada (alliancecan.ca).

by **Lisa Schielicke**
Associate Professor, Department of Physics and Astronomy, Western University

Simulation d'un phénomène météorologique extrême



L'image de couverture montre une supercellule simulée avec un vortex semblable à une tornade : les surfaces grises et blanches représentent les particules de précipitations, le bleu plus foncé indiquant la pluie. Le cyan met en évidence les zones de forts mouvements ascendants et de rotation. Les couleurs au niveau du sol indiquent la réflectivité radar, qui reflète la quantité de particules de la taille des précipitations présentes dans l'atmosphère. Des valeurs plus élevées signifient qu'il y a davantage de particules ou que celles-ci sont plus grosses. Les lignes blanches et roses indiquent les trajectoires des flux d'air (lignes de courant). Les lignes de courant blanches traversent le centre de l'orage et illustrent comment l'air provenant des couches inférieures alimente l'orage. Les lignes de courant roses prennent naissance à l'intérieur de la tornade simulée. Dans les études scientifiques, les tornades simulées sont souvent appelées « tourbillons de type tornade », car elles ressemblent étroitement à des tornades mais sont identifiées à partir de simulations de modèles plutôt que d'observations directes. Les lignes de courant roses mettent en évidence la forte rotation au sein du tourbillon et restent relativement proches du sol. La simulation s'appuie sur la tornade de catégorie EF4 qui s'est produite près de Didsbury, en Alberta, le 1er juillet 2024. Les simulations numériques ont été réalisées par Luna Awad et Keya Raval, étudiantes de premier cycle participant à un programme de recherche d'été, sous la supervision de la Dre Lisa Schielicke, dans le cadre du projet financé par le CRSNG intitulé « Étude des interactions entre tourbillons à plusieurs échelles et de leur importance pour les phénomènes météorologiques extrêmes au Canada ». Cette recherche a été rendue possible en partie grâce au soutien apporté par SHARCNET (www.sharcnet.ca) et la Digital Research Alliance of Canada (alliancecan.ca).

par **Lisa Schielicke**
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Physics in Canada
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Canadian Association of Physicists (CAP)
Association canadienne des physiciens et physiciennes (ACP)

The Canadian Association of Physicists was founded in 1945 as a non-profit association representing the interests of Canadian physicists. The CAP is a broadly-based national network of physicists working in Canadian educational, industrial, and research settings. We are a strong and effective advocacy group for support of, and excellence in, physics research and education. We represent the voice of Canadian physicists to government, granting agencies, and many international scientific societies. We are an enthusiastic sponsor of events and activities promoting Canadian physics and physicists, including the CAP's annual congress and national physics journal. We are proud to offer and continually enhance our web site as a key resource for individuals pursuing careers in physics and physics education. Details of the many activities of the Association can be found at http://www.cap.ca. Membership application forms are also available in the membership section of that website.

L'Association canadienne des physiciens et physiciennes a été fondée en 1946 comme une association à but non-lucratif représentant les intérêts des physicien(ne)s canadien(ne)s. L'ACP est un vaste regroupement de physiciens et de physiciennes oeuvrant dans les milieux canadiens de l'éducation, de l'industrie et de la recherche. Nous constituons un groupe de pression solide et efficace, ayant pour objectif le soutien de la recherche et de l'éducation en physique, et leur excellence. Nous sommes le porte-parole des physicien(ne)s canadien(ne)s auprès du gouvernement, des organismes subventionnaires et auprès de plusieurs sociétés scientifiques internationales. Nous nous faisons le promoteur enthousiaste d'événements et d'activités mettant à l'avant-scène la physique et les physicien(ne)s canadien(ne)s, en particulier le congrès annuel et la revue de l'Association. Nous sommes fiers d'offrir et de développer continuellement notre site Web pour en faire une ressource clé pour ceux qui poursuivent leur carrière en physique et dans l'enseignement de la physique. Vous pouvez trouver les renseignements concernant les nombreuses activités de l'ACP à http://www.cap.ca. Les formulaires d'adhésion sont aussi disponibles dans la rubrique « Adhésion » sur ce site.

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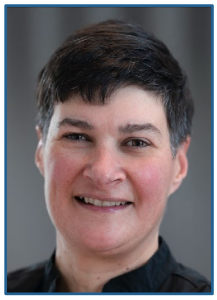
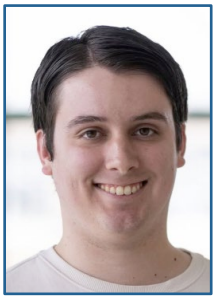
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The Editorial Board welcomes articles from readers suitable for, and understandable to, any practising or student physicist. Review papers and contributions of general interest of up to four journal pages in length are particularly welcome. Suggestions for theme topics and guest editors are also welcome and should be sent to the Editor-in-Chief, Béla Joós, at bjoos@uottawa.ca.

Le comité de rédaction invite les lecteurs à soumettre des articles qui intéresseraient et seraient compris par tout physicien, ou physicienne, et étudiant ou étudiante en physique. Les articles de synthèse d'une longueur d'au plus quatre pages de revue sont en particular bienvenus. Des suggestions de sujets pour des revues à thème sont aussi bienvenues et peuvent être envoyées à la Redacteur-en-chef, Béla Joós, à bjoos@uottawa.ca.

PHYSICS, CLIMATE AND THE TRANSITION TO SUSTAINABILITY

Pierre Bénard, Kris Poduska, and Jake Breen, Guest Editors, *Physics in Canada*

Understanding the mechanisms responsible for climate change and the capacity to predict its impact on ecosystems is essential for devising strategies to counteract or manage these changes—whether through policy action or the development of new environmental technologies. This task is fundamentally multidisciplinary, yet physics plays a significant role that often goes unrecognized.

The contribution of physics to the field of climate change can be broadly categorized into two domains. First, physics is crucial to understanding the underlying mechanisms—whether anthropogenic, atmospheric, geological, or astronomical in origin – including the analysis of how matter and energy flows resulting from human activity impact the environment at all scales. Second, physics plays a key role in developing the new materials, devices, and systems required for technologies that facilitate the energy transition.

These activities span a wide range of physics disciplines, crossing subdisciplines. In addition to core physics fields, they encompass atmospheric physics, geophysics, statistical physics, fluid mechanics, condensed matter physics, thermodynamics, and even astrophysics.

With this special issue of *Physics in Canada*, we aim to showcase the work of physicists in the fields of climate change and ecological transition technologies—areas that are growing in importance but remain, in our view, underrepresented in Canada. We therefore present an overview—necessarily incomplete—of the field through various contributions from fellow physicists across Canada.

In this special issue, there is an example of a climate tipping point by examination of the historical context and physical underpinnings of the hypothesis regarding the collapse of the Atlantic Meridional Overturning Circulation. Another article offers a discussion on the physics of contrails and their impact on climate change. The issue continues with a contribution on how physics enables a better understanding and prediction of severe storms to help mitigate their impacts, and another on the influence of climate cycles on the formation of specific patterns and landforms in the Canadian Arctic. Next, we examine how to quantify and characterize the environmental impact of our energy system through an article on the role of energy system modeling in developing decarbonization strategies to combat climate change.

We also recognize that climate change and the energy transition are changing physics education and training. In this context, there is an interview featuring an early-career researcher and two professionals in the field, discussing the challenges associated with research and researcher training in such a complex, multidisciplinary area. Additionally, there is a contribution from colleagues specializing

in physics education; they discuss how to incorporate atmospheric and environmental physics—subjects relevant to the research activities of approximately 20% of the faculty but traditionally underrepresented in university experimental curricula—into experimental physics courses.

We hope this special issue will illustrate the role physicists play in the energy transition and raise awareness of Canadian contributions to both climate change mitigation and adaptation.

Pierre Bénard, Université du Québec à Trois-Rivières
Kris Poduska, Memorial University
Jake Breen, Memorial University

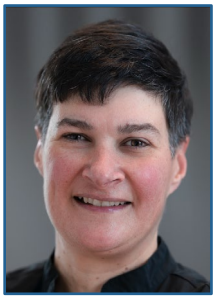
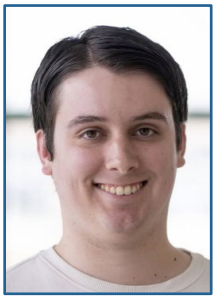
Guest Editors, Physics in Canada

The contents of this journal, including the views expressed above, do not necessarily represent the views or policies of the Canadian Association of Physicists.

Comments of readers on this Foreword are more than welcome.

LA PHYSIQUE, LES CHANGEMENTS CLIMATIQUES ET LA TRANSITION VERS LE DÉVELOPPEMENT DURABLE

Pierre Bénard, Kris Poduska, and Jake Breen, Rédacteurs invités, *La Physique au Canada*

La compréhension des mécanismes responsables des changements climatiques et la capacité de prédire leur impact sur les écosystèmes est nécessaire à l'élaboration de stratégies permettant de les contrecarrer ou de les gérer, soit par l'action politique ou par le développement de nouvelles technologies environnementales. Cette tâche est fondamentalement multidisciplinaire, mais la physique y joue un rôle significatif qui n'est pas souvent mis en exergue.

On peut en gros situer à deux niveaux la contribution de la physique au domaine des changements climatiques. La physique intervient d'abord la compréhension des mécanismes responsables sous-jacents, qui peuvent être d'origine anthropique, atmosphérique, géologique ou astronomique, incluant l'analyse de l'impact des courants de matière et d'énergie dégagés par l'activité humaine sur l'environnement, à tous les niveaux. Elle intervient également dans le développement de nouveaux matériaux, dispositifs ou systèmes nécessaires aux technologies de la transition écologique.

Ces activités recoupent des disciplines de la physique très différentes. Outre les disciplines de base, on y retrouve la physique de l'atmosphère, la géophysique, la physique statistique, la mécanique des fluides, la physique de la matière condensée, la thermodynamique et même l'astrophysique.

Nous cherchons, par ce numéro spécial de la Physique au Canada, à illustrer les activités des physiciennes et de physiciens dans le domaine des changements climatiques et des technologies de la transition écologique, un domaine qui gagne en importance mais qui demeure, nous le pensons, sous-représenté au Canada. Nous vous proposons donc un tour d'horizon forcément incomplet du domaine par l'entremise de plusieurs contributions de collègues physiciens à travers le Canada.

Nous abordons dans ce numéro spécial un exemple de point de basculement climatique en examinant le contexte historique et les fondements physiques de l'hypothèse de l'effondrement de la circulation méridienne de retournement de l'Atlantique. Nous vous proposons également une discussion sur la physique des trainées de condensation et leur impact sur les changements climatiques. Nous poursuivons avec une contribution sur comment la physique permet de mieux comprendre et prédire les orages violents afin de limiter leurs impacts, et une autre sur le rôle des cycles climatiques dans la formation de motifs et de reliefs inusités dans l'Arctique canadien. Nous examinons ensuite comment quantifier et qualifier l'impact de notre système énergétique sur l'environnement grâce à un article

portant sur le rôle de la modélisation des systèmes énergétiques pour établir des stratégies de décarbonation dans le contexte de la lutte aux changements climatiques.

L'importance des enjeux liés aux changements climatiques et à la transition énergétique a forcément des impacts sur enseignement et la formation en physique. Nous proposons donc une entrevue entre un chercheur en début de carrière et deux professionnels du domaine sur les enjeux liés à la recherche et à la formation de chercheurs dans une thématique aussi complexe et multidisciplinaire. Nous proposons également une contribution de nos collègues spécialisés en enseignement de la physique, portant sur comment inclure dans les cours de physique expérimental des éléments de la physique de l'atmosphère et de l'environnement, des sujets pertinents aux activités de recherche d'environ 20% du corps professoral, qui sont traditionnellement sous-représentées dans le curriculum expérimental universitaire.

Nous espérons que ce numéro spécial permettra d'illustrer le rôle des physiciens dans la transition écologique et de mieux faire connaitre les contributions canadiennes dans la lutte et l'adaptation aux changements climatiques.

Pierre Bénard, Université du Québec à Trois-Rivières
Kris Poduska, Memorial University
Jake Breen, Memorial University

Rédacteurs invités, *La Physique au Canada*

Le contenu de cette revue, ainsi que les opinions exprimées, ne représentent pas nécessairement les opinions ou les politiques de l'Association canadienne des physiciens et physiciennes.

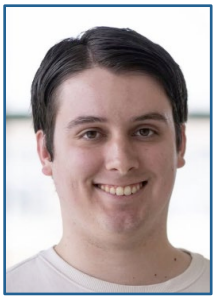
Les commentaires des lecteurs sur cette préface sont toujours les bienvenus.

NOTE: Le genre masculin n'a été utilisé que pour alleger le texte.

PERSPECTIVES ON EARLY CAREER AND HIGH-LEVEL TRAINING FOR CLIMATE AND ENVIRONMENTAL CHALLENGES

SUMMARY: An interview between an early career researcher and two professionals about their thoughts and perspectives on the challenges associated with climate, the environment, and education.





By **KRIS PODUSKA**[1,2] <kris@mun.ca>,
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In recent years, many new challenges have developed with the progression of climate change. One such challenge has been navigating how we, as scientists, can adjust our research and training to consider the importance of the environment. Whether we are looking at the reagents we chose for our experiments, or simply the energy needed to power our research, there are always potential environmental impacts that should be considered, no matter the scientific discipline. One of the best ways to address these challenges is to stay educated and be aware of our environmental footprint, and to take measures to reduce our impact whenever possible – this all starts with training.

As early career professionals, it is helpful to be aware of how researchers are adjusting their perspectives toward science, training, and student development. Speaking directly with experts in the field allows students to learn about the shift in thinking that is required to address challenges related to climate change and to be successful in their careers.

In this interview, an early career researcher (Jake Breen) spoke directly with two professionals (Dr. Rachel Chang, a professor of atmospheric science, and Dr. Kris Poduska, a professor of physics) about their thoughts and perspectives on dealing with the challenges associated with climate and the environment. The interview addresses how they deal with these challenges directly in their research, how they have shifted their training of new students, the importance of collaboration, and what steps

you, as the reader, can take to make positive changes in the world. Photo highlights from their field work are shown in Figs. 1-4.

THE INTERVIEW – QUESTIONS AND ANSWERS

TOPIC ONE – ADJUSTING OUR RESEARCH

1 - How do you deal with complicated systems involving many variables that are common in climate / environment research?

Rachel Chang: *One helpful way to think about this is to realize that none of our findings are "the truth", because the conditions are always varying and we cannot constrain every parameter. However, our research can still help us understand a part of our environment, such as which parts of the parameter space are more important.*

Kris Poduska: *Sometimes, it can be helpful to look at simpler "toy models" that are trying to capture what the most important variables are in a given experiment, simulation, or model. That being said, I think that some of the most interesting and challenging research questions arise when lab experiments or simulations fail to capture what happens in real-life.*

2 - Geographic location is important in climate-based research. How does location influence the type of research and/or which research projects you get involved with?

Rachel Chang: *It's fascinating when unique processes occur in the location that you study. For example, I am really interested in how aerosols affect cloud droplet formation, and when I started my research career at Dalhousie, I took advantage of the prevalent fog in Halifax to study aerosol-droplet interactions. The challenge, however, is determining whether the insight that we learn about our location can be extended to other locations.*

Kris Poduska: *I used to brag that I could do my research (hard condensed matter) in a basement lab anywhere in the world! However, now that I am intentionally focusing on climate change mitigation work, local and regional relevance has become very important to me. With field work, each location functions like a different lab; travel is often interesting, but it changes the type and scope of work that can be done, and collecting data in the field often comes with an intense timeline.*

3 - How do you bridge research in the field with lab and/or modelling work?

Rachel Chang: *Field observations can sometimes differ significantly from model simulations. When this happens, it usually reveals a process (or processes) that was not sufficiently represented in models, suggesting that there was a gap in our understanding. Inputs and processes in the models can then be added or adjusted to better understand the processes that led to the observed phenomena, thus advancing the science. Similarly, control experiments in the laboratory can be used to constrain exact parameters used to represent a process in models.*



Figure 1. Dr. Rachel Chang and team working in the field. Photo provided by Rachel Chang through MEOPAR.

TOPIC TWO – TRAINING NEW RESEARCHERS

1 - How does your experience in environment / climate research inform how you train new researchers?

Rachel Chang: *Since environmental research is so interdisciplinary, I try to emphasize to new researchers that everyone's perspective can contribute to the field. At the same time, it also means working continuously to broaden everyone's perspectives, myself included, so that we can approach problems from new angles.*

Kris Poduska: *Complex problems – like many that appear in environment/climate research – can seem overwhelming. My strategy for training new researchers focuses on helping people to learn how to coarse grain a problem in order to break it into smaller pieces that are more manageable to address.*

2 - What key skills do you prioritize in training new researchers? What skills / experience do you want your trainees to remember in their future careers?

Rachel Chang: *In our current era of seemingly unlimited data available on the internet, it is really important that new researchers understand the origins of the data that they are working with as well as their limitations. Whether they are working with numbers from observations, model simulations, or*



Figure 2. Dr. Kris Poduska completing field work in Port au Choix, Newfoundland and Labrador.

AI, thinking about the assumptions upon which the calculations are based serves as an important check. Similarly, it is important to think critically about the results from their own analysis and consider whether they are realistic and believable.

Kris Poduska: *I want to train problem solvers! Complex research questions have a lot of details and a large scope, and I think that the physics approach to problem solving – coarse graining a complex problem so that it is more manageable – is a very valuable approach to many different real-life situations.*

3 – Are there any resources you would recommend for new researchers to develop their skills / knowledge of climate and the environment?

Kris Poduska: *Read broadly from trusted sources! One way to get a very broad perspective is to read about the United Nations Sustainable Development Goals, which cover many different topics including climate action, disaster risk reduction, food security, and sustainable cities (https://sdgs.un.org/topics*).

TOPIC THREE – THE VALUE OF DIFFERING PERSPECTIVES

1 - Environment / climate research often involves researchers from a variety of disciplines. How do you combine your expertise in physics to work effectively in interdisciplinary environments?

Kris Poduska: *When I work in teams, I find that I'm most successful when I'm curious and not afraid to ask questions. Physics helped train me to look at the big picture and not to get too bogged down in*



Figure 3. Dr. Rachel Chang at work during a field study. Photo provided by Rachel Chang through MEOPAR.

details that aren't the most important parts of the problem. It's not that the details don't matter, but it's often not practical to consider all factors at the same level of detail.

2- What value have you gained from connecting with researchers who have a different focus, in terms of lab work / field work / modelling?

Rachel Chang: *Here's a specific example of when working with modellers has been super rewarding for me. Our field observations showed that new particle formation (i.e. particle nucleation from gases) occurs frequently in the summer in the Canadian Arctic, but we had no idea what gas was driving the particle formation and growth, nor its source. Our modelling colleagues added new sources and processes into their model and determined that ammonia from bird guano contributed to the new particle formation, and that the particles grow by the condensation of organic vapours originating from geographic regions coinciding with open waters.*



Figure 4. Field work. Photo provided by Dr. Kris Poduska.

3 - How does your background in physics / atmospheric science influence how you approach climate / environment research? What value does the perspective of a physicist / atmospheric scientist add to this field?

Rachel Chang: *The atmosphere is connected to all the other components of the Earth systems (e.g. cryosphere, hydrosphere) and is an important transport pathway for many nutrients and contaminants. As an atmospheric scientist, I bring the perspective that the faster changes that happen in the air can have important impacts on slower-changing parts of the Earth.*

Kris Poduska: *There are so many aspects of physics that are involved in climate and environment research: thermodynamics, energy, waves, condensed matter, phase transitions, soft matter, modelling and simulations. I could keep going! In my opinion, what physics brings to the table is a respect for integrating models with data to aim for predictive power.*

TOPIC FOUR – CLIMATE SCIENCE FOR THE GENERAL PUBLIC

1 - What skills or information from environment / climate research would you teach to the general public, if given the opportunity?

Rachel Chang: *Again, in our current era of seemingly unlimited information available on the internet, it is really important that users understand the origins of the information that they are working with as well as their limitations. It is essential to think critically about the information, considering their sources and the context, and think about whether they are realistic and believable.*

Kris Poduska: *Science literacy and numerical literacy are really important skills. I'd like to help people have the confidence to question how information and numbers are interpreted.*

CONCLUSIONS

The responses from Dr. Poduska and Dr. Chang provide valuable insight into the shift in research perspective that is happening as our environment and climate changes. Through a series of different questions and topics, Poduska and Chang shared the importance of problem solving, simplifying complex ideas, interdisciplinary work, and above all, asking questions. Additionally, they emphasized the necessity of understanding the source of information both in the media and in scientific research, and how this impacts the analysis.

PATTERNS AND CURIOUS LANDFORMS OF THE CANADIAN HIGH ARCTIC

SUMMARY: We review examples of natural patterns found in Canadian Arctic landscapes and potential formation mechanisms.



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INTRODUCTION

Cold regions on Earth are dominated by cycles. On the millennial scale, Milankovitch cycles drive the global glacial coverage and the occurrence of Ice Ages. Over hundreds to thousands of years, individual glaciers advance and retreat, driving erosion and deposition of sediments and downslope movement of

meltwater in their forelands. In periglacial regions (cold, non-glacial environments), extreme yearly temperature cycles drive the seasonal freezing and thawing of the uppermost ground layer (active layer) above permanently frozen ground (permafrost) [1]. This repeated action generates thermal and mechanical stresses that reorganize sediments and fracture the ground. Both glacial and periglacial processes create a variety of mesmerizing patterns (e.g. [2]; Fig.1) in Earth's Arctic and high mountain regions over a wide range of timescales, effectively recording the climate history.

Scientists and mathematicians continue to be fascinated by the impressive collection of landforms and patterns produced by the cryosphere. Although mathematical theories have been developed that can reproduce similar patterns, a clear connection to the driving physical processes allows us to learn about past climate and landscape conditions on Earth and other planets from present day observations. As such, research is still underway to understand generative processes (e.g. [2]-3]), with much of the published research led by scientists at Canadian institutions. Canada, with its expansive permafrost and modern glaciers, is well positioned for studying these glacial and periglacial processes across Arctic and subarctic landscapes. The Canadian Arctic is a natural laboratory for investigating

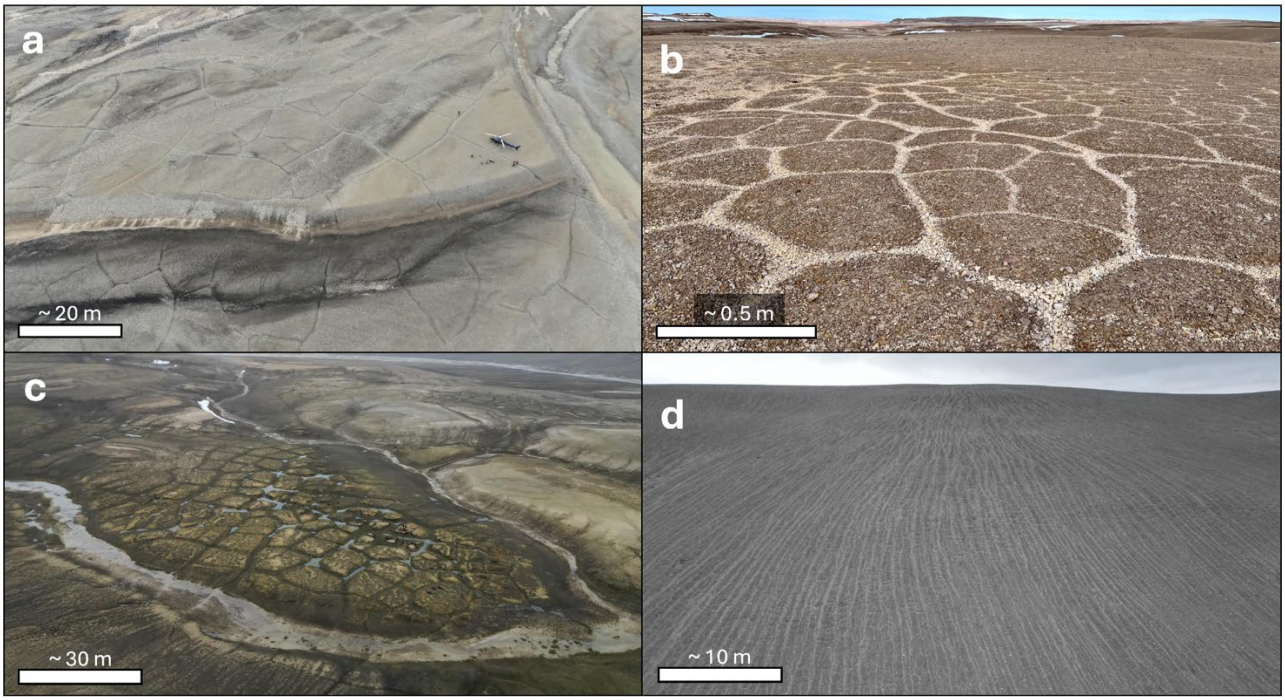


Figure 1. Examples of patterned ground found on Devon Island, Nunavut, Canada: a) a developing coastal polygon network (photo: Mark Jellinek), b) sorted polygon features on flat ground (photo: Shawn Chartrand), c) a degrading polygon network found alongside an arctic stream (photo: Sam Anderson), d) a hillslope exhibiting sorted stripe patterning, taken from the bottom of the hill and looking upslope. Photo by Grace Johnson.

how ice-rich landscapes evolve through time and respond to climate change. Below we provide a brief overview of research being done to understand some of the more curious landforms and patterns found in cold regions.

SORTED CIRCLES AND STRIPES

Sorted circles and stripes are a common periglacial landform found across a variety of cold region landscapes ([4]; Fig.2), including Mars (e.g. [5]). Sorted circles are characterized by circular to semi-circular ridges of concentrated coarse grains surrounded by a center of convex upward fine-grained material formed through a fascinating self-organizing process. These features are relatively small, with ridge heights ranging from a few millimeters up to 0.5 m, ridge widths from 0.5 to 1 m, and circle diameters from 2 to 5 m [6]. On slopes, they elongate downslope into sorted stripes with alternating coarse-grained ridges and fine-grained troughs (e.g. [3]). Sorted stripes found within the Haughton impact crater on Devon Island, Nunavut appear as darker-coloured topographic highs composed of compact, fine-grained sediments and lighter-coloured topographic lows composed of loose gravels (Fig. 2). These stripes are generally oriented along the direction of maximum slope and exist in the absence of vegetation and without clear evidence of seasonally flowing surface water. Stripe widths vary spatially across the hillslope and can be on the order of tens of centimetres up to several metres.

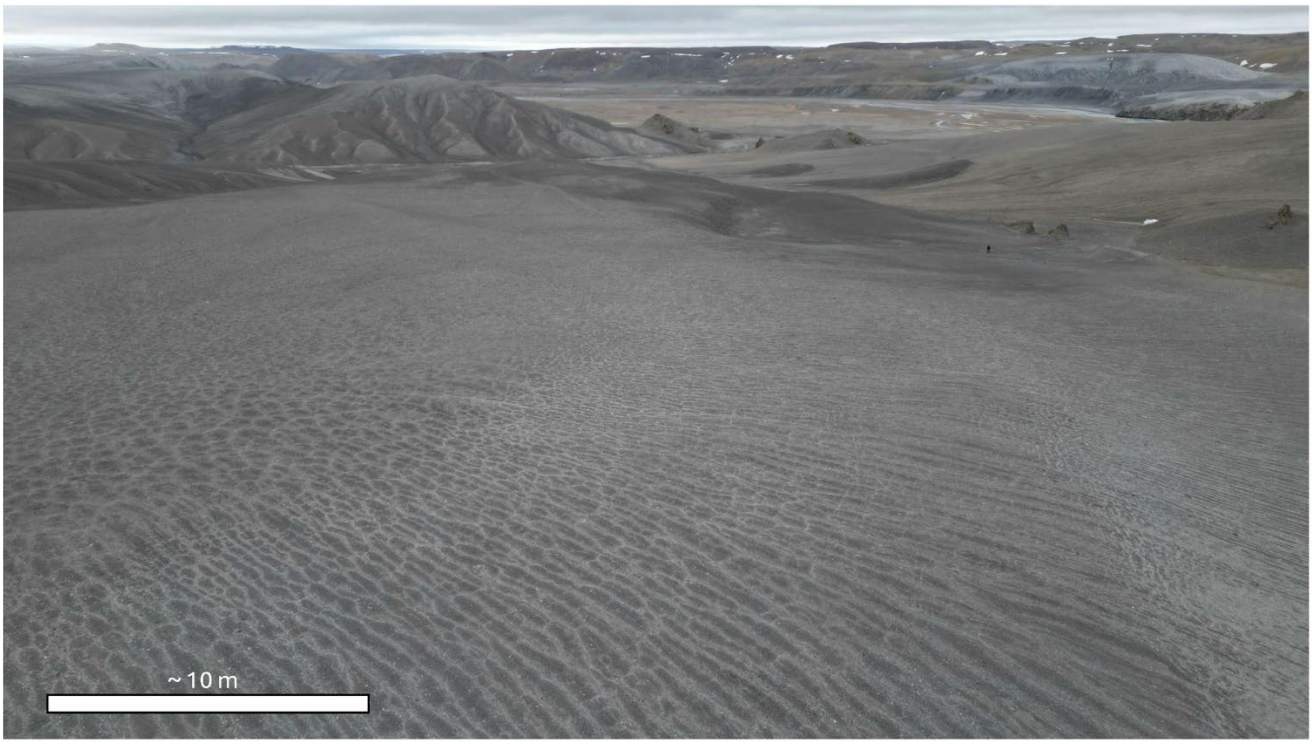


Figure 2. Sorted circular and hillslope stripes, Devon Island, Nunavut, Canada. Topographic gradient from higher to lower elevations is from image left to right. Photo by Grace Johnson.

Repeated freezing and thawing of the near surface is thought to preferentially move coarse grains upward and outward, effectively sorting the ground into fine grains encircled by a pile of coarse grains [7]. The preferential growth and collapse of needle ice in regions of fine-grained soils also act as drivers for stone sorting. Several attempts have been made to create frost-heave- and ice-needle-based models of sorted stripe formation using rules-based approaches (e.g. Kessler and Werner 2003), or analytical models derived from these rules [8]. These models, however, depend on geometric, rheological, and physical properties of the patterns that are poorly constrained. Similarly, convective models have been developed to simulate the growth of thaw front undulations located in seasonally-thawed surface and near-surface sediments (e.g. [9]). Water is unique in that, below 4 °C, the density decreases as temperature decreases. Thus, for a section of soil in the active layer with surface temperature higher than at the base of the frozen ground below, the density of water will be higher at the surface. If the viscous drag is sufficiently small, the dense surface water will tend to sink while the less dense water at the base will tend to rise, forming a pattern of convection cells. These cells transfer heat unevenly through the soil, creating undulations in the frozen front that are amplified with successive freeze-thaw cycles. However, observed sorted stripe spacing distributions are irregular and are not readily explained by these phenomena alone. It is evident that there are likely multiple competing processes at work to form hillslope sorted stripe patterns.

POLYGONS

Polygonal patterned ground ("polygons") is a type of sorted ground defined by a system of geometric raised mounds intersected by an interconnected trough network (Fig. 3). The raised polygons are typically tens of metres in diameter and are tens of centimetres to metres high (Fig. 4). Polygon networks are thought to develop over hundreds to thousands of years through a cycle where thermal contraction fractures open in the fall or winter when thermal stresses are relatively high. Fractures then fill with snow during winter storms, with meltwater or rain in the spring and early summer, or dust and sand in particularly dry polar deserts. Meltwater can percolate down into fractures and freeze once below the permafrost table, essentially filling the fracture with a vein of ice. This initial ice vein within the fractures then acts as a plane of weakness for subsequent thermal contraction fractures which get filled by ice, resulting in the growth of ice veins into metre-wide wedge-shaped bodies of ice that push the ground apart and up along the wedge margins [10]. Polygons are common landforms in Arctic landscapes, governing where water flows or stagnates within the landscape, and aiding in the formation of new river channel networks [11].

It is relevant and useful to ask how polygon landforms respond to changing climate conditions marked by amplified seasonal air temperature trends and more variable precipitation. As the Arctic warms and permafrost degrades, ice wedges melt at increasing rates, resulting in polygon troughs and shoulders subsiding more quickly than their centres. This can drive so-called low-centred polygons, where the polygon centre is lower than the shoulders and supports local water storage, into so-called high-centred polygons (Fig. 3). This decreases landscape water storage. However, the loss of ground ice also introduces new water into the landscape and rapid melting of massive ice during heatwaves can trigger

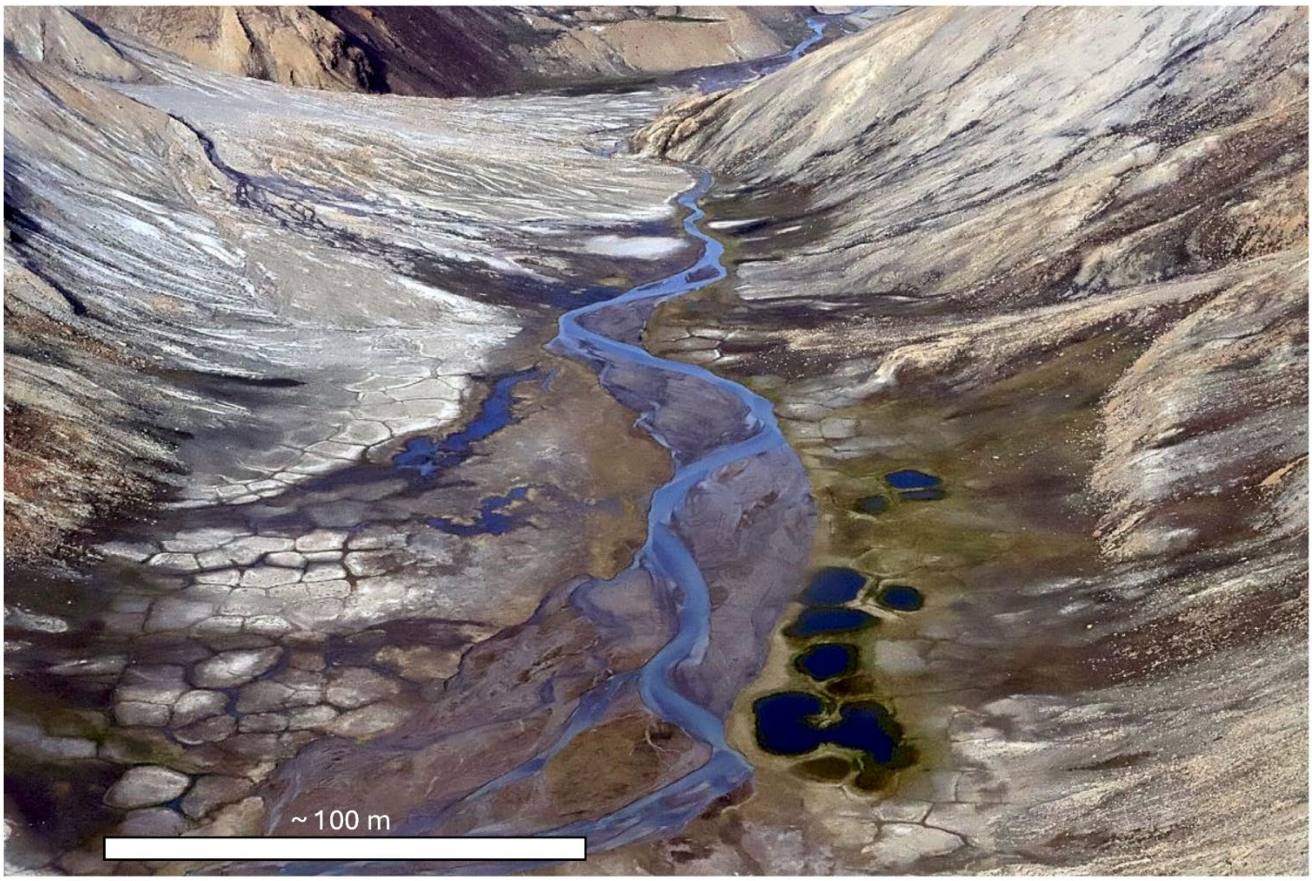


Figure 3. Polygons found on terraces along a river, Axel Heiberg Island, Nunavut, Canada. Both high-centred (image left) and low-centred (image right) occur on the terraces, and both are presently being incorporated into the developing river valley as increased melt waters from an ice cap promote river erosion of the terraces. Photo by Shawn Chartrand.

rapid channelization. It remains an open question whether the degradation of ice wedges will result in an overall drying or wetting of landscapes within and adjacent to polygons under climate change

In addition to contemporary changes due to permafrost degradation, polygon shape is known to evolve over time from primarily rectangular polygons with 90° trough intersection angles toward more circular geometries with 120° intersection angles. This is because when the initial fracture network develops, the most favourable configuration to release local stress is for two fractures to meet orthogonally. However, over subsequent fracture cycles, the network as a whole evolves towards the hexagonal polygons and intersection angles of 120°, minimizing total fracture length. This shift happens incrementally, with individual intersection angles increasing over each fracture cycle as the order of which fracture path is reactivated varies stochastically [12]. As such, the distribution of intersection angles potentially can be used as an indicator of relative maturity between polygon systems. While the uplift and shape evolution is typically neglected when considering polygon

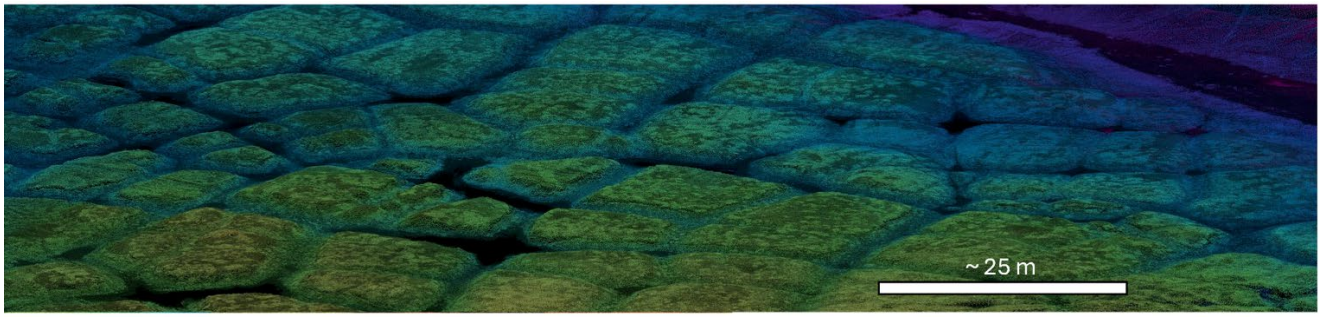


Figure 4. Digital terrain model of polygons found in the Haughton impact crater, Devon Island, Nunavut, Canada. The terrain model shows the relative topographic differences between polygons and the adjacent troughs. Terrain model by Antero Kukko.

evolution under climate change, recent observations show that polygons can form within decades, much faster than previously expected [11]. This suggests that permafrost degradation, channelization, and the evolution of the fracture network can act on similar timescales. This interaction between competing processes is still largely unexplored.

RING FORMS

Ring forms are an intriguing landform found in the Canadian High Arctic and across northern Europe, Scandinavia, and Alaska. These landforms are defined by their circular to irregular ring-shaped ridges and troughs that resemble brain-like patterns (Fig. 5). These features have been found on Devon Island ([13]; Fig. 5a) and Axel Heiberg Island [14] in Nunavut, Canada, with larger morphologically similar features found throughout continental Canada (e.g. [15-16]; Figs. 5b-d). Although the origin of these features remains debated, their formation is generally attributed to glacial processes, with many if not most of the details left to be determined. Hypotheses in the literature commonly suggest that ring forms develop within sediments left behind as buried glacial ice melts away at differential rates. As the ice melts, the overlying material shifts and redistributes into topographic highs and lows, leaving behind interconnected ridges and troughs which provide clues to the ongoing physical processes occurring long after glaciers have receded [13]. Others have suggested that these landforms develop due to squeezing of saturated subglacial sediments into cavities and crevasses at the base of a glacier. When the glacier recedes, the subglacial sediment rings become exposed and act as a fingerprint of past subglacial activity. Though specific glacial processes continue to be a topic of debate, others argue these may be periglacial in origin, forming from the formation and subsequent melting of ground ice derived from glacial meltwaters.

There is significant variation in the scale, association with other landforms, and sedimentology of glacial ring forms, with most examples disturbed by farming, infrastructure, and vegetation (Fig. 5). This may lead to the preferential preservation of large-scale ring forms leftover from the Last Ice Age. Those found in Nunavut, Canada (e.g. [13-14]) are the smallest and youngest of those described in the literature, with ridges ranging between 0.5 - 2.5 m in height and 4 - 72 m in diameter, within sands and

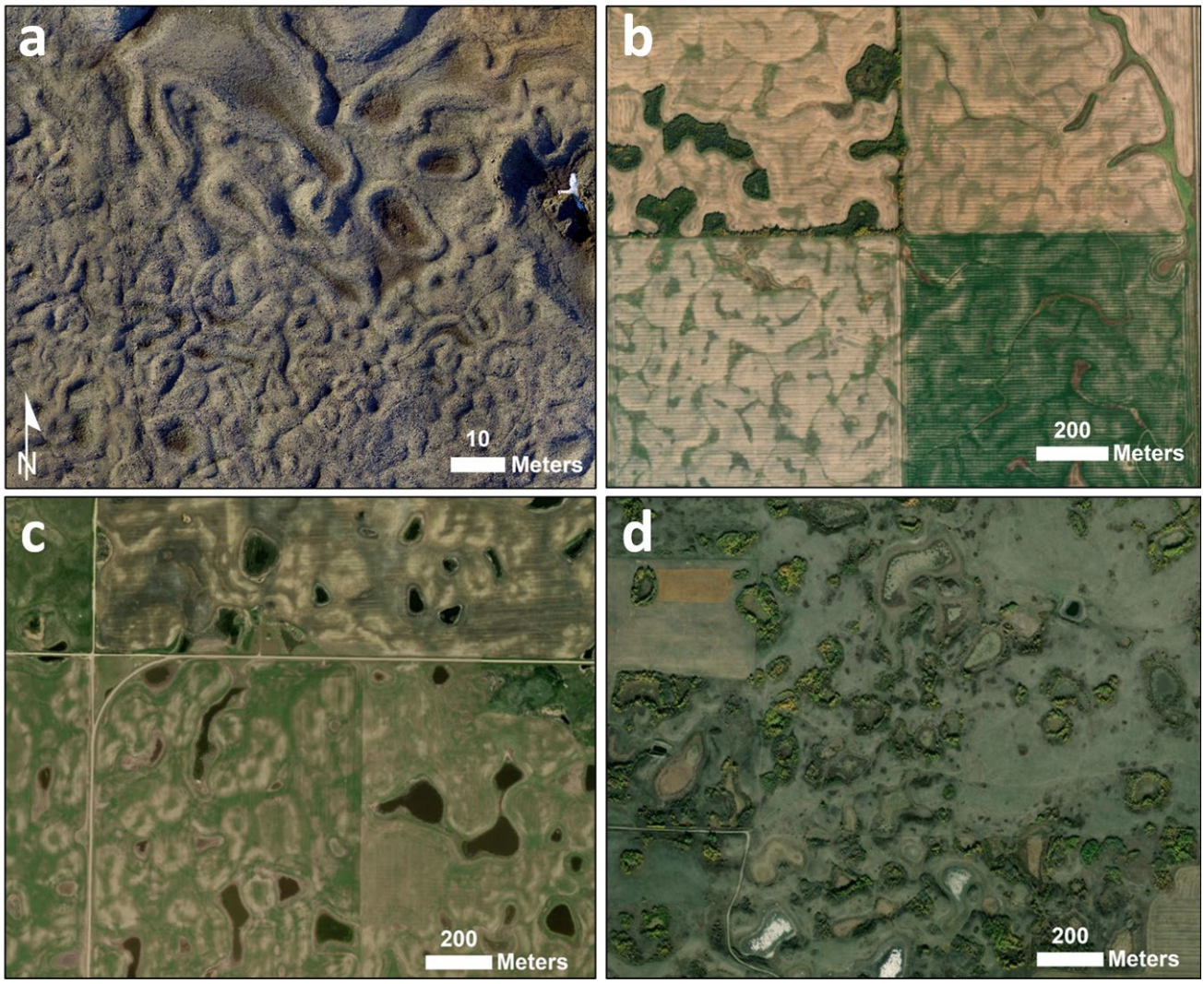


Figure 5. Examples of glacial ring forms across Canada. Ring forms in a) Devon Island, Nunavut, Canada, b) Saskatchewan, Canada, c) Saskatchewan, Canada, d) Alberta, Canada. Modified from Ref. [13].

gravels. These small-scale ring forms in Nunavut occur in a remote polar desert where vegetation and human impact is limited, acting as pristine examples that may provide additional insight into the origin of these features.

Understanding how ring forms develop not only aids scientists in reconstructing climate history over the past ~11,000 years and earlier within the Canadian Arctic and elsewhere, but it also helps to better understand how Arctic landscapes respond to a changing climate. Studying ring forms also holds value beyond Earth, as these landforms have been proposed to be a valuable terrestrial analogue for similar features found on Mars called “brain” terrain [14]. Understanding the processes that give rise to ring forms could provide insight into how brain terrain forms on Mars and how it is linked to ice and past

climate [17], providing opportunities for landing site selection for future Martian missions in the search for evidence of water ice.

SUBGLACIAL CHANNEL SYSTEMS

Subglacial meltwater channel systems are drainage pathways that develop underneath and at the margins of glaciers and ice caps. Although Devon Island in the Canadian High Arctic archipelago was covered by an ice sheet during the last glacial period, there is a conspicuous lack of typical glacial landforms in the region. Instead, subglacial meltwater channels dominate Devon Island's interior plateau (Fig. 6). In contrast to rivers, subglacial channels have networks that are composed of relatively short, straight, and evenly spaced valleys that drain into a wider, deeper main stem channel (Fig. 6d). Channel cross-sections are flat-bottomed with steep walls and along-channel (longitudinal) profiles are convex with some undulations, characteristic of formation or modification from pressurized water flow (i.e., subglacial meltwater) [18]. The presence of these interconnected channels in conjunction with distinct erosional surfaces suggests the development of a more complex out-branching of subglacial channel networks due to relatively high flow discharge events (i.e., floods). The characterization of subglacial meltwater pathways, including their spatial distribution and association with other landforms, can directly contribute to interpretations of paleoclimate and patterns of glacial advance and retreat.

Recent work has focused on the geomorphology of subglacial meltwater channels on Devon Island to build an interpretation of meltwater sources (i.e. supraglacial, englacial, subglacial) and timing and dynamics of meltwater delivery to the ice-bed interface [19]. Subglacial channels on Devon Island have also been the subject of analogue studies for morphologically similar features such as valley networks and shallow valleys on Mars. Due to the polar desert climate coupled with the lack of vegetation on Devon Island, it is a prime candidate analogue site for glacial and subglacial processes on Mars. Consistent with recent climate models that predict a cold and dry early Mars [17], valley network geomorphology on Mars [20] suggests erosion due to localized basal meltwater flow under ice sheets is a plausible explanation for these landforms. Continued work to further characterize and interpret terrestrial subglacial channels, particularly those on Devon Island, can also help inform and reconstruct Martian glacial history, ice dynamics, and paleoclimate.

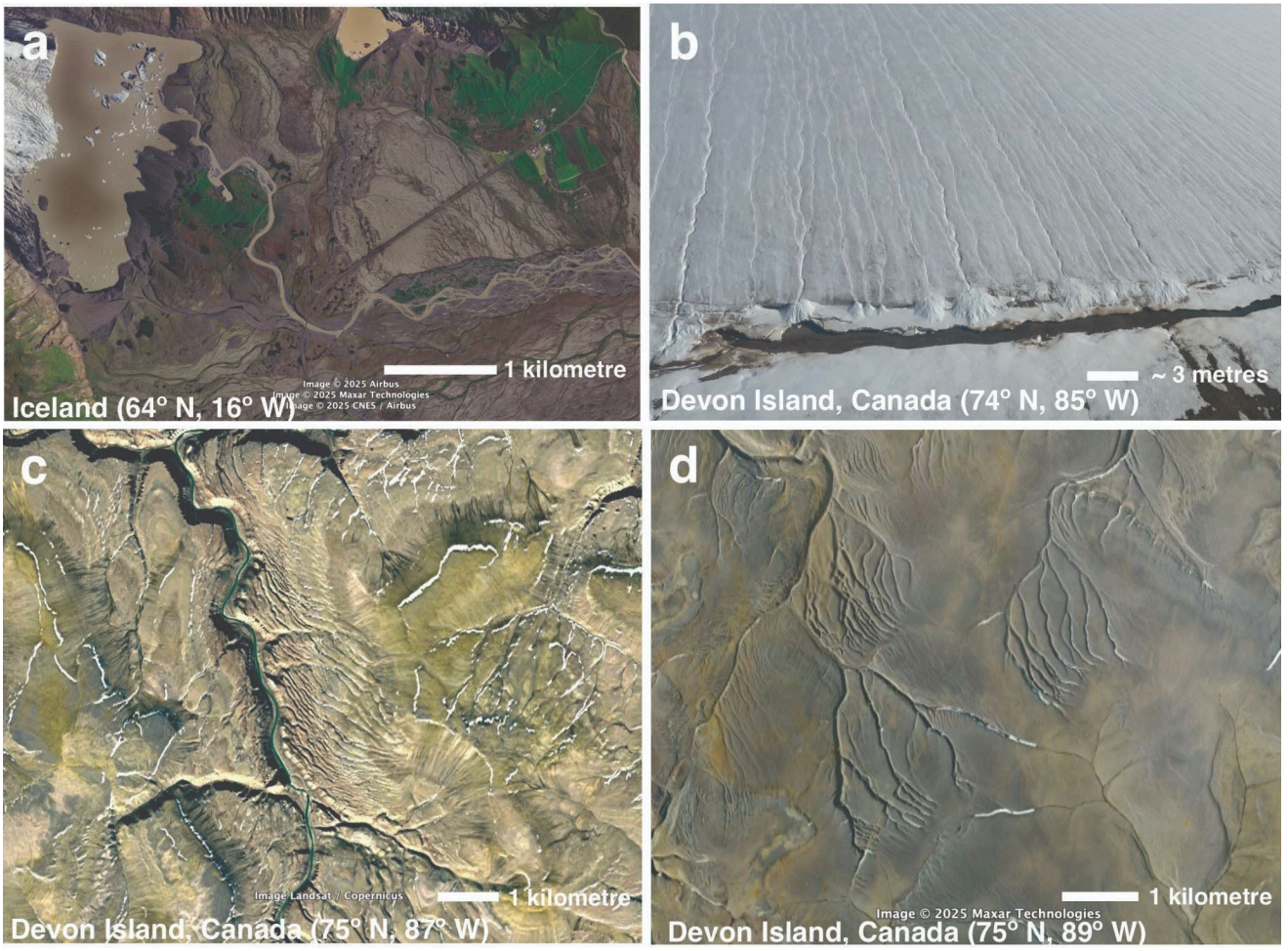


Figure 6. Various types of meltwater channels. a) Proglacial, b) supraglacial, c) lateral (marginal), and d) subglacial channels perched on the side of a large valley. Images a, c, and d from Google Earth (Airbus/MAXAR Imagery). Image b) taken in the field in July 2024 by Simona Ruso.

CONCLUSION

Earth's cold regions are home to a striking array of natural patterns on a range of scales. The Canadian Arctic provides a natural laboratory to study a variety of patterns of both glacial and periglacial origins, from metre-scale sorted circles and stripes to kilometre-scale subglacial channel networks. Though mathematical theories exist that can reproduce visually similar patterns, details of the driving physical processes are not fully understood. Research is being conducted across Canada to understand the mechanisms by which these patterns form and inform reconstructions of past climate conditions on Earth and other planets.

ACKNOWLEDGEMENTS

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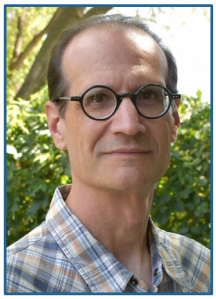
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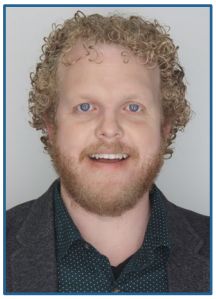
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SEVERE THUNDERSTORM RESEARCH IN CANADA

SUMMARY: Improving the understanding, prediction, and mitigation of severe thunderstorms requires physics-based research conducted by interdisciplinary teams.









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On August 7, 1979, two violent F4 tornadoes struck the towns of Woodstock and Stratford, Ontario, damaging and destroying homes within minutes, injuring 141 people and causing three fatalities [1]. Thunderstorms on May 21, 2022, left a continuous path of widespread severe wind damage from Windsor to Quebec City, killing 16 people and causing power outages for millions of customers. The Calgary hailstorm of August 5, 2024 caused more than 3.2 billion Canadian Dollars in insured damage. Events like this demonstrate the destructive power of severe thunderstorms, which can produce tornadoes, large hail, flash floods, and damaging wind gusts within very short periods of time. Even small improvements in forecasting can have significant societal benefits, allowing individuals to protect themselves, their property and helping emergency services respond more effectively.

Understanding these storms requires a grounding in fundamental physics such as fluid dynamics, thermodynamics and electromagnetism. Predicting severe thunderstorms remains one of the most

challenging problems in atmospheric science. A key difficulty lies in the scale of the problem. A tornado may be only tens of meters wide, which is comparable to the width of a street, yet it forms within storm systems that can travel hundreds of kilometers. Meanwhile, weather prediction models typically operate at resolutions of several kilometers, leaving critical small-scale processes unresolved.

This article explores the physical processes behind thunderstorms, how they are observed and studied in Canada, and how research is evolving to meet future challenges.

THE PHYSICS OF THUNDERSTORMS

Thunderstorms form when three key ingredients are present: instability, moisture, and lift [2]. Instability occurs when a parcel of air becomes buoyant relative to its surroundings. It accelerates upward due to density differences. This is often quantified by Convective Available Potential Energy (CAPE), which measures the energy available for vertical motion. As air rises, it expands and cools. When it reaches its dew point temperature, water vapour condenses into liquid droplets. This phase change releases latent heat, warming the air parcel and increasing its buoyancy. If enough instability and moisture are present, this feedback process can lead to strong updrafts. Lift is required to initiate this process because the air in the lower-most part of the atmosphere tends to inhibit vertical motion, which is a common feature of severe storm days. A source of lift in a stably stratified lower atmosphere may arise from large-scale systems such as cold fronts or from smaller features such as surface heating or boundaries created by previous storms.

Once initiated, storm structure depends strongly on wind shear, which is the change in wind direction and speed with height. In weak shear environments, storms are short-lived. With moderate shear, storms organize into mesoscale systems such as squall lines, which can produce widespread wind damage. In strong vertical shear, supercells become likely. These are highly organized storms with rotating updrafts. These storms are responsible for many of the most severe weather events in Canada, including large hail and tornadoes [3].

A major challenge in thunderstorm physics is the interaction between processes across scales. Large-scale flow organizes the ingredients of storms and provides a suitable setting for storm formation, while small- and micro-scale processes such as droplet formation and hail growth contribute to their hazard impact. Numerical models solve the governing equations (Navier-Stokes equation, first law of thermodynamics, continuity equation) of atmospheric motion. They are crucial to bridge these scales. An example is the idealized Cloud Model 1 [4], which allows to test how small-scale changes in the environment influence the potential for high impact events.

OBSERVING THUNDERSTORMS AND THEIR IMPACTS IN CANADA

To understand the dynamics and structure of thunderstorms, they must first be observed. The most important tool for this purpose is the weather radar. Radar systems emit microwave pulses and measure the energy scattered back by precipitation particles. The timing of the return signal determines distance, while its strength indicates precipitation intensity. This relies on electromagnetic wave scattering, directly linking meteorology with physics. Modern Canadian radars are dual-

polarization Doppler systems, which transmit waves in both horizontal and vertical orientations. This allows differentiation between raindrops and hail, as well as measurement of wind velocity within storms. Features such as rotating updrafts can be detected in real time, providing crucial information for forecasting. Certain radar signatures are strongly associated with severe weather. For example, hook-shaped echoes and rotating winds often indicate rotation and possible tornado formation. These observations allow meteorologists to issue warnings with limited but valuable lead time.

Canada has a long history of radar development [1]. Research led by J. Stewart Marshall at McGill University in the 1940s established key relationships between rainfall and drop-size distributions that are still used today. The modern Canadian radar network now consists of 32 Doppler radars, greatly improving national coverage. Radar research remains important to maximize its benefit.

Other observational tools complement radar. Satellites provide a large-scale view of storm systems and can detect water vapour and cloud features in various wavelengths. This can be used, for example, to locate jet streams, areas of enhanced lift and vertical wind shear. Lightning detection networks provide additional information about storm intensity. After severe events, researchers analyze damage patterns using drones and ground observations. These surveys improve essential understanding of storm impacts and help refine models and building standards.

CURRENT CANADIAN RESEARCH EFFORTS

Thunderstorm research in Canada has expanded significantly in recent years through coordinated field programs and interdisciplinary collaboration. A major development is the establishment in 2024 of the Canadian Severe Storms Laboratory (CSSL) at Western University, which brings together meteorologists, physicists, engineers, and social scientists to study severe weather and its impacts. Meteorologists and physicists focus on understanding the atmospheric processes behind thunderstorms using, for example, numerical models to analyze storm environments [5] and simulate storm dynamics (Fig. 1d,e). Engineers use observations of damage patterns to improve building codes, develop better representations of wind and vortex behaviour, and conduct controlled experiments. Social scientists study the human dimension of severe wind, including how risk is perceived, how people prepare and keep themselves safe during hazard exposure, and how social and structural impacts are experienced to foster improvements in early warning processes and protective action decision-making [6]. The CSSL hosts several major initiatives: The Northern Tornadoes Project documents tornadoes and downbursts across Canada, including in remote regions, using tools such as damage surveys and machine learning to better understand frequency and risk (Fig. 1a-c) [7]. The Northern Hail Project investigates hail events by collecting hailstones in the field and analyzing their size, shape, impact, and climatology [8]. Techniques such as 3D scanning and printing allow controlled experiments on hail damage and sensor development. The Northern Mesonet Project aims to better monitor severe convective storms by increasing the spatial density of real-time advanced weather observations and enhancing data availability and quality for severe weather analysis and prediction. In addition, the CSSL offers undergraduate research opportunities, combining fieldwork and research to train students across disciplines (Fig. 2) [9].

Furthermore, experimental facilities such as the WindEEE Dome enable controlled simulations of downbursts and tornado-like flows, offering insight into how buildings and vegetation respond to extreme winds.

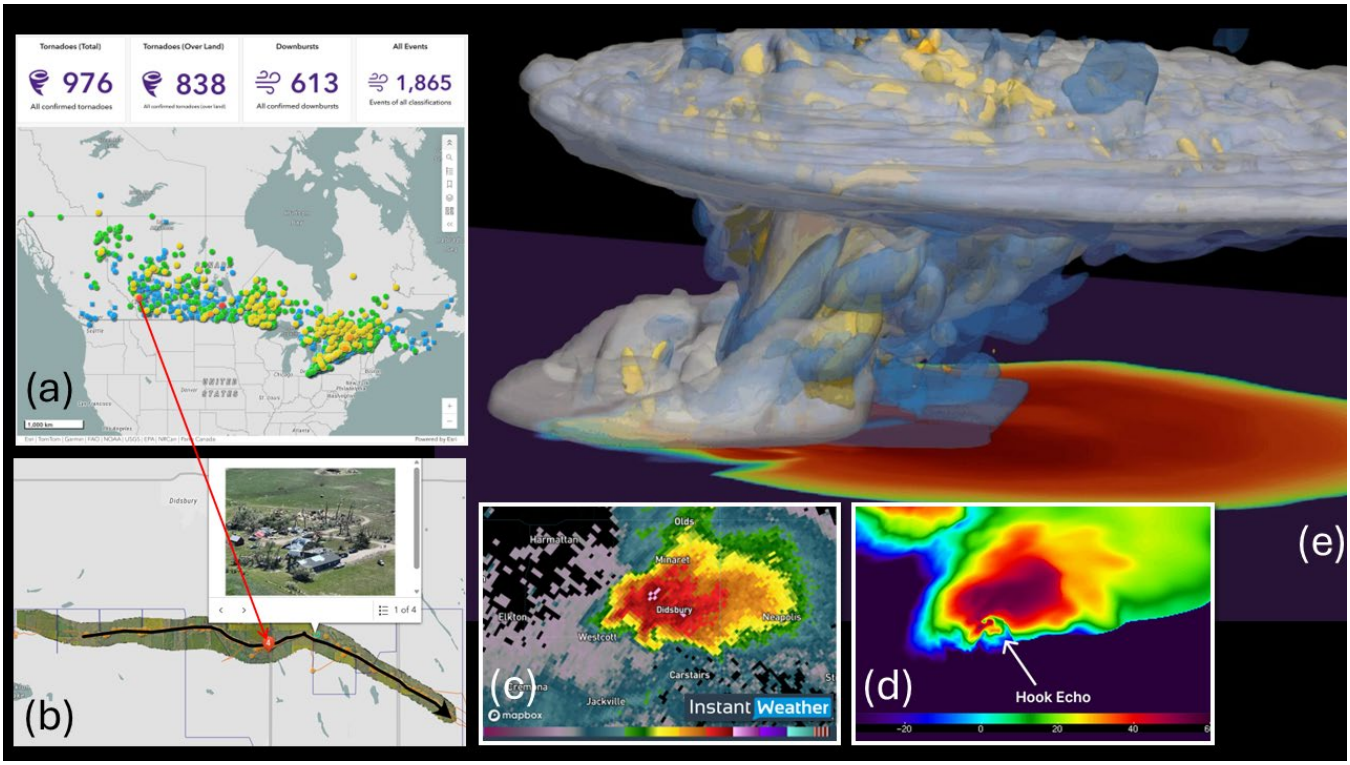


Figure 1. (a) Northern Tornadoes Project Dashboard displaying all events between 2017 and May 2026 (Screenshot taken May 24, 2026). Colors indicate tornado strength. (b) Event Summary of the Didsbury EF4 tornado occurring on July 1, 2023 with tornado path and drone photo taken of damage along the path. (c) Radar Reflectivity (dBZ) of the Didsbury EF4 tornado case on July 1, 2023, observed by the CASSM (Strathmore, AB) radar at an elevation of 0.3955° at 15:53 EDT. Image: Instant Weather, data: Environment Canada. (d) Radar Reflectivity (dBZ) at lowest model level (z=125 m) of a numerical simulation of the Didsbury EF4 tornado case using Cloud Model 1. (e) 3D visualization of the simulated thunderstorm displayed in (c) at another, earlier timestep. Gray: Cloud; Yellow: Vertical Vorticity; Blue: Rain; Shaded: Reflectivity at lowest model level. Visualizations in (d,e) by Luna Awad and Keya Raval.



Figure 2. Impressions from the CSSL summer internship fieldwork and damage surveys [9]. Photos originally published at https://uwo.ca/cssl/internships (May 31, 2026).

FUTURE OF THUNDERSTORM RESEARCH

Future thunderstorm research in Canada will be significantly influenced by technological progress and climate change. A warmer atmosphere can hold more moisture (Clausius-Clapeyron equation) and according to the Intergovernmental Panel on Climate Change (IPCC) extreme precipitation is projected to increase across Central and East North America with high confidence while trends for other parts of the continent cannot be clearly stated [10]. For severe thunderstorms, downbursts, tornadoes and lightning strikes, future changes are still unclear, although observations indicate a reduction in the number of days when tornadoes occur, but an increase in days with ≥30 (E)F1+ tornadoes in the USA [11]. However, there is medium confidence that severe storms will become more frequent and that the storm season will become longer in the USA. Future projections of severe thunderstorms in Canada are an active area of research, and while there are uncertainties, the scientific consensus points to more intense storms, with regionally variable changes in frequency over the coming decades.

Furthermore, advances in computing are enabling higher-resolution models that can better resolve storm-scale processes, while machine learning techniques are being integrated with physics-based models to optimize predictions. Improved observational systems, including denser sensor networks

and enhanced radar capabilities, will also play a critical role. Together, these developments will help address current limitations in severe weather prediction.

HOW PHYSICISTS CAN CONTRIBUTE

Thunderstorm research is deeply rooted in physics. Fluid dynamics governs storm structure and turbulence, thermodynamics explains convection and phase changes, and electromagnetism plays a key role for radar observations and lightning. Physicists can contribute through numerical modeling, data analysis, and improving observations through novel and improved instrumentation. Storm simulations involve solving the Navier–Stokes equations, while radar interpretation requires understanding electromagnetic scattering. Studying physics not only provides a foundation in fundamental concepts and their applications but also builds skills in physical interpretation, programming, experimentation, and data analysis. Furthermore, physics students can get involved in research and field internships of the CSSL [9] or graduate programs of several Canadian Universities. Interdisciplinary collaboration and teamwork are essential. Combining physics with other scientific fields allows for a more complete understanding of severe weather and its impacts.

CONCLUSIONS

Severe thunderstorms are complex phenomena that combine processes across multiple scales. From early radar research to modern interdisciplinary efforts, Canada has made significant contributions to understanding these storms. Despite this progress, challenges remain, particularly in predicting small-scale processes and extreme impacts. As climate change continues to influence weather patterns, improving our understanding of severe thunderstorms will become increasingly important. For physics students, this field offers an opportunity to apply fundamental principles to real-world problems with direct societal impact. Continued research and collaboration will be essential for improving resilience to severe weather in Canada.

ACKNOWLEDGEMENTS

The authors would like to thank their colleagues at the CSSL, especially Greg Kopp, Julian Brimelow, Aaron Jaffe, and Simon Eng. The CSSL team acknowledges the funding from ImpactWX and Western University for the CSSL operations and NSERC and Mitacs for partial student and staff support. Thanks to Luna Awad and Keya Raval, who produced the CM1 simulations presented in Fig. 1 during their Undergraduate Summer Research Internship 2025.

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PREDICTING AND OBSERVING CONTRAILS AND THEIR IMPACTS

SUMMARY: Contrails contribute to global warming. Mitigation is possible but requires improved prediction and observation, with ground-based cameras offering new opportunities.






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Aviation contributes to climate change through both carbon dioxide emissions and shorter-lived atmospheric phenomena such as condensation trails (contrails). A cost-effective strategy to reduce aviation's climate impact is avoiding contrail formation through relatively small adjustments to aircraft flight altitude, a method already proven feasible for commercial flights [1]. However, implementing such strategies requires reliable prediction and observation of contrails, which is still a grand challenge.

Contrails are line-shaped ice clouds that form behind aircraft. Early observations of contrails date back to the beginning of the 20th century as aircraft began reaching sufficiently high altitudes. Depending on the atmospheric conditions, contrails may be short-lived and dissipate within minutes (Fig. 1a), or persistent, lasting for more than 10 minutes up to several hours and spreading into extended cirrus-like cloud structures (Fig. 1b). Persistent contrails are particularly important because they can modify the Earth's radiation budget (Fig. 1c). The climate impact of contrails is assumed to be significant, but large uncertainties still exist. Estimates suggest that contrails contribute approximately 1–2% of total anthropogenic warming and account for roughly half of aviation's climate impact [2]. According to the International Air Transport Association, global air traffic demand is projected to more than double by 2050. As a result, the importance of understanding and mitigating contrail effects will only grow, given their significant contribution to aviation-related climate impacts.

Contrail persistence is governed by the presence of ice supersaturated regions (ISSRs), where the relative humidity with respect to ice exceeds 100%. Avoiding these relatively thin layers of air could

substantially reduce persistent contrail formation. However, predicting the occurrence and distribution of ISSRs remains challenging due to limitations in atmospheric models and observations.

To improve predictions of ISSRs, increased observational capabilities are required. High-resolution observations that allow contrails to be associated with individual flights are particularly valuable for validating prediction models. While satellite observations have significantly advanced the field, they exhibit important limitations due to their coarse resolution. This motivates the development of complementary techniques such as ground-based camera systems, which provide continuous, high-temporal-resolution observations.

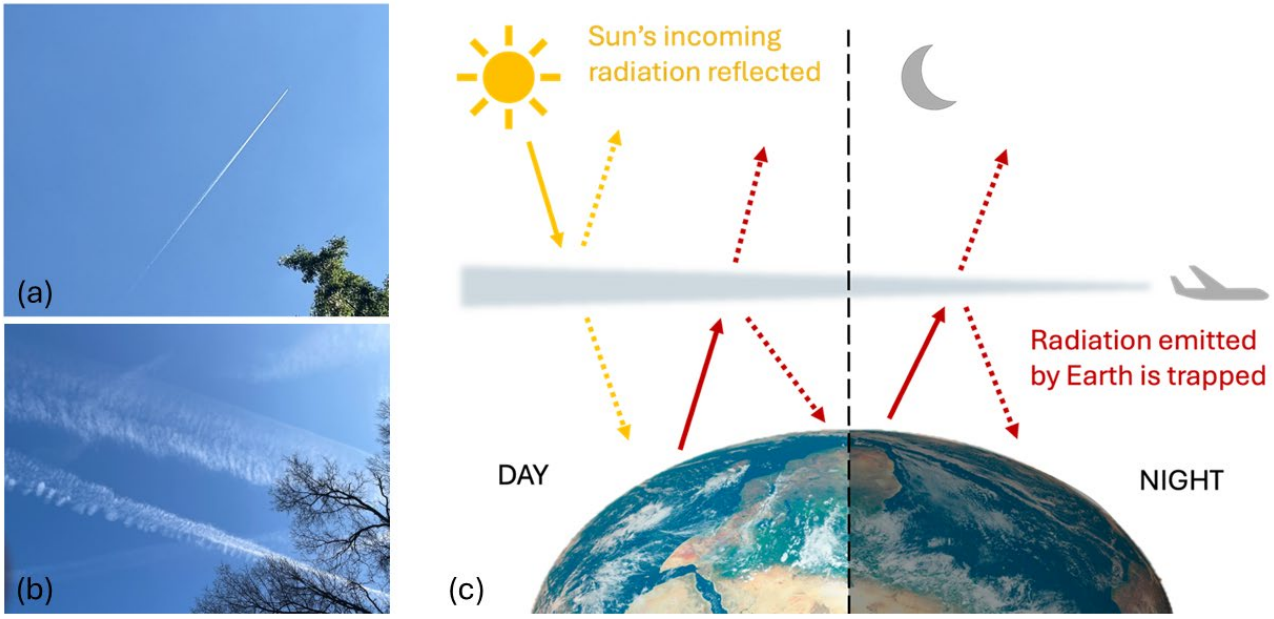


Figure 1. Examples of: (a) a short-lived contrail that dissipates in a short distance behind the aircraft and (b) persistent contrails that grow and remain in the sky for longer periods of time after the aircraft's passage (10 min to several hours). (c) Illustration depicting the interaction of contrails with the Sun's incoming shortwave radiation and Earth's outgoing longwave radiation. The net effect of contrails is warming. Photos taken by Emily Tracey.

CONTRAIL FORMATION

The formation and evolution of contrails are governed by a combination of thermodynamic, microphysical, and dynamical processes. Aircraft engines emit hot, humid exhaust containing water vapor, heat, and soot particles. As this exhaust mixes rapidly with the cold ambient air at cruising altitude, the temperature decreases while the relative humidity increases. If saturation is reached,

water droplets form on available condensation nuclei and quickly freeze into ice crystals, producing a visible contrail. Emitted soot particles provide the surface for water vapour to condense onto.

The thermodynamic conditions required for contrail formation are described by the Schmidt–Appleman criterion, which depends on ambient temperature, pressure, and humidity, as well as engine-specific parameters such as propulsion efficiency and water vapor emissions [3-5]. Together, these variables determine a critical temperature threshold below which the mixing of exhaust gases with ambient air leads to saturation and contrail formation. While the Schmidt-Appleman criterion predicts the formation of contrails, it does not predict their persistence. Contrails persist only when they form within ISSRs. These regions are relatively common in the upper troposphere because the ice nuclei required for ice formation are rare, allowing air to remain supersaturated with respect to ice for extended periods. ISSRs typically occur in ascending air, where cooling reduces the saturation vapor pressure faster than the water vapor concentration decreases. The upward motion of humid air is a relatively small-scale phenomena that occurs commonly near fronts and warm conveyor belts around storm systems. The vertical extent of ISSRs is often small, typically on the order of 500–1000 m [6] due to the strong temperature gradient in the upper tropopause and local variations in atmospheric water vapour. ISSR occurrence varies seasonally with minimum occurrence in the summer and maximum in late winter.

Beyond initial formation, contrail evolution is strongly influenced by aircraft wake dynamics. Four phases are usually distinguished: the jet, vortex, vortex dissipation, and diffusion phases [7,8]. During the jet phase, immediately after emission, exhaust gases mix with ambient air and initial ice crystals form. In the vortex phase, counter-rotating wingtip vortices transport the contrail downward by tens of meters. The primary vortex pair may descend into warmer air, causing ice crystals to sublimate, while secondary vortices may lift some ice crystals back toward altitudes more favorable for persistence. During the vortex dissipation phase, the wake breaks down and ice crystals are released into the surrounding atmosphere. In the final diffusion phase, the contrail spreads both horizontally and vertically due to atmospheric turbulence, wind shear, particle sedimentation, and radiative processes. Persistent contrails can evolve into cirrus-like clouds that last for several hours with significant impact on Earth's radiation balance.

CONTRAIL MODELS AND PREDICTION

Predicting contrail formation and evolution is essential for implementing mitigation strategies such as altitude adjustments. The Schmidt–Appleman criterion provides a first-order estimate of whether contrails will form under given atmospheric conditions. However, it does not determine whether they will persist. Persistence depends primarily on the distribution of ISSRs, but numerical weather prediction models often struggle to accurately resolve humidity at higher altitudes, where ISSRs occur [9].

More advanced models, such as the Contrail Cirrus Prediction model (CoCiP), simulate the full lifecycle of contrails. These models combine flight trajectory data with meteorological inputs to predict contrail formation, evolution, and radiative forcing. They incorporate processes such as ice crystal growth,

sedimentation, contrail spreading, and interactions with radiation. However, uncertainties due to the meteorological input data and parametrized microphysical processes remain. Improving observational data is therefore critical for validating and refining contrail prediction models [9].

CONTRAIL OBSERVATION

Satellite observations are currently the primary tool for large-scale contrail detection. Two main types of satellites are used: low Earth orbit (LEO) and geostationary (GEO) systems. LEO satellites provide high spatial resolution, allowing contrails to be resolved in detail. However, they revisit the same location relatively infrequently, typically every 12 hours to several days. This limits their ability to track contrail evolution and makes it difficult to observe all events. Additionally, attributing observed contrails to specific flights is challenging due to the limited temporal coverage. GEO satellites, in contrast, provide high temporal resolution, often delivering imagery every 5–30 minutes. However, their spatial resolution is coarser, typically on the order of 1–2 km. As a result, newly formed contrails, which are initially very thin, may not be detectable for the first 20–30 minutes. This again complicates flight attribution and limits the study of early contrail evolution. These complementary limitations highlight the need for additional observational approaches that can bridge the gap between spatial and temporal resolution. ***Lidar systems*** provide detailed vertical profiles of atmospheric properties and are highly sensitive to thin clouds, including contrails. They are particularly useful for determining contrail altitude, optical depth, and microphysical structure. However, lidar measurements are typically limited to narrow fields of view. Furthermore, only a small number of lidars are operated globally. Hence, lidar observation cannot provide continuous large-scale coverage.

Ground-based camera systems provide a promising complement to satellite and lidar observations. All-sky or wide-field cameras can continuously monitor large portions of the sky with high temporal resolution, capturing the full lifecycle of contrails. A key advantage of these systems is the ability to associate contrails with individual flights. By combining camera observations with flight tracking data, it is possible to match observed contrails to specific aircraft (Fig. 2). This enables direct validation of contrail prediction models and allows observed contrail properties such as lifetime, width, and spreading rate to be linked to aircraft characteristics and atmospheric conditions. Ground-based camera observations can also help quantify biases in satellite detection by identifying contrails that are missed due to spatial or temporal limitations. With appropriate calibration or multi-camera configurations, it is possible to reconstruct contrail geometry and estimate altitude, further increasing their scientific value. Single ground-based camera systems are limited by a lack of global coverage, however, a network of cameras like the Global Meteor Network [10] can provide both high-resolution observations and increased coverage.

FUTURE WORK

Future research should focus on integrating observational and modeling approaches to reduce uncertainties in contrail prediction and climate impact. Ground-based camera networks, similar in concept to existing meteor observation networks, offer a scalable and cost-effective means of continuously monitoring the sky at high temporal resolution. Combining these observations with

satellite images, lidar measurements, and flight trajectory information would enable more comprehensive validation of contrail models. Improved characterization of ISSRs, particularly their small-scale variability, remains a key challenge that requires both enhanced modeling and targeted observation campaigns. Finally, improving prediction accuracy is essential for implementing

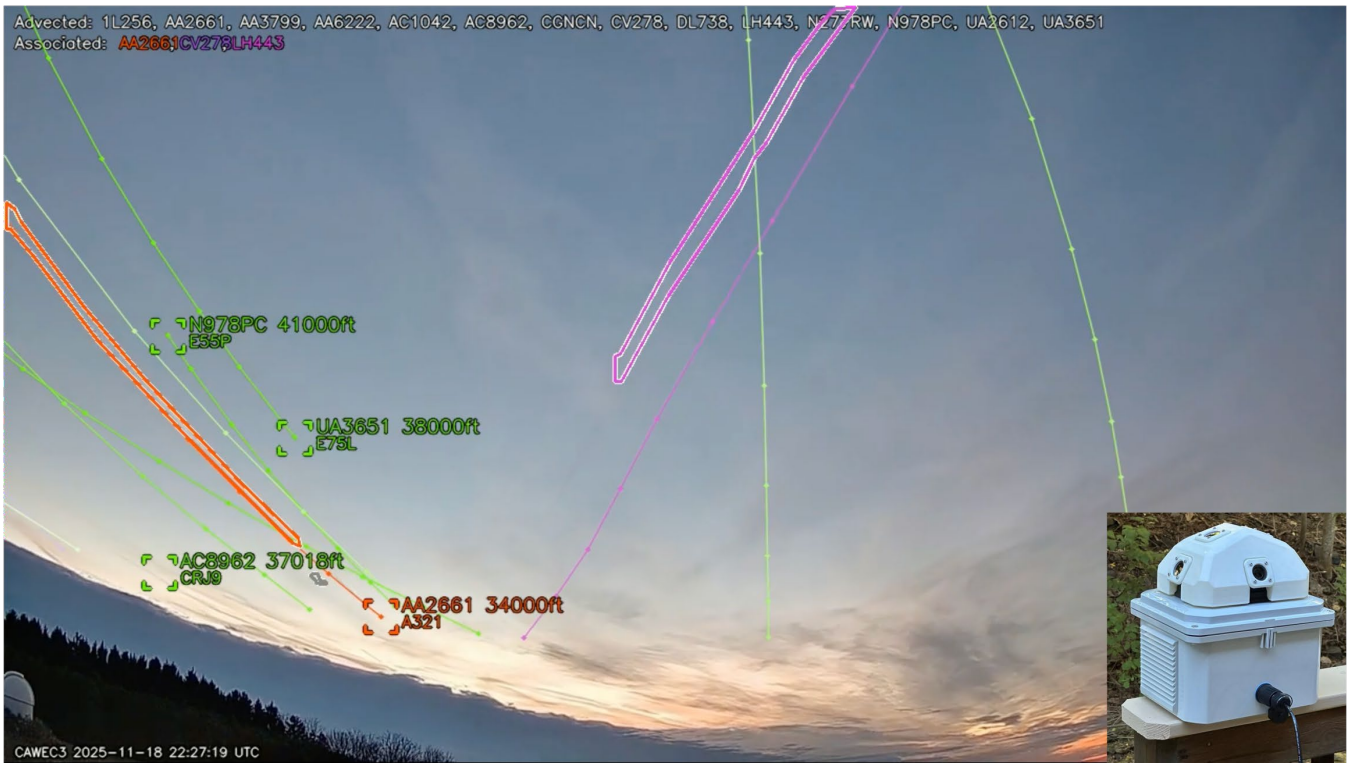


Figure 2. Contrails observed by a global Meteor Network (GMN) camera on November 11th, 2025 in London, Ontario. The flight tracks from Automatic Dependent Surveillance–Broadcast (ADS-B) data are overlayed on the image. Green flight tracks were not associated with a contrail. The pink and orange flight tracks were automatically associated with a contrail segmented by the same colour. The inset shows the GMN all-sky camera used to capture the image.

operational contrail avoidance strategies. By identifying flights most likely to produce persistent contrails, it may be possible to achieve substantial reductions in aviation climate impact with only minor changes to flight operations.

CONCLUSIONS

Contrails are a significant but uncertain contributor to aviation-induced climate change. While the physical mechanisms governing contrail formation are relatively well understood, predicting their occurrence and long-term evolution remain challenging due to limitations in atmospheric data and modeling. Current observational tools, particularly satellites, provide valuable insight but are

constrained by trade-offs between spatial and temporal resolution. Ground-based camera systems offer a promising complementary approach, especially for enabling direct association between contrails and individual flights. Reducing uncertainties in both prediction models and observations will be essential for developing effective mitigation strategies. As aviation demand continues to grow, improving our understanding of contrails represents an important opportunity to reduce the climate impact of air travel.

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OCEAN COLLAPSE? HISTORICAL, CONTEMPORARY, AND PHYSICAL BASIS OF THE ATLANTIC MERIDIONAL OVERTURNING CIRCULATION (AMOC)

SUMMARY: This paper examines how scientific understanding of the AMOC has evolved, key physical processes that sustain it, and what observations and models suggest about its future.





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The 2004 Science Fiction disaster film "The Day After Tomorrow" depicted the world instantly plunged into an Ice Age with the cessation of the "North Atlantic Current". While highly exaggerated, such narratives reflect a broader and persistent concern: the stability of the Atlantic Meridional Overturning Circulation (AMOC). In recent years this concern has been amplified by recurring coverage in the mainstream media suggesting the possibility of a rapid AMOC collapse, including coverage from The Guardian [1], the New York Times [2], the Globe and Mail [3], and the CBC [4]. While at times sensational, the coverage underscores the significant role that ocean circulation plays in the climate and the uncertainty surrounding its future behavior under anthropogenic forcing.

Ocean circulation is driven by a combination of boundary processes (wind stress, solar heating, evaporation, precipitation, and bottom friction) together with internal fluid dynamics (pressure gradients, viscosity, and convective instabilities). These motions are fundamentally shaped by fluid flow on a rotating sphere, where Earth's rotation and orbital geometry influence circulation across a wide range of spatial and temporal scales. Although the oceans are geographically distinct, they are connected through a global network of currents that redistributes heat, salt, nutrients, and carbon throughout the climate system.

The AMOC is a part of this network of currents and is a system of meridional (north–south) overturning circulation that links surface and deep ocean flows in seas adjacent to the North Atlantic (Labrador and Greenland-Irminger-Norwegian (GIN)) through the decadal variations of western boundary currents in the sub-polar North Atlantic [5] and interactions between currents and ocean bottom topography [6].

Surface circulation, primarily driven by wind, fluctuates at time scales of days to decades within an ocean basin. Deep ocean circulation, principally propelled by Southern Ocean winds and modulated by buoyancy changes in the sub-polar North Atlantic, spans the globe and has response timescales of decades to millennia. Thus, AMOC circulation strength is not solely controlled within the North Atlantic but derives much of its energy from the Southern Ocean, where wind-driven upwelling and abyssal-water formation regulate the return pathway of deep waters that ultimately feed the Atlantic overturning circulation. Figure 1 simplistically depicts the structure, pathways, and drivers of the global meridional overturning circulation.

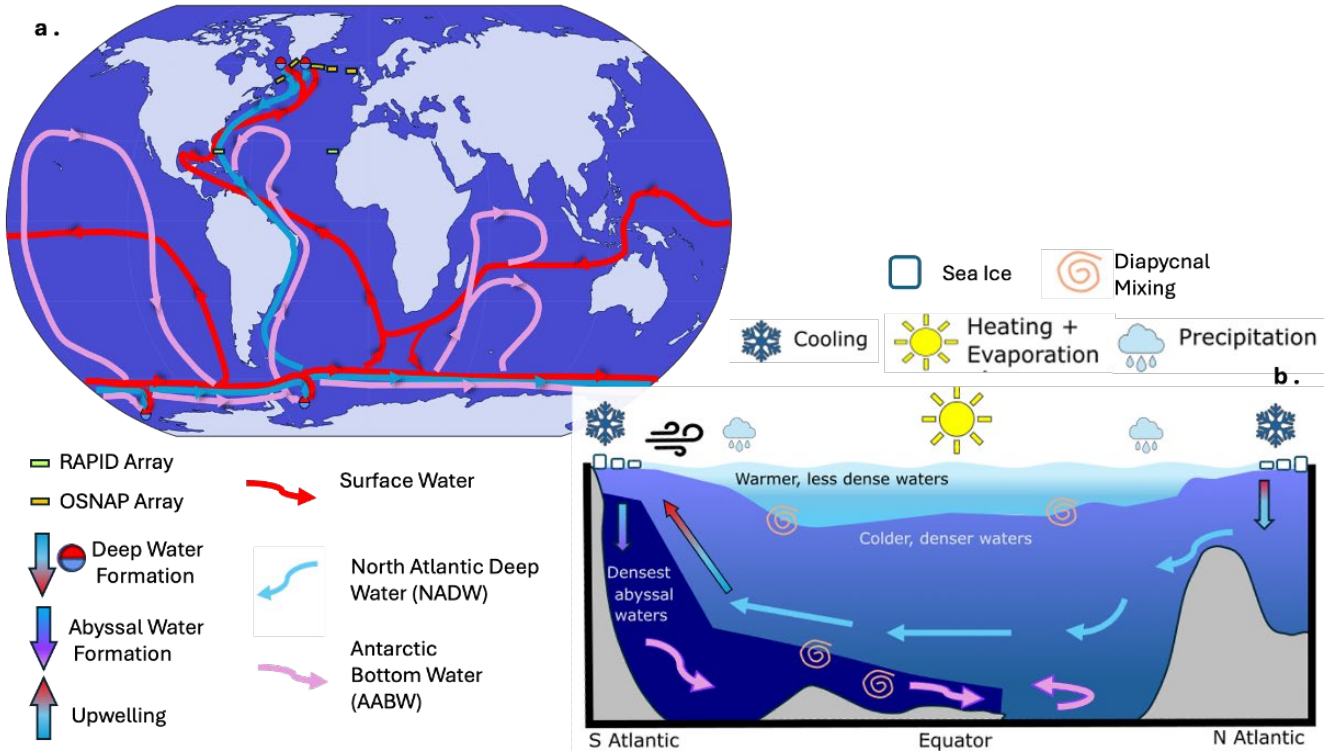


Figure 1. Conceptual diagrams of meridional overturning circulation. a. Global map, modified from [7], with warm/surface circulation (red), cold/deep circulation (blue), and abyssal circulation (pink). Circles indicate regions of deep-water formation. The locations of the RAPID (yellow) and OSNAP (gold) observational arrays are shown. b. Meridional depth section of the Atlantic Ocean, modified from [5], showing key physical processes controlling overturning circulation and their locations in the basin.

The strength and structure of the AMOC depend on the climate; warm climates generally support a stronger, deeper AMOC while glacial climates favor a weaker, shallower circulation. Yet, climate models show that the AMOC can behave in different ways under the same external conditions, including transitions between multiple stable states or natural oscillations between strong and weak

circulation. AMOC collapse, a state where the average current strength is reduced by 70-80%, has happened before during transitions from ice age climates to warm climates, through the stratification of the water column with the release of fresh water from retreating ice sheets.

Atlantic Canada's ecosystems, communities, and cultures, from the First Peoples of Turtle Island through to present inhabitants, are connected to the ocean. The meeting of warm Atlantic currents with the cool Labrador Sea supports a rich marine ecosystem. With AMOC shaping ocean conditions, weather patterns, and the global distribution of heat and nutrients, concerns about its changes are heightened by the risks of stronger hurricanes, increased storm surge, and impacts on coastal livelihoods. Here, we provide a brief introduction from the historical to present understanding of the AMOC, the underlying physics, and discuss what might happen in the future.

HISTORICAL TO PRESENT AMOC

Understanding of the AMOC has developed incrementally, beginning with observations of its surface expression. The Gulf Stream, the surface limb of the AMOC, was first noted in European records by Spaniard Juan Ponce de León in the 16th century and later charted by Americans Benjamin Franklin and Timothy Folger in 1768. Progress in understanding ocean circulation accelerated in the late 19th and early 20th centuries. Observations from high Arctic expeditions by Scandinavian explorers Nansen and Sverdrup informed the theoretical work of Vagn Walfrid Ekman, whose formulation of wind-driven surface transport laid the foundation for modern physical oceanography.

Despite these advances, the AMOC remained poorly characterized until the mid-20th century. The post–World War II period marked a turning point, driven by improved bathymetric mapping and expanded hydrographic observations. Pioneering theoretical work by Henry Stommel validated by observational data collected by Walter Munk integrated wind-driven and thermohaline processes, providing the first coherent framework for basin-scale and global ocean circulation.

Integrating decades of ocean chemistry observations and marine sediment core research, Wally Broecker introduced the term "The Great Ocean Conveyor" in the mid-1980s to describe the global ocean circulation that redistributes heat and proposed that it could switch on and off. Later work attempting to identify the energetic drivers that sustain this global circulation led to the identification of wind-driven Southern Ocean upwelling as fundamental to Atlantic overturning. This led to a change in terminology from thermohaline circulation to meridional overturning circulation [8-11].

Contemporary understanding of the AMOC comes from observational data obtained at different locations in the circulation. In the Florida Strait, at 26.5°N, there is the Rapid Climate Change-Meridional Overturning Circulation and Heatflux Array (RAPID) which has been collecting hourly data on a series of vertical moorings since 2004, complemented by ocean glider data [12]. This location is where peak northward transport of the surface component of the circulation is observed due to the narrowing of the Gulf Stream current through the Florida Strait. Farther to the North is the Overturning in the Subpolar North Atlantic (OSNAP) arrays; deployed in 2014, they consist of two mooring arrays and a series of float and ocean glider data spanning 52-60°N [13]. The OSNAP arrays are located to

enable observations of both the surface transports as well as deep-water return flows, from which deep-water formation rates can be estimated. With the OSNAP arrays, there is the ability to compare between the two North Atlantic sites of deep-water formation, the Labrador Sea and the GIN Seas.

These two data sets have provided immense insight into the variability of the AMOC. The average AMOC strength is ~17 Sverdrups (Sv, with 1 Sv = 10^6 m^3 s^{-1}), and the data captures the seasonal and inter-annual high frequency fluctuations of the current (Fig. 2). However, observational records span at most two decades and may therefore fail to capture the original state of the circulation and instead may observe the circulation already in a state of decline. Ocean transport operates on long timescales; a parcel of water in the deep and abyssal circulation can take on the order of ~2000 years to complete a full circuit of the global ocean, further complicating our understanding of the state of the system.

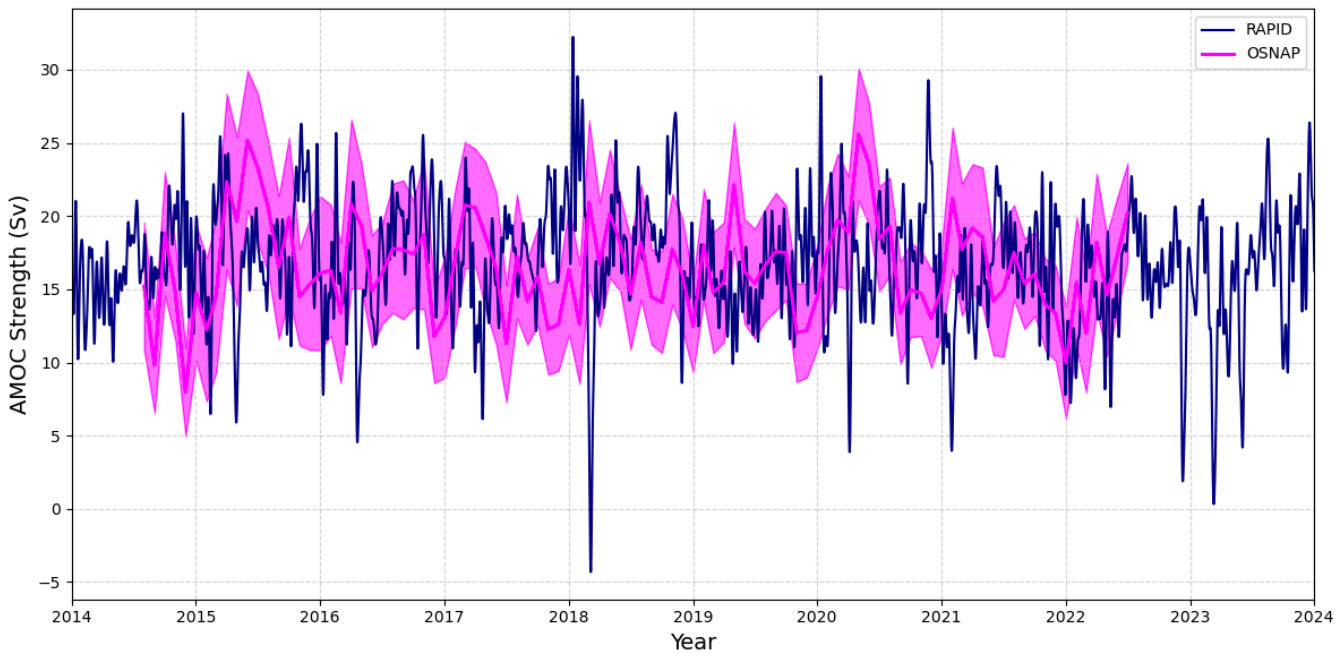


Figure 2. Meridional Overturning Circulation strength data from RAPID (navy) and OSNAP (magenta) from 2014 to 2024.

The emergence of geophysical fluid dynamics combined with increasing computational capacity enabled the transition from observations and simple theoretical models to robust quantitative modeling of the global overturning circulation through ocean General Circulation Models (GCMs). Modeling can bridge the gap between limited present and historical data and provides a physics-based understanding as to how changes in the current transpire. Ocean models provide our current understanding of the AMOC's sensitivity to climate change and the timescales over which it responds.

AMOC PHYSICS

The physics of the AMOC is complex. While these descriptions capture the large-scale circulation, they omit seasonal variability and smaller-scale processes such as eddies, tidal turbulence, and other energetically significant features found along boundary currents and in individual basins. Surface Western Boundary currents can be found in all ocean basins, including the Kuroshio in the Pacific and the Agulhas in the Indian Ocean. Likewise, there are multiple locations globally where deep-water forms, such as the Weddell and Ross Seas in Antarctica. What makes the AMOC unique is that it links wind-driven surface circulation in the Atlantic Ocean to deep-ocean circulation through high-latitude overturning convection. It is driven by a combination of wind forcing, buoyancy forcing (associated with temperature and salinity contrasts), and diapycnal mixing. These forcings interact nonlinearly.

Upwelling in the Southern Ocean supplies much of the water that feeds the upper branch of the AMOC. Strong westerly winds coupled with diapycnal mixing (interactions between stratified flow and rough topography) over the Southern Ocean drive Ekman transport, causing surface waters to diverge, and be replaced by deep water that upwells to the surface. Once at the surface, this water is transported northward through the Atlantic by the wind-driven subtropical gyre, where it is warmed and becomes increasingly saline through evaporation. As the flow approaches the western side of the basin, it is concentrated into a narrow, fast current by western boundary intensification, first described by Stommel [14]. This produces the Gulf Stream, which transports warm, saline water poleward along the eastern coast of North America before the water eventually reaches the high-latitude North Atlantic.

Thermohaline circulation is dependent on the nonlinearity of the equation of state for sea water. As water moves north in the Atlantic it cools and the density increases. Wintertime sea ice formation continues to increase the density of high latitude water through brine rejection, increasing sea water salinity and decreasing stratification of the water column. The resulting dense waters in the top 1000 m of the water column sink and form North Atlantic Deep Water (NADW) that moves towards the equator as the southward-flowing limb of the AMOC, connecting the Atlantic to the global circulation. This process occurs primarily in the Labrador Sea and in the GIN Seas. While flowing south, NADW can continue to increase in density as it interacts with Antarctic waters to further sink and form a component of Antarctic Bottom Water (AABW). Alternatively, NADW may upwell in the Southern Ocean, returning to the surface in processes described previously.

AMOC FUTURE

In a warming climate, the future response of the AMOC is complicated by competing mechanisms. Deep-water formation will be maintained or enhanced by increased evaporation, enhancing surface salinity and density of the surface water, supporting overturning. However, deep-water formation will decrease through increased stratification through ocean warming and increased freshwater input from melting Greenland and Antarctic ice sheets. Additionally, with increased water temperature less sea ice forms, reducing brine rejection and decreasing the production of dense waters that contribute to deep-water formation. Some factors can have opposite effects depending on the timescale analyzed. For example, a sustained positive phase of the North Atlantic Oscillation can have an immediate reducing effect on the AMOC followed by a strengthening effect approximately a decade later [15,16].

Modeling of past episodes of AMOC collapse (strength of ~5 Sv, 70% reduction of 17 Sv) were largely driven by the release of fresh water from the retreat of continental ice sheets in North America and Eurasia. The meltwater fluxes into the North Atlantic and Arctic Oceans were far greater than those expected from modern Greenland melt and strongly freshened and stratified the upper ocean. Importantly, these events occurred during deglaciations, when large ice sheets were retreating and the climate system was transitioning from glacial to interglacial conditions, rather than within our current warm state. This challenges the use of historical collapse for projections of the AMOC.

Although observational records remain relatively short, removing high frequency variability from the RAPID and OSNAP arrays suggests that the AMOC is declining by 0.6–1.4 Sv/decade [17]. Coordinated climate model experiments assessed by the IPCC project forecast continued AMOC weakening across all future socioeconomic pathways throughout the twenty-first century, with current strength declines ranging from approximately 10–50% by 2100 [18]. Baker *et al.* [19] analyzed 34 climate models and found that although the AMOC weakens substantially under extreme greenhouse gas and freshwater forcing, Southern Ocean wind-driven upwelling prevents a complete collapse by sustaining a reduced overturning circulation. In several models, prolonged AMOC weakening also promotes the development of a Pacific Meridional Overturning Circulation (PMOC), suggesting that deep-water formation can shift from the Atlantic to the Pacific under sufficiently altered climate conditions. However, model projections remain uncertain due to differences in how key oceanic and atmospheric processes are represented, particularly those governing deep-water formation, mixing, and freshwater forcing. In addition, the IPCC models likely underestimate or incompletely represent freshwater input from Greenland Ice Sheet melt, which may influence the magnitude of future AMOC weakening.

Not all modeling work suggests long term collapse. Nobre *et al.* [20] demonstrated that greenhouse warming can produce a pronounced but reversible AMOC weakening, highlighting the roles of Arctic sea-ice loss, freshwater input, and salt advection in controlling overturning circulation. Additionally, the grid resolution of the ocean model also impacts the resulting AMOC circulation. Modeling work by Pennelly and Myers [21] at an unusually high resolution of $1/60^{o}$ in the Labrador Sea indicated mesoscale and sub-mesoscale eddies control the mixing of coastal freshwater into the interior of the Labrador Sea. Coarser-resolution models do not explicitly resolve these eddies and instead tend to overestimate freshwater exchange across the shelf break, which could amplify the slowdown of the AMOC in their model results.

Predicting the future behavior of the AMOC, both near and long term, remains difficult; anthropogenic warming may be pushing the system beyond conditions previously experienced during the paleoclimate record. Past AMOC variability may not fully constrain the future response. Foundational, theoretical work done by Stommel [22] proposed that overturning circulation may possess multiple stable states, including the modern vigorous circulation and weaker salinity-driven mode. Once the transition between bistable states is made it could be very hard to reverse. While the magnitude and timing of future AMOC change remain uncertain, climate warming is expected to alter overturning dynamics. The AMOC strongly influences Canadian climate and ocean conditions, and continued research spanning paleoclimate reconstructions, modern observations, and future projections remains

essential to assess the range of possible outcomes. Unlike "The Day After Tomorrow", however, any AMOC weakening would unfold over decades to centuries and is expected to produce regional climate changes rather than an abrupt transition to an ice age.

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LE RÔLE DE LA MODÉLISATION DES SYSTÈMES ÉNERGÉTIQUES POUR APPUYER LA DÉCARBONATION DU CANADA

RÉSUMÉ : Longtemps le domaine de la recherche opérationnelle et des économistes, la modélisation des systèmes énergétiques a tout à gagner de la contribution de la physique.



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Les systèmes énergétiques représentent l'ensemble des sources d'énergie utilisées par nos sociétés, ainsi que les infrastructures et les technologies associées à leur production, à leur transport, à leur transformation et à leur utilisation dans leur service final, ce qui inclut : chauffage, un bâtiment, transport de personne et de marchandise, fabrication d'un bien et autres [1]. Ces systèmes sont complexes, interconnectés et, dans la plupart des cas, se sont développés au fil du temps dans un mélange de croissance organique, de planification publique et de lutte pour la protection de divers intérêts. Le rôle central des systèmes énergétiques dans nos sociétés est devenu évident après les premières crises pétrolières du début des années 1970. Les interruptions brutales de livraison de pétrole ont fait apparaître la nécessité de comprendre le système énergétique, ce qui a propulsé le développement des premiers modèles, basés sur une représentation ascendante de ce système. Ces modèles, qui décrivent avec détails les représentations et les relations techniques et économiques de la production à la consommation finale, jouent différents rôles dans la compréhension et la planification des systèmes énergétiques.

Plusieurs familles de modèles existent : des modèles de simulation, qui évaluent, à partir de diverses règles, l'évolution des besoins énergétiques en fonction de la croissance démographique et économique, en plus des transformations technologiques [3] ; des modèles d'optimisation ascendants, qui partent de l'état actuel du système énergétique (de la production aux technologies de consommation) [4] et qui évaluent, souvent en fonction des demandes évaluées par simulation, les choix énergétiques et technologiques optimaux afin de réduire les coûts du système tout en répondant aux demandes affichées; des systèmes descendants [5], souvent basés sur une théorie classique d'équilibre général, qui partent d'une description globale et à haut niveau du système économique pour évaluer le lien entre ces transformations et le reste de l'économie. En parallèle, bien sûr, d'autres modèles techniques ont été développés pour représenter, entre autres, les réseaux électriques, les

réseaux gaziers et le système pétrolier, en appui à la planification et à la gestion de ces réseaux complexes.

Après une période relativement tranquille dans le domaine énergétique, l'intérêt pour les modèles systémiques fut relancé avec les grands traités internationaux sur le climat, et la volonté affichée par de nombreux pays de réduire de manière importante leurs émissions de gaz à effet de serre, et même, avec l'Accord de Paris, signé en 2015, de viser la carboneutralité à l'horizon 2050 (Fig. 1) [5]. Puisque le secteur énergétique est responsable des deux tiers des émissions mondiales, il allait de soi que toute réduction allait impliquer des transformations du système énergétique tout en élargissant les variables considérées pour inclure des enjeux climatiques, environnementaux et de cycle de vie, avec les modèles d'évaluation intégrée [6].

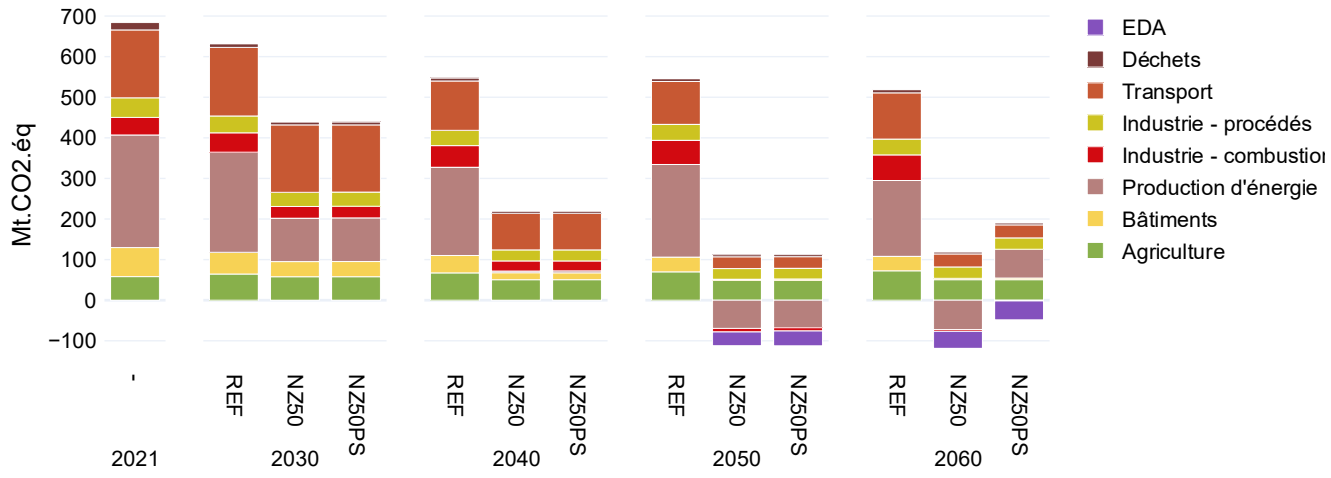


Figure 1. Émissions totales de gaz à effet de serre par secteur entre 2021 et 2060 pour le Canada dans un contexte de carboneutralité pour 2050 obtenu avec le modèle ascendant d'optimisation technico-économique NATEM de la firme ESMIA Consultants. On remarque, à partir de 2050, une quantité importante d'émissions négatives, c'est-à-dire retirées de l'atmosphère. REF est le scenario de référence sans objectifs de réduction des émissions de gaz d'effets de serre. NZ50 vise la carboneutralité d'ici 2025, tandis que NZ50PS ajoute au NZ50 les coûts des petits réacteurs nucléaires (Source: Fig. 4.1 de Ref. [2])

Si, dans un premier temps, avec des objectifs de réduction marginaux, les efforts se sont d'abord concentrés sur une meilleure utilisation des sources énergétiques et des technologies qui leur sont associées, suivant les politiques d'efficacité énergétique développées dans la foulée des deux premières crises pétrolières, une telle approche n'est plus appropriée lorsqu'on vise la carboneutralité : il faut alors changer de source d'énergie, et non simplement en réduire l'utilisation à la marge. L'adoption d'objectifs de carboneutralité, couplée à l'intégration massive de nouvelles sources d'énergie, principalement olienne et solaire, avec des caractéristiques très différentes des sources traditionnelles, a donc relancé l'intérêt pour la modélisation de systèmes énergétiques, incluant le développement de nouveaux outils, d'approches et de paramétrisation, ainsi que de nouvelles technologies énergétiques pour le transport, le chauffage, etc., dans le but de faciliter la planification et le développement de politiques publiques. Cette relance d'efforts pour modéliser les systèmes énergétiques survient alors que la communauté scientifique se tourne de plus en plus vers le développement de modèles ouverts, des codes aux données, alors que les codes historiques sont majoritairement privés et fermés.

On a donc assisté, au cours des dernières années à un renouveau dans la communauté de la modélisation énergétique, avec la participation de nombreux nouveaux joueurs. Longtemps réservés aux spécialistes de la recherche opérationnelle, aux économistes et aux ingénieurs, particulièrement provenant du génie électrique, ce domaine attire maintenant des chercheurs de plusieurs autres disciplines, dont des physiciens, alors que les méthodes de simulation se diversifient avec, par exemple, des modèles stochastiques ou par agents [7], qui rejoignent les approches traditionnellement développées par les physiciens, mais aussi pour leur expérience avec des calculs plus importants.

La nouvelle philosophie de modélisation offre la possibilité de mieux intégrer les approches non linéaires ou basées sur les systèmes complexes et d'aller au-delà des modèles d'optimisation habituels dans le domaine, qui s'appuient essentiellement sur la minimisation de choix discrets, c'est-à-dire qui imposent de choisir une ou l'autre technologie, pas un mélange continu des deux. Ce type d'optimisation ne permet pas l'utilisation de dérivées et requiert souvent une formulation linéaire et l'utilisation d'outils privés et fermés pour leur solution.

Malgré les efforts considérables, que nous avons observés dans le domaine ces dernières années, de nombreux défis persistent pour la communauté. Des défis qui peuvent en partie intéresser les physiciens. Du côté des enjeux techniques, le développement de méthodes qui permettent d'aller au-delà des solutions linéaires de variables discrètes faciliterait certainement le développement de systèmes plus complexes. On peut imaginer, par exemple, que des approches stochastiques ou même les ordinateurs quantiques permettraient une exploration beaucoup plus riche de problèmes de ce type. De même, historiquement, les modèles de systèmes énergétiques sont généralement conçus pour rouler sur des infrastructures de calcul relativement légères, souvent des serveurs locaux. Repenser ces problèmes et les codes qui viennent avec pour l'utilisation sur des superordinateurs permettrait certainement de traiter des problématiques plus complexes.

Au cœur de ces enjeux techniques, se trouve également la question des données. Comment générer ces données alors qu'elles ne sont souvent pas disponibles publiquement? Est-ce que des approches

permettant de séparer des données assemblées, de retirer le bruit, d'utiliser des approches statistiques similaires aux traitements dans diverses branches de la physique permettrait de reconstruire certaines de ces données?

Finalement, se pose la question des approches de modélisation, des questions traitées. Par construction, les modèles de systèmes énergétiques ont tendance à se concentrer sur des systèmes grands, des provinces, des pays, des continents. Or, la transformation du système énergétique se passe aussi au niveau très local avec des impacts parfois très différents. L'intégration, des nouvelles technologies de consommation, mais aussi de production et de stockage d'énergie délocalisées implique des solutions et des analyses qui vont dans les deux directions et qui impliquent des échanges fortement non linéaires. Est-ce que des méthodes développées par des physiciens, que ce soit pour l'analyse des matériaux, l'approche multiéchelle à des problèmes complexes, seraient pertinentes ici? Dans ce contexte, l'analyse de ces systèmes complexes rejoint celles faites par les physiciens, spécialistes des systèmes complexes.

À ces questions techniques, il faut ajouter les questions comportementales, individuelles. Trop souvent, les modèles ont tendance à oublier les choix et les comportements des consommateurs, qu'ils soient des individus ou des personnes morales. Or, dans les contextes, bidirectionnels actuels, leur rôle devient crucial. Plutôt que d'imposer aux citoyens des comportements, qui permettent de reproduire les solutions optimisées des modèles, il est nécessaire de revoir les algorithmes et les méthodes de simulation afin d'intégrer les réalités individuelles pour une planification plus réaliste des transformations à venir.

ICI AU CANADA

Au fil des décennies, les chercheurs canadiens ont contribué de manière significative au développement de nombreux modèles, dont le modèle MARKAL-TIMES. Comme ailleurs dans le monde, l'importance renouvelée de la modélisation énergétique pour la planification de la transition énergétique a renforcé l'intérêt des gouvernements pour la modélisation énergétique. Cet intérêt a mené à la création du Carrefour de modélisation énergétique [8] en 2022, une structure initialement pilotée par Louis Beaumier et moi-même de l'Institut de l'énergie Trottier à Polytechnique Montréal, Madeleine MacPherson de l'Institut for Integrated Energy Systems à l'Université de Victoria et Blake Shaffer de la School of Public Policy de l'Université de Calgary et dont le financement par Ressources naturelles Canada a été renouvelé pour quatre ans en 2025, avec l'ajout de partenaires de l'Université York et de l'Université Carleton. En plus de rassembler les chercheurs et les parties prenantes intéressées par la modélisation énergétique, cette organisation développe et maintient une base de données énergétiques et des modèles ouverts accessibles à l'ensemble de la communauté canadienne. En parallèle, Ressources naturelles Canada a lancé quelques appels à projets au cours de dernières années pour favoriser le développement de modèles ouverts dont plusieurs seront intégrés, à divers niveaux, dans les outils du CME.

Ce contexte collaboratif canadien permet aux divers chercheurs intéressés par le domaine de s'intégrer facilement et de participer au développement d'outils sans avoir à commencer à zéro. C'est donc un excellent moment pour les physiciens intéressés par ces questions de s'intégrer dans cette

communauté croissante et de contribuer à faire progresser un domaine crucial pour la transformation du système énergétique canadien, mais aussi de celui de la planète toute entière.

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THE ROLE OF ENERGY SYSTEM MODELING IN SUPPORTING CANADA'S DECARBONIZATION

SUMMARY : Long the domain of operations research and economists, energy system modeling has much to gain from the contributions of physicists.



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Energy systems encompass all the energy sources used by a community, as well as the infrastructure and technologies associated with their production, distribution, conversion, and utilisation in end-use applications, such as: heating a building, transporting people and goods, manufacturing goods, etc. [1]. These systems are complex, interconnected, and, in most cases, have developed over time through a combination of organic growth, public planning, and the struggle to protect various interests. The central role of energy systems in our societies became evident following the first oil crises of the early 1970s. Sudden disruptions in oil supplies highlighted the need to understand energy systems, which spurred the development of the first models, based on bottom-up representations of these systems. These models, which describe in detail the technical and economic aspects and relationships from production to final use, play various roles in understanding and planning energy systems.

There are several families of energy system models: simulation models, which use various rules to assess how energy needs will evolve based on population and economic growth, as well as technological changes [3]; bottom-up optimization models, which start with the current state of the energy system (from production to utilisation technologies) [4] and—generally building on demand estimates derived from simulations—assess the optimal energy and technology choices that minimize system costs while meeting projected demand; and top-down systems [5], often based on classical general equilibrium theory, which start with a broad, high-level description of the economic system to assess the link between these transformations and the rest of the economy. In parallel, of course, more technical models have been developed to represent, among other things, electric grids, gas networks, and the petroleum system, in support of the planning and management of these complex networks.

After a relatively quiet period in the energy sector, interest in systemic models was reignited by major international climate treaties and the commitment expressed by many countries to significantly reduce their greenhouse gas emissions—and even, with the Paris Agreement signed in 2015, to aim for carbon neutrality by 2050 (Fig. 1) [5]. Since the energy sector is responsible for two-thirds of global emissions, it followed naturally that any reduction would require deep transformations of the energy system while broadening the range of variables considered in these models to include climate, environmental, and life-cycle issues, using integrated assessment models [6].

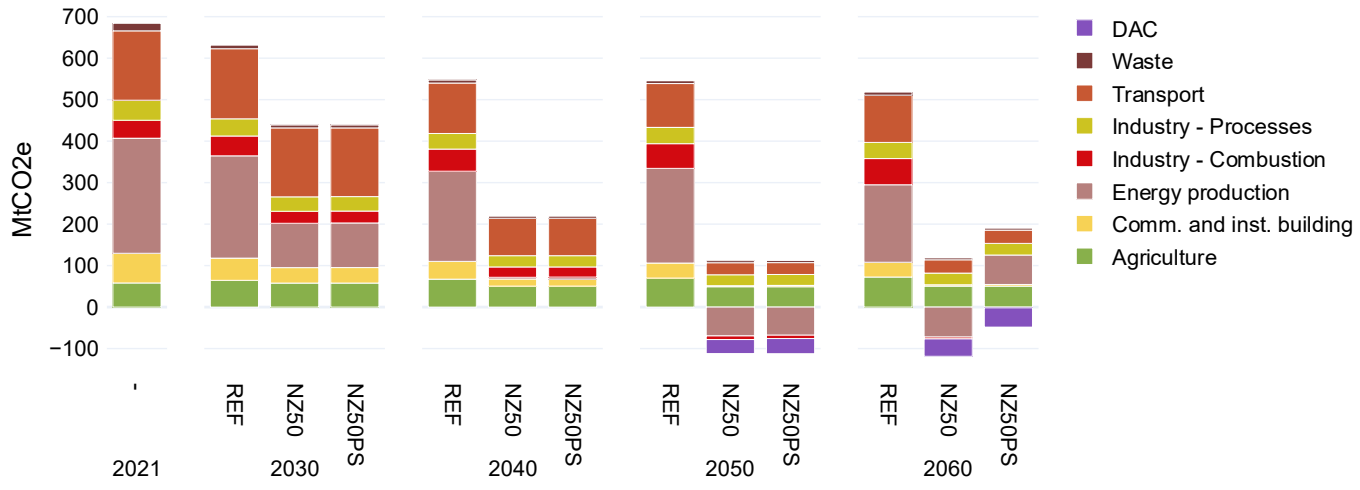


Figure 1. Total greenhouse gas emissions by sector between 2021 and 2060 for Canada under a carbon net-zero 2050 scenario, as calculated using the bottom-up techno-economic optimization model NATEM developed by ESMIA Consultants. Starting in 2050, there is a need for a significant amount of negative emissions—that is, emissions removed from the atmosphere, in order to reach net-zero. REF is the reference scenario with no greenhouse gas emission reduction targets. NZ50 aims for carbon neutrality by 2025, while NZ50PS adds the costs of small modular reactors to the NZ50 scenario (Source: Fig. 4.1 in Ref. [2])

While efforts initially focused on making better use of energy sources and related technologies—with modest GHG reduction targets—in line with the energy efficiency policies developed in the wake of the first two oil crises, such an approach is no longer appropriate when aiming for carbon neutrality: it is necessary to switch to different energy sources, rather than simply reducing marginally the use of fossil fuels. The adoption of carbon neutrality goals, coupled with the massive integration of new energy sources—primarily wind and solar, which have characteristics very different from traditional sources—has therefore reignited interest in energy system modeling, including the development of new tools,

approaches, and parameterization methods, as well as new energy technologies for transportation, heating, etc., with the aim of facilitating planning and the development of public policies. This renewed effort to model energy systems comes as the scientific community increasingly turns toward the development of open-source models—from codes to data—whereas historical codes are predominantly proprietary and closed-source.

In recent years, we have therefore witnessed a resurgence in the energy modeling community, with the participation of many new players. Long reserved for specialists in operations research, economists, and engineers—particularly those in electrical engineering—this field now attracts researchers from several other disciplines, including physicists, while simulation methods are diversifying to include, for example, stochastic and agent-based models [7], which complement the approaches traditionally developed by physicists, but also draw on their experience with larger-scale computations.

The new modeling philosophy offers the possibility of better integrating nonlinear approaches or those based on complex systems and of going beyond the standard optimization models in the field, which rely primarily on the minimization of discrete choices—that is, which require choosing one technology or the other, rather than a continuous mix of the two. This type of optimization does not allow for the use of calculus and often requires a linear re-formulation of the problem and the use of proprietary, closed-source tools for their solution.

Despite the considerable efforts we have seen in this field in recent years, many challenges remain for the community—challenges that may, in part, be of interest to physicists. On the technical front, the development of methods that go beyond linear solutions for discrete variables would certainly facilitate the development of more complex systems. One can imagine, for example, that stochastic approaches or even quantum computers would allow for a much richer exploration of problems of this type. Similarly, historically, energy system models have been designed to run on relatively lightweight computing infrastructures, often local servers. Rethinking these problems and the accompanying code for use on supercomputers would certainly make it possible to tackle more complex issues.

At the heart of these technical challenges lies the issue of data. How can we generate this data when it is often not publicly available? Would approaches that allow us to separate aggregated data, remove noise, and use statistical methods similar to those employed in various branches of physics enable us to reconstruct some of this data?

Finally, there is the question of modeling approaches and the issues addressed. By design, energy system models tend to focus on large-scale systems—provinces, countries, and continents. However, the transformation of the energy system is also taking place at the very local level, with impacts that can sometimes be very different. The integration of new technologies for energy consumption, as well as for decentralized energy production and storage, requires solutions and analyses that operate in both directions and involve highly nonlinear interactions. Would methods developed by physicists—whether for atomistic modelling or the multiscale approach to complex problems—be relevant here? In this context, the analysis of these complex systems aligns with that conducted by physicists who specialize in complex systems.

In addition to these technical issues, some behavioral and individual factors must also be considered. All too often, models tend to overlook the choices and behaviors of consumers, whether they are individuals or legal entities. Yet, in today's bidirectional contexts, these factors play a crucial role. Rather than imposing behaviors on citizens that merely replicate the models' optimized solutions, we need to revise algorithms and simulation methods to incorporate individual realities, thereby enabling more realistic planning for future transformations.

HERE IN CANADA

Over the decades, Canadian researchers have made significant contributions to the development of numerous models, including the MARKAL-TIMES model. As elsewhere in the world, the renewed importance of energy modeling for energy transition planning has strengthened governments' interest in energy modeling. This interest led to the creation of the Energy Modeling Hub [8] in 2022, an initiative initially led by Louis Beaumier and myself at the Institut de l'énergie at Polytechnique Montréal, Madeleine MacPherson of the Institute for Integrated Energy Systems at the University of Victoria, and Blake Shaffer of the School of Public Policy at the University of Calgary. Funding from Natural Resources Canada was renewed for four years in 2025, with the addition of partners from York University and Carleton University. In addition to bringing together researchers and stakeholders interested in energy modeling, this organization develops and maintains an open energy database and models accessible to the entire Canadian community. At the same time, Natural Resources Canada has issued several calls for proposals in recent years to promote the development of open models, many of which will be integrated, at various levels, into the CME's tools.

This collaborative Canadian environment allows researchers with an interest in the field to easily join and participate in the development of tools without having to start from scratch. This is therefore an excellent time for physicists interested in these issues to become part of this growing community and help advance a field that is crucial to the transformation of not only Canada's energy system but also that of the entire planet.

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ADDING ENVIRONMENTAL PHYSICS INTO ADVANCED PHYSICS LABORATORIES

SUMMARY: This paper describes the development of teaching laboratory experiments related to atmospheric processes to provide undergraduate students with authentic research experiences and exposure to scientific instrumentation used by scientists. We focus on a senior-level course that gives students freedom to ask their own research questions and, with guidance, design and pursue investigations aligned with their own research interests. This approach fosters inquiry, scientific autonomy, and development of research skills.



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One of the crucial missions of higher education is to train responsible citizens and contribute to a sustainable future [1]. Exposing students to research on Earth's climate and its components, and introducing them to relevant experimental techniques, is a crucial learning tool. The primary outcome of the Advanced Physics Laboratory courses at the University of Toronto is for students to explore how to measure and model physical systems and to critically assess, connect, and communicate their results [2]. Experiments in the course range from classical to very modern, and they represent fields of study pursued in the department. They are designed to "form a bridge to current experimental research" [3] by employing techniques and equipment used in professional laboratories in all fields of physics. The experiments are constantly updated, both through collaboration with the Engineering Science senior undergraduate design course at our institution [4] and through engagement with faculty members. In recent years, growing enrollment, student feedback, and analysis of the offerings identified a gap in the experiments; experiments related to atmospheric and environmental

physics, a field pursued by about 20% of the faculty members, was underrepresented in the experiment offering. This discovery inspired a focused developmental effort to address this issue and provide opportunities for students to pursue their research interests. The work resulted in significant updates to an existing experiment (*Fourier Infrared Spectroscopy, FTIR)* and the creation of three new experiments: a data-analysis focused *Anthropogenic Climate Change (ACC), a* field work inspired *Ozone Measurement* (*O3M)*, and geophysical fluid dynamics experiment *Weather in a Tank (WTK)*. Additional experiments being integrated into junior labs help develop interest in these experiments earlier in the undergraduate program and present a framework for integrating environment and climate physics into advanced laboratory curricula using a combination of data-driven, field-measurements, and analogue experiments.

COURSE OVERVIEW

The Advanced Physics Laboratory course at the University of Toronto hosts senior physics and engineering science students completing their third- or fourth-year course requirements. The course is staffed by faculty members, who supervise and assess students' work, and teaching assistants whose main role is to aid with setting up the equipment and conducting the experiments. The variety of experiments, skills, and tools required, and the expertise of the supervising faculty, ensure that the students experience a vibrant learning environment in which no two experiences are the same. Students state their experiment preferences in a selection process, and while not all requests can be honoured, most will work on one of their top choices. Students complete three experiments during the term, typically working individually, and they spend approximately 18 hours in the lab with each experiment over three weeks. The instruction manuals provide suggested experiments but leave room for students to design their own inquiry to extend their exploration. The course is integrated with an Engineering Science Capstone Design course [4], in which students work in small teams to redesign and implement experiments suitable for undergraduate laboratories at various levels.

FOURIER TRANSFORM INFRARED SPECTROSCOPY

Fourier Transform Infrared Spectroscopy (FTIR) is a technique commonly used to identify a wide range of materials, including atmospheric trace gases [5]. Bacsik *et al.* [6] reviewed the frequent and significant applications of FTIR in air monitoring studies in both environmental and industrial settings. The spectrometer, shown in Fig. 1, allows students to study gaseous and solid samples [7]. The laboratory provides a selection of gases, but students are encouraged to suggest and source their own samples. The primary goal of the experiment is to study the spectra and line-shapes of a variety of atmospheric gases at different pressures and temperatures and develop an understanding of how these spectra can be used in a simple retrieval to infer gas concentrations [7]. There is less ability to adjust the equipment in this experiment, but students have more freedom to explore other parameters, like the gas they choose, its temperature and pressure, and how they develop a simple retrieval algorithm.

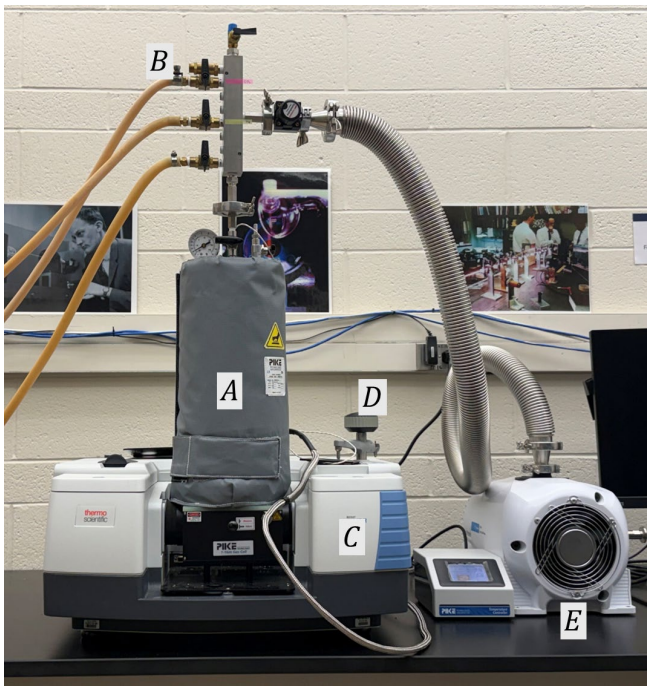


Figure 1. Multirange Nicolet iS50 spectrometer. A —gas sample compartment, B —entry points for gaseous samples, C —sample module, D —iS50 ATR module for investigation of solid and powder samples, E —pump.

ANTHROPOGENIC CLIMATE CHANGE

This experiment focuses on the analysis of large-scale climate datasets collected by researchers in the field. Students work with historical records of atmospheric composition, carbon dioxide emissions, temperature, and population data to investigate relationships between climate variables and develop their own research questions.

Students are provided with recommended sources for historical climate data [8] but are encouraged to find other suitable sources. Through guided preliminary experiments, students examine trends, consider data quality, and learn about future climate predictions and their societal relevance. In an open-ended exploration, students are asked to identify a suitable climate question from a selection of suggested topics, to identify relevant data, and to use that data to attempt to answer the question.

This experiment allows students to explore how complex environmental systems are studied using distributed datasets and to develop data analysis skills relevant to modern collaborative fields such as climate science, astrophysics, and particle physics. The experiment strongly emphasizes developing research questions and encourages students to connect environmental phenomena to the underlying physics. Both supervising professors and the TA supporting ACC highlight the importance and challenge of identifying research questions, encouraging the students to follow their curiosity.

OZONE MEASUREMENT

This experiment uses a portable instrument to measure solar radiation in narrow bands in the UV and near-IR bands to determine atmospheric composition. Students calibrate the instrument using nearby operational equipment and collect field measurements to determine the total ozone column and the concentration of water vapour in the atmosphere. The laboratory uses the Solar Light Microtops II Ozonometer [12], shown in Fig. 2. The instrument measures sunlight in three ultraviolet bands sensitive to light absorbed by Ozone and Oxygen (305 nm, 312.5 nm, and 320.5 nm), and two bands sensitive to light absorbed by water and aerosols (936 nm and 1029 nm). The device allows for dependable measurement of total ozone column per standard World Meteorological Organization configuration.

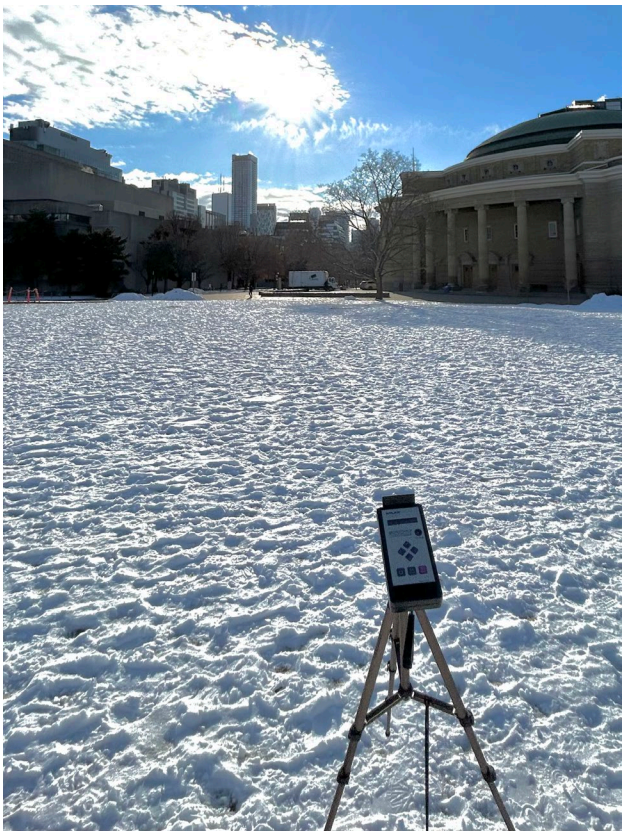


Figure 2. Solar Light's Model 520 Microtops II® Ozonometer [12], used in the *Ozone Measurement* experiment, set up on a sunny day (pointing at the Sun) during data collection in Winter 2025 at University of Toronto's St. George Campus.

The experiment emphasizes experimental design and planning in real-world conditions. The data acquisition takes place outside and depends on weather, time of day, and seasonal constraints.

Students must monitor weather conditions to identify suitable measurement windows, highlighting the challenges and uncertainties inherent in field-based research. After collecting their own measurements, students compare their localized measurements with the regional and global measurements of ozone from satellites and ground-based instruments.

WEATHER IN A TANK

This experiment uses a rotating tank of water as an analogue for Earth's atmosphere, allowing students to explore how large-scale flow patterns arise from the interplay of rotation and heating. By varying the rotation rate and imposing a temperature gradient, students observe how these fundamental drivers produce structured, weather-like circulation patterns. This design mimics larger-scale tanks [13] that are used as analogues of the Earth system.

In the experimental setup (Fig. 3), flow patterns are visualized using neutrally buoyant tracer particles illuminated by a laser sheet and recorded with a camera. The students then reconstruct the flow and analyze the fluid behaviour using Particle Image Velocimetry (PIV) software. The experiment emphasizes conceptual understanding through direct observations, connecting theoretical fluid dynamics to measurable phenomena.

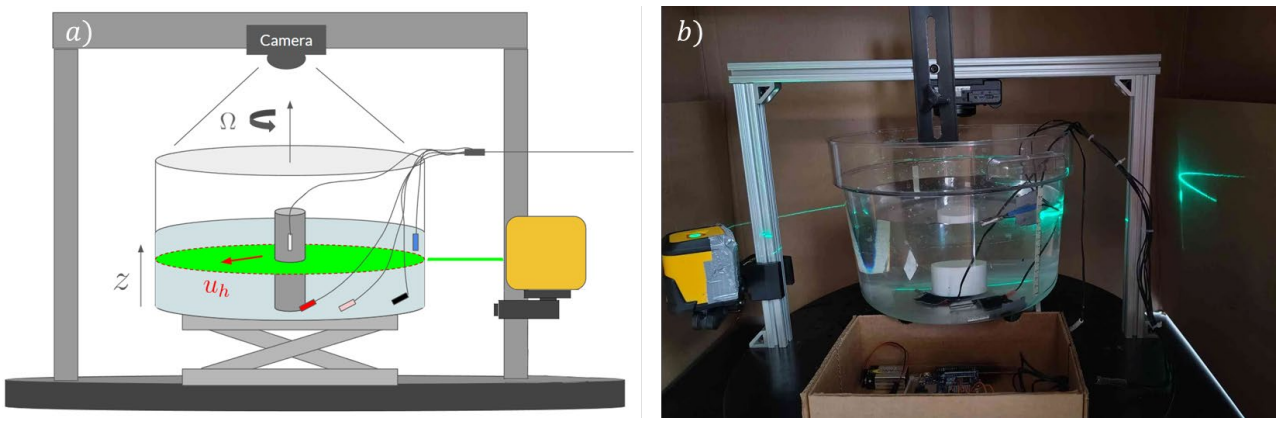


Figure 3. Experimental set up for the *Weather in a Tank* experiment. $a)$ The diagram of the set up viewed from the side, with z indicating the vertical direction, u_h indicating the radial component of of particle velocity, and Ω the angular velocity of the entire system. $b)$ The photograph of the set up enclosed in a box to minimize the external light.

Through this analogue system, students investigate how simplified physical models describe complex real-world phenomena. Although fluid motion is governed by the non-linear Navier-Stokes equations, the rotating tank configuration can be interpreted using simplified models, such as shallow-water approximations, that are commonly used to describe mid-latitude atmospheric dynamics. Students relate the phenomena in the tank to real atmospheric conditions using non-dimensional parameters that combine the rotation rate and fluid properties.

CONCLUSION

The integration of environmental and atmospheric physics experiments into the Advanced Physics Laboratory has expanded the range of experiences available to students. Together, these experiments demonstrate a framework for incorporating atmospheric physics into advanced laboratory curricula by combining data-driven analysis, field measurements, and analogue experiments. They are in demand – during the previous academic year approximately half of the students requested at least one of them among their top ten choices when stating preferences. Professors who conduct research related to environmental and atmospheric physics reported students looking for research projects reaching out to them quoting their experience in the lab as a factor in choosing the field.

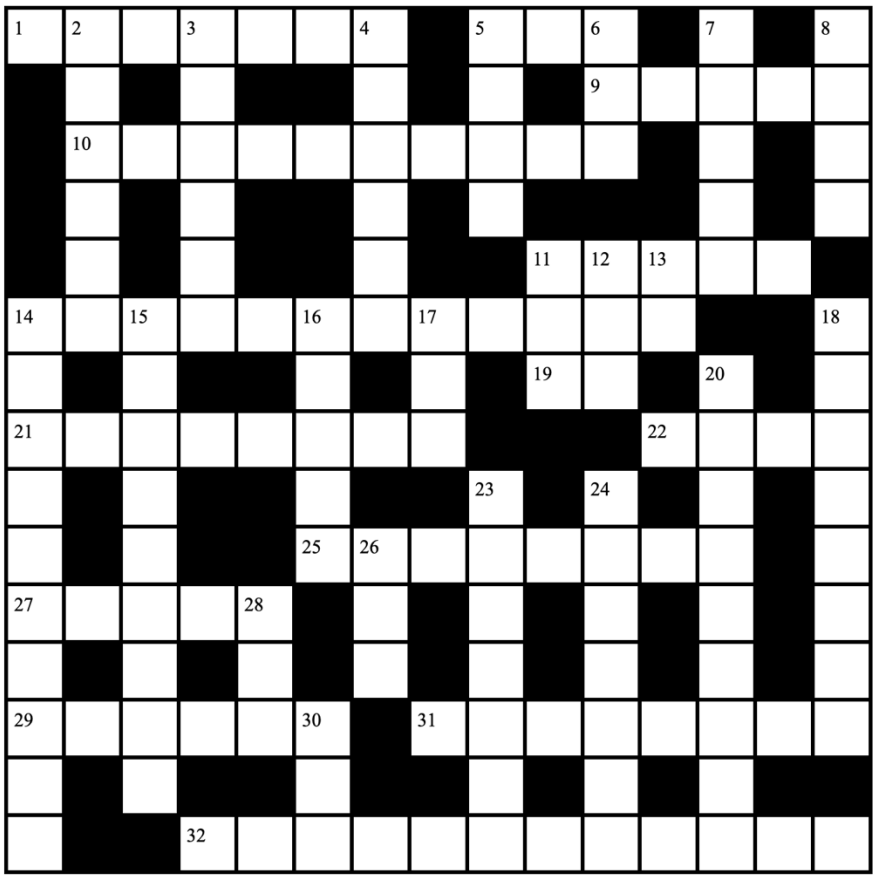
The current implementation focuses on experiments that reflect departmental strengths, but there are opportunities to develop experiments that explore a broader range of topics in environmental and atmospheric physics. In the junior laboratories, climate datasets [CO_2] are being used to introduce model fitting and forecasting, and a new experiment on the "Greenhouse effect" [14] is being developed, in which students will use a broadband heat source and detector to measure the IR absorption of gaseous carbon dioxide. Once incorporated into the junior laboratories, this experiment will serve as a precursor for FTIR and ACC projects in APL.

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CRYPTID CROSSWORD *BY DONERO*



VADOSE ZONE of SCRIBBLING

ACROSS

1. Rumour is: sasquatch leader is able and less than ideal. (7)
5. Assemble sixty percent left of right (3)
9. Electricity free from smelling unpleasant (5)
10. Replenished resources of the mixed eastern beer lawns (10)
11. Preserve bromine in last of wine (5)
14. Manipogo skin in strange raisin soup is cheap (12)
19. Silver is a drag in the end (2)
21. Conviction without a leader divides victories with death and brings nothing good (3,5)
22. West of one experimental site is an island (4)
25. It laid in mixed pasta (8)
27. Not quite quite soft (5)
28. A unit of it in east New York (6)
30. Cars made from boat parts with nothing changed (8)
31. Soup! To five of Lars' tasters as it cools initially in changing light (12)

DOWN

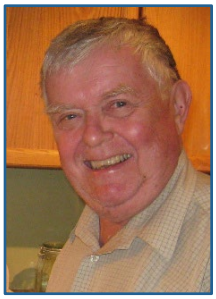
2. Crop each transparent layer (6)
3. Grandmother set up in France (6)
4. Sounds like a thin pair (4-2)
5. Right! One left drug muddy (4)
6. Up-bow air (3)
7. Jealous in Québec: large hesitation about width of letters (5)
8. Chupacabra dithers about drainage channel (4)
11. Stole tailless wild pig (3)
12. Hairpiece tops rude ugly guy (3)
13. Exists in the yeti story (2)
14. We hear our entry comes below soft red tin mixture in a list of outputs (5,5)
15. Family has French dreams about a curly tail (9)
16. Exploited? Object on air! (5)
17. We hear sunrise refusals (3)
18. 150:1 odds mean trees determine prevailing weather conditions (8)
20. In three states, fluorine, iodine and carbon become molten rock, rich in magnesium and iron (5,4)
23. Placed vase on five rockets (6,1)
24. I run, lad; weirdly every day! (7)
26. Irritate leaderless church (3)
28. Western giant regularly makes label (3)
30. Language sounds painful (3)

SOLUTIONS TO THE QUANTUM CRYPTIC CROSSWORD PUBLISHED IN ISSUE 81(2)

ACROSS: 1. (PA)(UL)(I) 4. BRAGG 9. ATO[H]M'S 10. TUN(ELL)ING 11. HE 12. (S)(O) 13. ISLE 14. (A)(S)(Y)(M)(P)(T)(O)(T)(I)(C) 20. (H)ELGOLAND (alt. spelling, no I) 21. (I)(DOL) 23. SUSPICIOUS 27. S(ITE)S 29. [M]ALIGNED 30. MAX BO[U]RNE 33. I'm TOADmit 35. (ST)(RUNG) 36. S(KET)(C)HED

DOWN: 2. (AN)(THE)(A) 3. finaL UNACYlization 4. (BALL)(OT) 5. hAiR tIeD 6. GAG 7. TOTA (anag.) (L) 8. (AS)(K)(S) 12. SPELLS 13. [N]ICE 15. SALES TAX (anag.) 16. (O)(INKS) 17. (S)(O)(L) 18. CHRISTMAS (anag.) 19. ADJOIN[T] 22. (AC)(HIEST anag.) 24. (UPEN[N])(D) 25. PLANCK 26. alSO DArk 28. (SW[IM])(O)(ON) 31. (B)(T)(U) 32. RAG[E] 34. [H]OH

BIRGER BERGERSEN (1938-2025)



Birger Bergersen was born in 1938 in Oslo, Norway, to Benedicte Nicolaysen and Birger Bergersen, a Norwegian anatomist and politician [1]. He spent much of his childhood in Sweden during the Second World War. He later attended the University of Trondheim, where he completed a degree in engineering. After graduation, he received a Wein Scholarship to study at Brandeis University in Massachusetts. While there, he met his wife, Silvia, in a beginner Russian class.

In 1964, after completing his Ph.D., Birger moved back to Norway, where he held a fellowship with the Norwegian Science Foundation. Silvia travelled to Norway with him, and they were married in Trondheim in 1966. In 1967, they moved to Gothenburg, Sweden, where Birger was a Nordita Fellow at the University of Gothenburg, and where their daughter, Eva, was born. In the summer of 1969, the family moved to Canada, with Birger taking a postdoctoral position at McMaster University, where he worked with Jules Carbotte. Then, in 1972, the family drove to Vancouver, where Birger joined the Department of Physics and Astronomy at the University of British Columbia as an Assistant Professor.

From 1972 until his retirement in 2004, Birger's research sought to clarify fundamental questions in statistical mechanics through the study of simple model systems that were designed to be realistic enough to reveal essential physical principles. His work focused especially on steady-state nonequilibrium phenomena and used computer simulations in combination with analytical methods such as renormalization group and mean-field theories. Birger also pursued interdisciplinary research, and his final project involved a critique of standard economic models that he believed were based on a faulty understanding of thermodynamics and statistical mechanics [2].

Birger had a genuine gift for independent and creative scientific thought, and he passed this on to his many students, encouraging them to follow their interests and scientific passions. He enjoyed wide-ranging conversations with them about science, life, current events, history, and personal experiences, and he often took them on hiking adventures in the local mountains. Birger had a strong desire to see as much of the world as possible, and throughout his career he worked with physicists in Australia, Singapore, and Europe.

With Michael Plischke of Simon Fraser University [3], he co-authored the well-regarded advanced textbook *Equilibrium Statistical Physics*, which appeared in three editions [4]. The first two editions, published in 1988 and 1994, were completed while he was still working at UBC. The third, expanded edition was published in 2006, after his retirement [4]. The family cabin in Tuwanek, near Sechelt, British Columbia, provided an ideal setting for working on his chapters.

Birger was deeply interested in nature and had been fascinated by mushrooms since the age of four. In retirement, he worked on labels and species lists based on many years of data documenting the varieties of mushrooms found near Vancouver. He enjoyed music and theatre, spending time at the cabin on the Sunshine Coast, and travelling with his family to Newfoundland, the Yukon, and Haida Gwaii. He never said no to an adventure or to the chance to see more of Canada.

He was concerned about climate change and consumerism and supported many not-for-profit organizations. He took pleasure in exploring and learning, whether about nature, authors, documentaries, or a new restaurant in the neighbourhood.

Birger's ability to understand complex ideas, his kindness, and his unwaveringly positive outlook on life were valued by the many people whose lives he touched. He will be deeply missed.

Béla Joós, University of Ottawa
Barbara Frisken, Simon Fraser University

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Allan Ian Carswell (1933-2026)

Optics Innovator, CAP Leader, and Philanthropist



Past President of the Canadian Association of Physicists Allan Carswell passed away on 29 March 2026 at the age of 93. Allan served as CAP President in 1985-86 when he contributed to the strengthening of the CAP's role in advocating for physics research and education in Canada.

Allan was an inspirational leader who joined the faculty at York University in 1968 and showed how a physicist in academia can leverage their knowledge and skills in physics to create technologies that take-off in the private sector through his research and development of LiDAR. He and his late wife, Helen Carswell, co-founded Optech Incorporated in 1974 and initially operated it out of their home with Helen taking care of the business and administrative matters of the company with Allan focusing on the technology and its exploitation. With Allan serving as its president until 2000, Optech became a global leader in LiDAR and continues to operate as Teledyne Optech. With the wealth acquired through the success of Optech, Allan and Helen established the Carswell Family Foundation which generously donated to many causes, including the CAP Foundation. His donation established a scholarship to encourage those with a physics degree to pursue a career as a secondary school teacher: the Allan Carswell Physics Educator Scholarship, which has been awarded to 12 students since its inception in 2020.

Born in Toronto on 4 October 1933, Allan Carswell attended Riverdale Collegiate and then the University of Toronto where he graduated with his Bachelor of Applied Science in Engineering Physics in 1956, his MA in 1957 and PhD in 1959. He then took up a Canadian National Research Council Postdoctoral Fellowship at the University of Amsterdam's Institute of Theoretical Physics where his research focused on high-power lasers and the new field of laser radar, now known as LiDAR. Moving back to Canada in 1961, he worked at RCA Victor Plasma Research Laboratories in Montreal. There he became the first Director of the RCA Optical and Microwave Research Laboratory, which under his leadership built the first CO_2 laser in Canada and this country's first helium-neon laser.

He returned to Toronto in 1968 where he advanced the field of LiDAR and laser research as a Professor in York University's Faculty of Science and mentored the next generation. Optech Incorporated was created as a spin-off from that work and was responsible for an expansion of LiDAR applications across a number of industries. These included airborne precision laser rangefinders used to build topographical profiles and bathymetric LiDAR systems for measuring the depth of water in oceans, lakes, and rivers. Optech's high-profile initiatives included working with NASA on its Phoenix Mars Mission to investigate the history of water on the planet as well as the potential for supporting microbial life on Mars. The robotic lander included an Optech LiDAR sensor developed under Allan Carswell's leadership, which was a key component of the Canadian Space Agency's Meteorological Station. The system sent laser pulses from the surface into the planet's atmosphere and

a telescope detected reflections from dust and ice yielding new information about the Marian atmosphere, including the first evidence of falling snow on Mars.

Allan Carswell was a founding member and board director of Ontario's Institute for Space and Terrestrial Science (now CRESTech), where he served as principal investigator overseeing LiDAR atmospheric observatories in Toronto and the Canadian High Arctic. Among his other contributions, he served as Chair and member of the National Science & Research Physics Committee (1977-81) and Chair of the committee on Laser Atmospheric Studies of the American Meteorological Association (1984-86).

Allan's accomplishments and service were recognized through numerous honours and awards. He was appointed a Fellow of the Canadian Aeronautics and Space Institute (1982) and a Fellow of the Royal Society of Canada (1984); invested as an Officer of the Order of Canada (2005); inducted into the University of Toronto Engineering Alumni Hall of Distinction (2006), the Canadian Academy of Engineering (2011), and the Order of Ontario (2021); and received the John H. Chapman Award of Excellence (2006), the Ernst & Young Ontario Entrepreneur of the Year Award (2009), the Volunteer Award from the Canadian Society of Petroleum Geologists (2010), the C.D. Howe Award from the Canadian Aeronautics and Space Institute (2010), and the Queen Elizabeth II Diamond Jubilee Medal (2012). In 2022, he was named Philanthropist of the Year by the Association of Fundraising Professionals.

In September 2019, the author of this obituary was invited by Allan to his family home in Thornhill, Ontario, to discuss how the Carswell Family Foundation might further promote physics education. Allan was a very gracious host, generously sharing stories of his family and introducing the author to Helen, whom he was lovingly caring for as she lived with dementia. His home was filled with a warmth and love that reflected Allan's deep devotion to Helen and the same generosity of spirit that characterized the work of the Carswell Family Foundation.

Through the Foundation, Allan and Helen supported education, scientific research, healthcare, and community engagement. Their philanthropy established scholarships, research chairs, and educational programs, advanced public understanding of astronomy and music education, strengthened medical education, and supported innovative Alzheimer's and dementia care, the Allan I. Carswell Observatory at York University—home to the largest telescope on a Canadian university campus—and the Canadian Association of Physicists' Allan Carswell Physics Educator Scholarship [1]. During the visit, Allan spoke with enthusiasm about founding Optech Incorporated with Helen and about the company's contribution to NASA's Phoenix Mars Mission. Allan, a truly inspirational physicist, entrepreneur, and technology pioneer, also shared that his greatest satisfactions were his family and the opportunity to give through the Foundation.

J. Michael Roney, University of Victoria

References

1. Please see the CAP website: www.cap.ca/capf/scholarships/carwell

2025 HIGH SCHOOL-CÉGEP PHYSICS TEACHING AWARDS / PRIX DE L'ACP EN ENSEIGNEMENT DE LA PHYSIQUE AU SECONDAIRE ET AU COLLÉGIAL 2025

The Canadian Association of Physicists joins members of our community in congratulating the winners of the 2025 CAP Award for Excellence in Teaching High School/CEGEP Physics. The award is intended to recognize excellence in teaching physics in Canadian high schools or CEGEPs and to encourage and promote physics at the high school/CEGEP level in Canada.

L'Association canadienne des physiciens et physiciennes se joint aux membres de notre communauté pour féliciter les lauréats des prix ACP pour l'excellence dans l'enseignement de la physique au lycée et au CEGEP 2025. Le prix vise à reconnaître l'excellence de l'enseignement de la physique dans les écoles secondaires ou les cégeps canadiens et à encourager et promouvoir la physique au niveau des écoles secondaires et des cégeps au Canada.

British Columbia and Yukon / Colombie-Britannique et Yukon



Brant Churchill, North Peace Secondary School (Fort St. John)

In recognition of his ability to provide an exciting and engaging environment for his students and, in particular, for his impact on rural and remote students by providing learning opportunities that are rare in the north.

En reconnaissance de sa capacité à créer un environnement stimulant et captivant pour ses élèves et, en particulier, pour son impact sur les élèves des zones rurales et isolées, auxquels il offre des possibilités d'apprentissage rares dans le Nord.

"I feel very honoured to receive this award from the Canadian Association of Physicists. I would like to thank my students and colleagues current and former for their constant inspiration and energy, which help me grow as an educator and person."

« Je suis très honoré de recevoir ce prix décerné par l'Association canadienne des physiciens et physiciennes. Je tiens à remercier mes élèves et mes collègues, actuels et anciens, pour leur inspiration et leur énergie constantes, qui m'aident à m'épanouir en tant qu'éducateur et en tant que personne. »

Prairies and Northwest Territories / Prairies et Territoires du Nord-Ouest



Philip Goldthorpe, Edmonton Public School Division

In recognition of his ability to inspire students to be "Lovin' the Physics" and encouraging them to be independent lifelong learners, earning him a reputation of being a "physics teacher of generational talent".

En reconnaissance de sa capacité à susciter chez les élèves l'amour de la physique et à les encourager à devenir des apprenants autonomes tout au long de leur vie, ce qui lui a valu la réputation d'être un « professeur de physique au talent générationnel »

"It is an honour to receive such a prestigious award. It compels me to continue striving for teaching excellence, in the ever-present hope of inspiring as many students as possible to find delight in the wondrous discipline of physics."

« C'est un honneur de recevoir un prix aussi prestigieux. Cela me pousse à continuer de viser l'excellence dans l'enseignement, dans l'espoir constant d'inspirer le plus grand nombre d'élèves possible à trouver du plaisir dans la merveilleuse discipline qu'est la physique. »

Atlantic / Atlantique



Mark Chiasson, Halifax West High School

In recognition of his accomplishments, particularly his focus on modernizing his class, and for his commendable community service

En reconnaissance de ses réalisations, notamment de ses efforts pour moderniser ses cours, ainsi que pour son engagement remarquable au service de la communauté.

"I am delighted, honoured, and humbled to receive this award. To be recognized alongside past recipients—educators I have looked up to, learned from, and been inspired by—means so much to me. I feel incredibly fortunate to be part of a community of passionate educators and school staff dedicated to student (and teacher) success, and I'm so grateful to work with today's youth and the curiosity, energy, and laughter they bring. Thank you!"

« Je suis ravi, honoré et touché de recevoir ce prix. Être reconnu aux côtés des lauréats précédents – des éducateurs que j'ai admirés, qui m'ont appris beaucoup et m'ont inspiré – signifie énormément pour moi. Je me sens incroyablement chanceux de faire partie d'une communauté d'éducateurs et de membres du personnel scolaire passionnés, dévoués à la réussite des élèves (et des enseignants), et je suis très reconnaissant de travailler avec la jeunesse d'aujourd'hui et de profiter de la curiosité, de l'énergie et des rires qu'elle apporte. Merci ! »

Unfortunately, there were no nominations received for the Ontario or Quebec-Nunavut regions for the 2025 awards. Please consider nominating high school or CEGEP teachers from these regions when the call for nominations is launched in the spring. Your nominations are vital to ensure we can recognize and honour deserving educators.

Malheureusement, aucune candidature n'a été reçue pour les régions d'Ontario ou du Québec / Nunavut pour les prix 2025. Veuillez proposer la candidature d'enseignant(e)s de lycée ou de CEGEP pour les prix 2026 lorsque l'appel à candidatures sera lancé au printemps. Vos candidatures sont essentielles pour que nous puissions reconnaître et honorer les éducateurs / éducatrices méritants.

2025 CAP-CAPF Scholarship Recipients / Bénéficiaires de bourses d'études de l'ACP-FACP 2025

The CAP is pleased to announce the recipients of the 2025 CAP-CAPF student scholarships, made possible through the generous donations to the CAP Foundation. Please visit the CAP website for the list of scholarship recipients with a link to the detailed citations and any remarks submitted by the recipient following the receipt of the award.

L'ACP est heureuse d'annoncer les récipiendaires des bourses étudiantes de l'ACP-FACP pour 2025, rendues possibles grâce aux généreux dons à la Fondation de l'ACP. Veuillez consulter le site web d'ACP pour obtenir la liste des récipiendaires des bourses d'études, ainsi qu'un lien vers les citations détaillées et les remarques à la suite de la réception de la récompense.

The 2025 Allan Carswell Physics Educator Scholarships / Les Bourses Allan Carswell d'enseignant en physique 2025



ANNABELLE CIZHALY, University of Victoria

In recognition of her excellent academic record and her strong commitment to physics education and mentorship. She has volunteered in a secondary school science classroom and mentored fellow graduate students in effective lab teaching, demonstrating both initiative and leadership in supporting physics learning at multiple levels. Annabelle recognises that physics can be seen as intimidating, resulting in "students [feeling] discouraged before we even [begin];" she hopes to "challenge these notions by making physics accessible, interesting, and engaging".

En reconnaissance de son excellent parcours universitaire et de son engagement sans faille en faveur de l'enseignement de la physique et du mentorat. Elle a fait du bénévolat dans une classe de sciences au niveau secondaire et a encadré d'autres étudiants de troisième cycle pour les aider à enseigner efficacement en laboratoire, faisant ainsi preuve d'initiative et de leadership pour soutenir l'apprentissage de la physique à différents niveaux. Annabelle reconnaît que la physique peut être perçue comme intimidante, ce qui conduit les élèves à « se sentir découragés avant même d'avoir commencé » ; elle espère « remettre en question ces idées reçues en rendant la physique accessible, intéressante et captivante ».



COURTNEY KATES, University of Waterloo

In recognition of her excellent academic record and extensive experience in physics education and outreach. Additionally, she has demonstrated remarkable innovation and initiative by designing low-cost experiments, developing lab resources, and delivering outreach sessions to students across Canada. Courtney's passion for teaching stems from a lifelong curiosity about the world, and she hopes to share that wonder by "[showing] people that physics is fun" and "creating free enrichment opportunities for students so they can have their love of physics nurtured".

En reconnaissance de son excellent parcours universitaire et de sa vaste expérience dans l'enseignement et la vulgarisation de la physique. De plus, elle a fait preuve d'une innovation et d'un esprit d'initiative remarquables en concevant des expériences à faible coût, en développant des ressources de laboratoire et en animant des sessions de sensibilisation auprès d'étudiants à travers le Canada. La passion de Courtney pour l'enseignement découle d'une curiosité de longue date pour le monde, et elle espère partager cet émerveillement en « [montrant] aux gens que la physique est amusante » et en « créant des opportunités d'enrichissement gratuites pour les étudiants afin qu'ils puissent cultiver leur amour de la physique ».

The 2025 Eric C. Svensson Memorial Graduate Scholarship / La Bourse commémorative pour étudiants de cycles supérieurs Eric C. Svensson 2025



RIKU MIZUTA, University of British Columbia

In recognition of his pioneering investigations of mechanisms for dark matter creation in the earliest moments after the Big Bang, and for multifaceted contributions to the broader physics community, including EDI programs at TRIUMF, and development of the CAP Student Advisory Council web site.

En reconnaissance de ses recherches pionnières sur les mécanismes de création de la matière noire dans les instants qui ont suivi le Big Bang, ainsi que pour ses contributions variées à la communauté scientifique au sens large, notamment aux programmes EDI de TRIUMF et à la mise en place du site web du Conseil consultatif des étudiants de l'ACP.

2026 CAP Medal Recipients / Lauréats des médailles de l'ACP de 2026

The CAP is very pleased to recognize its 2026 medal recipients. Please visit the CAP website for the list of medal recipients with a link to the detailed citations.

L'ACP est très heureuse de reconnaître ses récipiendaires de médailles 2026. Veuillez consulter le site web de l'ACP pour obtenir la liste des récipiendaires de médailles, ainsi qu'un lien vers les citations détaillées.

CAP Medal for Lifetime Achievement in Physics / Médaille de l'ACP pour contributions exceptionnelles à la physique



BRUCE GAULIN, McMaster University

In recognition of his groundbreaking applications of neutron scattering to the understanding of quantum materials, especially in studies of geometrically frustrated magnetic systems.

En reconnaissance de ses applications novatrices de la diffusion neutronique à la compréhension des matériaux quantiques, notamment dans le cadre d'études sur les systèmes magnétiques à frustration géométrique.

"I've felt part of the CAP family since I was a grad student in the early 1980's and couldn't be more thrilled with this 2026 CAP Medal of Achievement recognition. I've been more than lucky to work with wonderful students, collaborators and colleagues over four decades and gratefully acknowledge all of their contributions."

« Je me sens membre de la famille de l'ACP depuis mes études de troisième cycle au début des années 1980, et je ne pourrais être plus ravi de recevoir cette Médaille de l'ACP 2026 pour l'ensemble de mes réalisations. J'ai eu l'immense chance de travailler avec des étudiants, des collaborateurs et des collègues formidables pendant plus de quatre décennies, et je tiens à les remercier chaleureusement pour toutes leurs contributions. »

CAP Herzberg Medal / Médaille Herzberg de l'ACP



JEFFREY RAU, University of Windsor

In recognition of his international leadership in the theory of frustrated magnetism, and especially for elucidating the theory of a new form of magnetism called altermagnetism.

En reconnaissance de son rôle de premier plan au niveau international dans le domaine de la théorie du magnétisme frustré, et plus particulièrement pour avoir mis en lumière la théorie d'une nouvelle forme de magnétisme appelée altermagnétisme.

"I am honoured to receive this recognition from the Canadian Association of Physicists. My work in quantum magnetism, from frustrated and anisotropic systems to recent questions in altermagnetism, has been a deeply collaborative effort. I am grateful to the students, postdocs, colleagues, and collaborators whose contributions have made it possible."

« Je suis honoré de recevoir cette distinction de la part de l'Association canadienne des physiciens et physiciennes. Mes travaux en magnétisme quantique, allant des systèmes frustrés et anisotropes aux questions récentes sur l'altermagnétisme, ont été le fruit d'une collaboration étroite. Je suis reconnaissant envers les

étudiants, les postdoctorants, mes collègues et mes collaborateurs dont les contributions ont rendu cela possible. »

CAP-CRM Prize in Theoretical and Mathematical Physics / Le Prix ACP-CRM de physique théorique et mathématique



PAVEL KOVTUN, University of Victoria

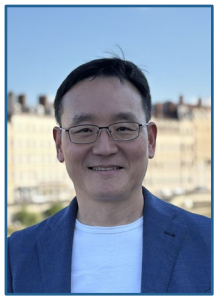
In recognition of his pioneering contributions establishing unexpected applications of the AdS/CFT correspondence to the computation of viscosity, leading to the celebrated Kovtun–Son–Starinets bound, which revealed deep connections between gravity, quantum field theory, and fluid dynamics; and for his foundational work in relativistic hydrodynamics, as well as quantum anomalies and associated transport phenomena.

En reconnaissance de ses contributions pionnières qui ont permis de mettre en évidence des applications inattendues de la correspondance AdS/CFT au calcul de la viscosité, aboutissant à la célèbre borne de Kovtun-Son-Starinets, laquelle a révélé des liens profonds entre la gravité, la théorie quantique des champs et la dynamique des fluides ; ainsi que pour ses travaux fondamentaux en hydrodynamique relativiste, ainsi que sur les anomalies quantiques et les phénomènes de transport associés.

"It is a privilege to be recognised for my work by CAP-CRM. I would like to thank all my mentors, colleagues, collaborators, and students over the years from whom I have learned so much."

« C'est un privilège que l'ACP-CRM reconnaisse mon travail. Je tiens à remercier tous mes mentors, collègues, collaborateurs et étudiants qui, au fil des ans, m'ont tant appris. »

CAP-DCMMP Brockhouse Medal / Médaille Brockhouse de l'ACP-DPMCM



YOUNG-JUNE KIM, University of Toronto

In recognition of his pioneering contributions to quantum magnetism, including the discovery that the material alpha-$RuCl_3$ may realize the topological magnetic state predicted by Alexei Kitaev, and for his leadership in elucidating its properties, culminating in key experimental signatures of a Kitaev spin liquid under high magnetic fields; work that has advanced the search for Majorana fermions and opened promising pathways toward topological quantum computing.

En reconnaissance de ses contributions pionnières au domaine du magnétisme quantique, notamment la découverte que le matériau alpha-$RuCl_3$ pourrait présenter l'état magnétique topologique prédit par Alexei Kitaev, ainsi que pour son rôle de premier plan dans l'élucidation de ses propriétés, qui a abouti à l'observation de signatures expérimentales clés d'un liquide de spin de Kitaev sous champs magnétiques élevés ; ces travaux ont fait progresser la recherche sur les fermions de Majorana et ouvert des voies prometteuses vers l'informatique quantique topologique.

"I am deeply honoured to receive the CAP Brockhouse Medal and sincerely thank the Canadian condensed matter community for this recognition. I am especially grateful to the many students, postdoctoral fellows, and collaborators, as well as to the mentors and colleagues who have supported me throughout my career."

« Je suis profondément honoré de recevoir la médaille Brockhouse de l'ACP et je remercie sincèrement la communauté canadienne de la matière condensée pour cette reconnaissance. Je suis particulièrement reconnaissant envers les nombreux étudiants, boursiers postdoctoraux et collaborateurs, ainsi qu'aux mentors et collègues qui m'ont soutenu tout au long de ma carrière. »

CAP-TRIUMF Vogt Medal for Contributions to Subatomic Physics /Médaille Vogt de l'ACP-TRIUMF pour contributions en physique subatomique



VIKTOR ZACEK, Université de Montréal

In recognition of important contributions to the direct search for dark matter using bubble chamber techniques. Highlights include the development and refinement of these methods for dark matter investigation and leadership on the PICASSO and PICO experimental programs.

En reconnaissance de ses contributions majeures à la recherche directe de la matière noire à l'aide de techniques de chambres à bulles. Parmi ses réalisations, on peut citer le développement et le perfectionnement de ces méthodes pour l'étude de la matière noire, ainsi que son rôle de premier plan dans les programmes expérimentaux PICASSO et PICO.

"I feel truly honored to receive the 2026 CAP–TRIUMF Vogt Medal. Canada has an exceptionally strong subatomic and astroparticle physics community, which makes this recognition special. The search for dark matter is a collective endeavor, and I have been extraordinarily privileged to work with a highly talented team of colleagues, postdoctoral fellows, students and technical professionals at our collaborating institutions. I am very proud to share this recognition with all of them."

« Je me sens vraiment honoré de recevoir la médaille Vogt 2026 de l'ACP–TRIUMF. Le Canada dispose d'une communauté de physique des particules subatomiques et astroparticulaires exceptionnellement solide, ce qui rend cette reconnaissance particulière. La recherche de la matière noire est un effort collectif, et j'ai eu l'extraordinaire privilège de travailler avec une équipe hautement talentueuse composée de collègues, de boursiers postdoctoraux, d'étudiants et de professionnels techniques au sein de nos institutions partenaires. Je suis très fier de partager cette reconnaissance avec eux tous. »

CAP Medal for Excellence in Teaching Undergraduate Physics / Médaille de l'ACP pour l'excellence en enseignement de la physique au premier cycle



ADRIAN LIU, McGill University

In recognition of his sustained excellence in classroom instruction and impressive record of undergraduate research mentorship.

En reconnaissance de l'excellence dont il fait preuve depuis longtemps dans l'enseignement en classe et de ses résultats remarquables en matière d'encadrement de la recherche chez les étudiants de premier cycle.

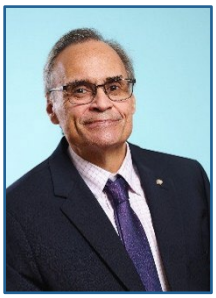
"I am honoured to have been selected for the CAP Medal and am extremely grateful and humbled to join a group of distinguished pedagogues. At the same time, I wish to acknowledge the thousands of physics educators across the country whose daily diligence and innovations in teaching form the basis of our success."

« Je suis honoré d'avoir été sélectionné pour la médaille d'enseignement de l'ACP et je suis extrêmement reconnaissant et touché de rejoindre un groupe de pédagogues éminents. Je tiens également à rendre hommage aux milliers d'enseignants en physique à travers le pays dont le dévouement quotidien et les innovations pédagogiques constituent la base de notre succès. »

2026 CAP Fellows / Les Fellows de l'ACP de 2026

The CAP is pleased to announce the 2026 CAP Fellows (FCAP). The CAP Fellowship Program recognizes CAP members who have made important contributions in physics research, in physics teaching, in the advancement of technology, or in service to physics in Canada.

L'ACP est heureuse d'annoncer les Fellows de l'ACP (FACP) de 2026. Le programme de bourses de l'ACP reconnaît les membres de l'ACP qui ont apporté une contribution importante à la recherche en physique, à l'enseignement de la physique, à l'avancement de la technologie ou au service de la physique au Canada.



Richard Boudreault, Nanotech

En reconnaissance de ses contributions pionnières en physique appliquée, en science quantique et en ingénierie arctique, qui ont renforcé le leadership du Canada en matière d'innovation ; et pour son leadership en matière de politique scientifique, notamment dans les domaines de l'innovation quantique, des énergies propres, des infrastructures nordiques et de la stratégie climatique.

In recognition of his pioneering contributions in applied physics, quantum science, and Arctic engineering that have strengthened Canada's leadership in innovation; and for leadership in science policy, including quantum innovation, clean energy, northern infrastructure, and climate strategy.



Cliff Burgess, McMaster Univeristy

In recognition of his groundbreaking work linking dark matter, dark energy, and primordial fluctuations to fundamental physics; and for inspiring contributions to high-energy physics education and outreach.

En reconnaissance de ses travaux novateurs reliant la matière noire, l'énergie noire et les fluctuations primordiales à la physique fondamentale ; et pour ses contributions inspirantes à l'enseignement et à la vulgarisation de la physique des hautes énergies.



Robert Fedosejevs, University of Alberta

In recognition of his distinguished leadership in high-intensity lasers, nonlinear optics, and plasma physics; and for service to the Canadian Association of Physicists as President.

En reconnaissance de son leadership exceptionnel dans les domaines des lasers à haute intensité, de l'optique non linéaire et de la physique des plasmas ; et pour ses services rendus à l'Association canadienne des physiciens et physiciennes en tant que président.



Barbara Frisken, Simon Fraser University

In recognition of her contributions to the Canadian Association of Physicists over four decades that have helped to streamline and modernize the organization; and for the application of scattering techniques to soft matter, especially lipid vesicles and complex ion-containing polymers used in fuel cells.

En reconnaissance de ses contributions à l'Association canadienne des physiciens et physiciennes sur quatre décennies, qui ont aidé à rationaliser et à moderniser l'organisation ; et pour l'application de techniques de diffusion à la matière molle, en particulier aux vésicules lipidiques et aux polymères complexes contenant des ions utilisés dans les piles à combustible.



Luis Lehner, Perimeter Institute

In recognition of his outstanding contributions to the Canadian and international professional physics communities; and for leadership in physics education and mentoring.

En reconnaissance de ses contributions exceptionnelles aux communautés professionnelles de la physique au Canada et à l'échelle internationale ; et pour son leadership dans l'enseignement de la physique et le mentorat.



Roman Maev, University of Windsor

In recognition of his deep and lasting contributions to industrial and applied physics in Canada, especially the application of acoustic microscopy in the automotive industry; and for service to the Industrial and Applied Physics Division of the Canadian Association of Physicists.

En reconnaissance de ses contributions profondes et durables à la physique industrielle et appliquée au Canada, en particulier l'application de la microscopie acoustique dans l'industrie automobile ; et pour ses services rendus à la Division de physique industrielle et appliquée de l'Association canadienne des physiciens et physiciennes.



Rowan Thomson, Carleton University

In recognition of her major research contributions to Monte Carlo dose calculations for radiation medicine, as well as her advocacy for equity, diversity, and inclusion in STEM, through leadership and the development of widely used community tools.

En reconnaissance de ses contributions majeures à la recherche sur les calculs de dose par la méthode de Monte Carlo en radiothérapie, ainsi que de son engagement en faveur de l'équité, de la diversité et de l'inclusion dans les STIM, grâce à son leadership et au développement d'outils communautaires largement utilisés.



Manuella Vincter, Carleton University

In recognition of her achievements in precision measurements of the carriers of the electroweak force, the observation of the Higgs boson, and benchmarking of its properties; and for leading roles in the scientific development of the ATLAS Collaboration.

En reconnaissance de ses réalisations dans le domaine des mesures de précision des porteurs de la force électrofaible, de l'observation du boson de Higgs et de l'étalonnage de ses propriétés ; ainsi que pour son rôle de premier plan dans le développement scientifique de la collaboration ATLAS.

2025 PhD Physics Degrees Awarded in Canadian Universities

Doctorats en physique décernés par les universités canadiennes 2025

January 1 2025 to December 31 2025 / 1 Janvier 2025 à 31 Décembre 2025

This list documents recipients of Ph.D. degrees as reported by Canadian physics departments. Each entry lists the recipient, thesis title, advisor(s), semester of graduation, and current position (if known).

Cette liste répertorie les titulaires d'un doctorat tels que déclarés par les départements de physique canadiens. Chaque entrée indique le nom du titulaire, le titre de la thèse, le ou les directeurs de thèse, le semestre d'obtention du diplôme et le poste actuel (si connu).

CARLETON UNIVERSITY

NORMAN, B., “The ABCStar Readout ASIC for the ATLAS Inner Tracker Upgrade and Evidence for the Decay of the Higgs Boson to Two Muons”, (D. Gillberg, T. Koffas), June 2026, now currently employed as a Data Scientist at PolyML, Waterloo, ON, Canada.

PIZZI, D., “Measuring the electroweak production of a W boson in association with two jets using the ATLAS detector”, (A. Bellerive), June 2025.

STAATS, E., “Projected Measurement of WH Production via Vector-Boson Fusion at the High Luminosity LHC with the ATLAS Detector and Associated Inner Tracker Upgrade”, (D. Gillberg, T. Koffas), June 2026.

CONCORDIA UNIVERSITY

BHAGAT, SHUBHAM, “Probing microstructure and optical properties of organic semiconductor thin films”, (I. Salzmann), January 2025.

ÇINGILOLU, KIVANÇ, “Imprints of vector-like fermions on electroweak vacuum stability in extended Higgs frameworks”, (M. Frank), October 2025.

DEHGHANI, PARHAM, “Phenomenology of Beyond Standard Model at Present and Future Colliders”, (M. Frank), October 2025, Data Scientist at Groupe Dynamite, Montreal, QC, Canada.

HOSSEIN, YUSEFI, “Numerical Investigation of Ultrasound-Triggered Microbubble Contrast Agent Dynamics”, (B. Helfield), January 2025.

JODAEEASL, NAZLI, “Theoretical investigation of small molecules adsorption and reactions on metal-organic frameworks and silicene”, (G. Peslherbe), October 2025.

MEMARI, ELAHE, "Ultrasound-assisted modulation of the endothelial cell membrane for cellular immunotherapy", (B. Helfield), June 2025, Postdoctoral Fellow at the Montreal Neurological Institute, Montreal, QC, Canada.

SANAMI, SAFA, "Brain vascular and metabolic biomarkers in age-related diseases", (C. Gauthier), October 2025.

TREMBLAY, STEPHANIE, "Is white matter the weakest link? - Early detection of white matter changes with MRI", (C. Gauthier), Jan 2025, Postdoctoral Fellow at McGill University, Montreal, QC, Canada.

DALHOUSIE UNIVERSITY

BOND, T., "Mapping the Complex Patterns of Degradation in Commercial Lithium-Ion Batteries Using X-Ray Imaging and Diffraction", (J. Dahn), Winter 2025.

BRYENTON, K., "Physics-guided Solutions to Dispersion in Density-functional Theory", (E. Johnson), Summer 2025.

DRESSLER, R., "Enabling High Energy Density Lithium-Ion Batteries with Silicon Negative Electrodes", (J. Dahn), Summer 2025.

DUPLESSIS, P., "From Aerosol to Climate Patterns: a Multi-scale Study of Marine Fog Variability in Atlantic Canada and the Central Arctic", (R. Chang), Fall 2025.

GARAYT, M., "Active Material Investigations in Lithium- and Sodium-Ion Batteries", (M. Metzger), Fall 2025, Battery Engineer at SpaceX in Redmond, WA, USA.

McCOOMBS, J., "Magnetic properties of ABC-stacked kagome antiferromagnets through the lens of novel Mn3Ge thin films", (T. Monchesky), Winter 2025.

RIBERDY, V., "Advanced analysis of contrast agents in x-ray and magnetic resonance imaging", (K. Brewer, J. Rioux), Summer 2025.

VEREVKIN, I., "Spatial and Temporal Mechanisms Controlling Convection over the Great Plains", (I. Folkins), Fall 2025.

MCMASTER UNIVERSITY

BORGES ZAPATA, F., "Recent Developments in the Antiferromagnetic Quantum Critical Metal: Pairing Instability, Emergent Momentum-Spacetime Geometry, and Kondo Effect", (S. Lee), November 2025, Quantum Software Developer at SoftwareQ Inc., Waterloo, ON, Canada.

COURNOYER-CLOUTIER, C., "Dynamics and Feedback of Massive Binaries in Young Massive Star Clusters", (A. Sills, W. Harris), November 2025, Postdoctoral Fellow at the Max Planck Institute for Astrophysics, Munich, Germany.

DORNAN, V., "From Giants to Dwarfs: A Comprehensive Observational Study of the Globular Cluster System Mass - Halo Mass Relation", (W. Harris), November 2025, Postdoctoral Fellow at the University of Edinburgh, Edinburgh, UK.

DUTCHER, L., "How Elastomers Wet, Swell and Deform", (K. Dalnoki-Veress), November 2025, searching for employment while working as a Postdoctoral Fellow at McMaster University, Hamilton, ON, Canada.

KARAM, J., "The Role of Gas in Star Cluster Formation", (A. Sills), November 2025, Postdoctoral Fellow at the University of Tokyo, Tokyo, Japan.

PULA, M., "Rare-Earth Ions on the Shastry-Sutherland Lattice: Determining the Magnetic Ground-States of the Rare-Earth Melilites RE2Be2GeO7 (RE=Yb, Er, Gd,Dy)", (G. Luke), November 2025, Postdoctoral Research Fellow at Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.

RICHARDS, A., "Tensor-Network Simulation of Quantum Spin Systems with Bond-Dependent Interactions", (E. Sorensen), November 2025, Mathematics Libraries Engineer, NVIDIA, Toronto, ON, Canada.

ROBINSON, H., "Simulations Exploring Magnetic Fields in Spiral Galaxies", (J. Wadsley), November 2025.

MCGILL UNIVERSITY

ANDERSEN, B., "New techniques for unveiling the radio transient sky with the CHIME telescope", (V. Kaspi, J. Prochaska), Fall 2025.

BUSTAMANTE GUEVARA, J., "Low Temperature Atomic Force Microscope for the Study of Atomically Defined Quantum Dots", (P. Grutter), Summer 2025.

CURTIN, A., "Probing the origins of FRBs using CHIME: High-energy counterpart searches and burst morphology", (V. Kaspi), Summer 2025.

DRINGOLI, B., "Terahertz spectroscopy of ultrafast photoinduced phase dynamics in single-crystal tin selenide", (D. Cooke), Fall 2025.

FARUK, M., "de Sitter spacetime: Black holes, holography and String theory", (K. Dasgupta), Summer 2025.

FAVERO, A., "Studies of Cosmic Strings and Superfluid Dark Matter", (R. Brandenberger), Summer 2025.

GIROUX, M., "Computational aspects of scattering observables", (S. Caron-Huot), Summer 2025.

JIAO, H., "Structure formation with cosmic strings", (R. Brandenberger), Summer 2025.

LALIBERTÉ, S., "Topics in matrix cosmology", (R. Brandenberger), Winter 2025.

LAURENT, B., "Phenomenology and dynamics of cosmological first-order phase transitions", (J. Cline), Summer 2025.

LUNDY, M., "Probing the rapid transient gamma-ray sky", (K. Ragan), Fall 2025.

MAMAEV, A., "Phase field modelling of nucleation processes in binary alloys", (N. Provatas), Fall 2025.

McINTYRE, Z., “Quantum information processing in modular cavity QED architectures”, (W. Coish), Winter 2025.

MERULIYA, V., “Non-Perturbative effects in Gravity and Conformal Field Theories Alexander Maloney”, (K. Dasgupta), Summer 2025.

NAMJOU, K., “Semiclassical studies in quantum gravity and holography”, (S. Caron-Huot, A. Maloney), Summer 2025.

NELSON, C., “Measurement of the production cross-section for W bosons in association with jets in proton-proton collisions at a center of mass energy of 13 TeV using data collected by the ATLAS detector”, (F. Corriveau), Fall 2025.

PASCUA, B., “Calibration and validation strategies for 21 cm cosmology”, (A. Liu), Summer 2025.

RAZA, N., “Leveraging machine learning to classify gravitational-wave events for multi-messenger observations”, (D. Haggard), Fall 2025.

ROUBLE, M., “Elements in the readout of microwave kinetic inductance detectors”, (M. Dobbs), Summer 2025.

SAND, K., “Studying Fast Radio Bursts Rates and Burst Morphologies using CHIME/FRB”, (V. Kaspi), Summer 2025.

SOUSA-FRONENBERG, H., “Unveiling our early universe using cross-correlation analyses of multiple cosmological probes”, (A. Liu), Winter 2025.

SUVIRANTA, J., “Dynamics of crystal sub-grain phenomena: a phase field crystal modelling study, (N. Provatas), Winter 2025.

VIEIRA, N., “Uncovering the origins of the heavy elements with Spectroscopic r-Process Abundance Retrieval for Kilonovae (SPARK)”, (D. Haggard, J. Ruan), Summer 2025.

QUEEN'S UNIVERSITY

ALIAHMADI, H., “Physical Inference for Optimization and Design”, (G. van Anders), Spring 2026, Casual Contract with G. van Anders at Queen's University.

CORNING, J., “Temperature Dependent Emission of Acrylic Relative to Tetrapheynl Butadiene (TPB)”, (P. Di Stefano), Spring 2026, Postdoctoral Fellow at the University of Melbourne, Melbourne, Australia.

FUNG, S., “New physics searches in rocks and stars”, (A. Vincent), Fall 2025, Postdoctoral Fellow at the Asia-Pacific Centre for Theoretical Physics, Pohang, South Korea.

GUO, Z., “Photonic Tensor Machine and Information Encoding and Decoding in Wavelength-Multiplexed Photonic Processors”, (B. Shastri), Spring 2026, employed at Ciena, Ottawa, ON, Canada.

TYAGI, N., “Dark Matter and Neutron Stars”, (J. Bramante), Fall 2025.

SIMON FRASER UNIVERSITY

AZARI, N., "Muon Spin Rotation/Relaxation Studies of UTe2", (J. Sonier), October 2025, Adjunct Faculty Member at Fairleigh Dickinson University, Vancouver, BC, Canada.

FAWZY, M., "Two-Dimensional Materials for Sensing Applications", (K. Kavanagh), October 2025, Staff Scientist at Authentix Solutions Canada, Inc., Burnaby, BC, Canada.

HANIF, H., "Pushing into the Unknown: A Search for light long-lived particles with the ATLAS detector", (M. Danninger), October 2025.

JOSE, A., "Mapping the Electrostatic Potential in GaN based NW p-n junctions using Off-axis Electron Holography", (K. Kavanagh), June 2025, MSALABS, Langley, BC, Canada.

LEIGHTON, M., "Stochastic Thermodynamics of Multicomponent Molecular Machines", (D. Sivak), June 2025, Mossman Postdoctoral Fellow at Yale University, New Haven, CT, USA.

TORONTO METROPOLITAN UNIVERSITY

BARTLETT, J., "Development of Fractal Methods to Assess Airway Structure and their Associations with Lung Function in Chronic Obstructive Pulmonary Disease", (M. Kirby), June 2025.

HAGHI, H., "The Effect of Inter-Bubble Interactions on The Effective Resonance Frequency of Ultrasonically Excited Lipid Coated Microbubbles", (M. Kolios), June 2025, Clinical Scientist at Exact Imaging, Markham, ON, Canada.

KOO, M., "Improving the Understanding of Structural and Biomechanical Changes in Chronic Obstructive Pulmonary Disease (COPD) Using Expiration CT-derived Texture-Based Radiomics", (M. Kirby), June 2025, Therapeutic Medical Physics Resident at UCLA Health, Los Angeles, CA, USA.

MAKIMOTO, K., "Computed Tomography Texture-Based Radiomics with Machine Learning for Predicting Chronic Obstructive Pulmonary Disease Outcomes", (M. Kirby), October 2025, Postdoctoral Research Fellow at Brigham and Women's Hospital and Harvard Medical School, Boston, MA, USA.

SOLTANI, N., "Applying New Dynamic Models to Near-Infrared Spectroscopy Measurements of Cerebral Changes", (V. Toronov), October 2025, Medical Physics Resident at Hamilton Health Sciences, Hamilton, ON, Canada

UNIVERSITY OF ALBERTA

ALTINCICEK, FURKAN MUHAMMET, "Atomic Silicon Dimer Wires on The Hydrogenated Silicon Surface", (R. Wolkow), November 2025, now a Postdoctoral Fellow at the University of Alberta, Edmonton, AB, Canada.

BANDARA, YAPA MUDIYANSELAGE AKILA DINETH JITHMAL, "Magnetic Field Devices and Yeast Magnetobiology", (D. Charlebois), June 2025.

FAST, KATRYNA RAE, "Multi-Modal Torque Magnetometry of Nanomechanical Resonators as a Probe of Frequency Dependence in Einstein-de Haas Torques", (M. Freeman), November 2025.

HEBBAR, PAVAN RAMACHANDRA, “Data Driven Classification of X-Ray Sources”, (C. Heinke), December 2025.

HIRSCHEL, MARVIN, “Listening to the Sound of Gravitational Waves and Dark Matter with Superfluid Helium“, (J. Davis), October 2025, Scientist at Zero Point Cryogenics, Edmonton, Alberta, Canada.

LYONS, AARON DOUGLAS, “Single-Molecule Characterization of Biomolecular Self-Assembly Dynamics”, (M. Woodside), September 2025.

MIELNICHUK, COURTNEY TAYLOR, “Degraded Alpha Decay Backgrounds in the DEAP-3600 Detector and Associated Hardware Upgrades”, (A. Hallin), June 2025.

PAN, ZHIHONG, “Dynamics of the Initiation and the Evolution of Cordilleran Orogeny”, (C. Currie), July 2025.

PINEDO SOTO, JOSE ABRAHAM, “Modified Gravity and Regular Black Hole Models”, (V. Frolov, D. Pogosian), November 2025.

RIDDER, MARGARET, “Radio Emission Mechanisms in Cataclysmic Variables”, (C. Heinke), November 2025, Postdoctoral Fellowship that the U. S. Naval Research Laboratory, Washington, DC, USA.

SEKAR, ROHITH VEDHTHAANTH, “Computational Studies of Threaded Viral RNA Pseudoknots as Therapeutic Targets”, (M. Woodside), November 2025.

SHEN, WEI, “Ionospheric Feedback Instability in Magnetospheric Field Line Resonances and the Ionospheric Alfvén Resonator”, (R. Rankin), November 2025.

SHOOK, ALEXANDER JAMES, “Fourth Sound Helmholtz Resonator as a Probe for Confined Superfluid ^{3}He”, (J. Davis), June 2025, Experimental Physicist at D-Wave, Burnaby ,BC, Canada.

YUAN, MAX, “Dangling Bond Wires for Atom-Scale Silicon Circuitry“, (R. Wolkow), March 2026.

ZHAO, JIAQI, “The Fascinating Neutron Stars in X-rays: Millisecond Pulsars, Globular Clusters, and Beyond”, (C. Heinke), November 2025, Postdoctoral Fellow at Tsinghua University, Beijing, China

UNIVERSITY OF BRITISH COLUMBIA

AHAMED, L., “Deep-learning-guided image generation, enhancement and analysis: with applications to nuclear medicine imaging”**,** (A. Rahmim)**,** November 2025**.**

BALAJI, S., “Characterizing white matter: adventures with quantitative magnetic resonance imaging”**,** (S. Kolind, A. MacKay)**,** November 2025**,** Research Assistant at Djavad Mowafaghian Centre for Brain Health (CBH), Vancouver, BC, Canada**.**

BELANGER, P., “Topological formulation of beam dynamics: a study of quasiperiodic motion in Hamiltonian systems”, (R. Kruecken, R. Baartman), November 2025.

BISWAS, S., “Zero-energy modes in quantum field theories”, (G. W. Semenoff, J. Karczmarek), November 2025, Senior Risk Modelling Analyst at RBC, Vancouver, BC, Canada.

CROWTER, K., “Searching for millisecond and slow pulsars with CHIME”, (I. Stairs), November 2025.

DERRICHE, N., “Effects of electric polarization in hybridized materials”, (G. Sawatzky), May 2025, Researcher in Quantum Error Correction at Ericsson, Montreal, QC, Canada.

DUFRESNE, S., “Ultrafast photoemission studies of bulk and exfoliated Ta_2NiSe_5”, (A. Damascelli, F. Boschini), May 2025, Postdoctoral Researcher at Goethe University Frankfurt, Frankfurt am Main, Germany.

FLEURY, L., “White dwarfs as probes of novel physical phenomena”, (J. Heyl), May 2025, Model Validation Analyst at RBC, Vancouver, BC, Canada.

GODIN, S., “Decoupled magnetic centers in anion-substituted Nickel Oxide”, (K. Zou), November 2025.

KINACH, M., “Electrodynamics of non-topological solitons”, (M. Choptuik), May 2025, Computational Research Consultant at ACENET, Canada.

KIRMIZIBAYRAK, D., “New tricks for old stars: studying compact objects through novel methodologies in timing, energy and imaging”, (J. Heyl), May 2025, Postdoctoral Scholar Research Associate at Caltech, Pasadena, CA, USA.

KNEE, A., “Searches for novel gravitational-wave sources with ground- and space-based detectors”, (J. McIver), November 2025, Research Fellow at University of Michigan, Ann Arbor, MN, USA.

LECKENBY, G., “Exotic decay measurements at the Experimental Storage Ring for neutron capture processes”, (R. Kruecken, I. Dillmann), May 2025, Postdoctoral Researcher at LP2i, Bordeaux, France.

MALHOTRA, A., “Predictive metrics for moist desquamation in treatment planning for breast radiotherapy”, (C. Duzenli, S. Reinsberg), May 2025, Medical Physics Resident at BC Cancer, Vancouver, BC, Canada.

PATHAK, V., “Time-reversal symmetry breaking in topological and unconventional superconducting heterostructures”, (M. Franz), May 2025, Researcher at IBM Quantum, Yorktown Heights, NY, USA.

ROEMER, R., “Layer dependent electronic structure and magnetic transition evolution in two-dimensional ferromagnetic van der Waals films”, (K. Zou), November 2025, Senior Engineer in CVD/DIFF DRAM at Micron Technology, USA.

SMITH, G., “Detecting antihydrogen annihilations in ALPHA-g for measurement of gravitational free fall”, (M. Fujiwara, T. Momose), November 2025, Postdoctoral Researcher at TRIUMF, Vancouver, BC, Canada.

SULLIVAN, R., “Anomalies in the cosmic microwave background”, (D. Scott), May 2025, Postdoctoral Fellow at University of Oslo, Oslo, Norway.

THOENG, E., “Depth-resolved studies of SRF materials using high parallel-field beta-NMR spectrometer”, (R. Laxdal, A. MacFarlane), November 2025.

VANBERGEN, S., “Studies of ultracold neutron dynamics and systematic effects for the TUCAN EDM experiment”, (R. Picker, K. Madison), May 2025.

UNIVERSITY OF GUELPH

GREAVES, B., "β-Oslo Constraint of the Astrophysically relevant Neutron-capture rates of ^{90}Sr and ^{140}Cs", (C. Svensson), October 2025, Postdoctoral Fellowship at LNL-INFN, Legnaro, Padova, Italy.

LAHAYE, M., "Gravitational Wave Modelling for Deviations from Kerr/Schwarzschild Geometry in Compact Object Inspirals", (E. Poisson), February 2025, Chief Operations Officer at Clinical Software Systems, Kingston, ON, Canada.

MIKI, C., "Hydration Properties of Chemically Modified Phytoglycogen Nanoparticles", (J. Dutcher), February 2025, Medical Lead, Meducum Health Inc, Guelph, ON, Canada.

UNIVERSITY OF MANITOBA

GORGANNEJAD, F., "Correcting for Parity-Violating and Parity-Conserving Asymmetries from Pions in the MOLLER Experiment", (W. Deconinck), February 2025, Data Analyst at Insporos, Vancouver, BC, Canada.

LAVVAF, M., "Characterization of the Magnetically Shielded Room for the Neutron Electric Dipole Moment Experiment at TRIUMF", (R. Mammei), October 2025, Postdoctoral Fellow, Quantum Valley, University of Waterloo, Waterloo, ON, Canada.

WALLS, C., "Multiple-Reflection Time - of - Flight Mass-Spectrometry Not Just for High Precision Mass Measurement", (G. Gwinner), October 2025, Postdoctoral Fellow, Technical University of Darmstadt, Germany.

UNIVERSITY OF NEW BRUNSWICK

TROJAND, D., "Student Decision Making in Undergraduate Physics Laboratories", (B. Newling), May 2025.

YAN, P., "Magnetic Resonance Relaxation in Porous Media Interpreted by Brownstein-Tarr Theory", (B. Balcom), October 2025.

UNIVERSITY OF OTTAWA / UNIVERSITÉ D'OTTAWA

BARLOW, B., "Simulating Action Potential Initiation and Propagation in Physically Detailed Damaged and Healthy Neurons", (B. Joos, A. Longtin), June 2025.

BÉGIN, J.-L., "Strong-field chiral light-matter interaction", (R. Bhardwaj), June 2025, Postdoctoral Fellow at the University of Ottawa, Ottawa, ON, Canada.

CHARRON, M., "Nanopore Resistive Sensing: Bridging Theory and Experiments", (V. Tabard-Cossa), June 2025, Postdoctoral Fellow at the University of Ottawa, Ottawa, ON, Canada.

ERNOTTE, G., "Real space perspective on High Harmonic Generation in Solids", (P. Corkum), June 2025, Desk Quant Analyst at Squarepoint, Ottawa, ON, Canada.

FENWICK, K., “All-Optical Quantum Information Processing in the Ultrafast Regime”, (S. Benjamin), June 2025, Luise and Gerhard Herzberg Postdoctoral Fellow, National Research Council of Canada, Ottawa, ON, Canada.

FERRER GARCIA, M., “Structuring Light: From knots to geometrical phases”, (E. Karimi), June 2025, Postdoctoral Fellow at the University of Ottawa, Ottawa, ON, Canada.

FORCADE, G., “High-Efficiency III-V Semiconductor Device and System Optimization for Photovoltaic Applications”, (K. Hinzer), June 2025, Research Scientist at CIENA, Ottawa, ON, Canada.

HUFNAGEL, F., “High-Dimensional Quantum Information: From Sensing to Underwater Quantum Communication”, (E. Karimi), June 2025, Postdoctoral Fellow at Simon Fraser University and Research Assistant at Photonic, Burnaby, BC, Canada.

JAIN, A., “Helical phase-based spectroscopy in matter”, (R. Bhardwaj), June 2025, Research Scientist at Irradiant Technologies, Boston, MA, USA.

KILLAIRE, G., “Applications of Ultrafast Laser Ablation to Material Colouring and Physical Unclonable Functions”, (A. Weck, P. Berini), June 2025, Laboratory Technician at Carleton University, Ottawa, ON, Canada.

MOLINO, R., “Scanning induced microscopy investigations of interlayer interaction induced superstructures in transition metal dichalogenides”, (A. Luican-Mayer), June 2025, Application Scientist at Onnes Technologies, Leiden, Netherlands.

TONITA, E., “Bifacial Photovoltaic Performance and Optimization in Mid-to-High Latitudes”, (K. Hinzer), June 2025, Solar Resource Scientist at CanmetEnergy, Ottawa, ON, Canada. .

UNIVERSITY OF REGINA

KOERICH, L., “Development of scintillator-based components for the photosensor system for the Intermediate Water Cherenkov Detector of the Hyper-K experiment and for the time of flight system of the Water Cherenkov Test Experiment”, (M. Barbi, N. Kolev), Postdoctoral Fellow at the University of Regina, Regina, SK, Canada.

OŘESIĆ, S., “Signal extraction and simulations for $\eta \rightarrow \pi^0\gamma\gamma$ and $\eta \rightarrow \pi^+\pi^-e^+e^-$ decays at the Jefferson Lab Eta Factory”, (Z. Papandreou), Radio Frequency Engineer at Infostellar Inc., Shinjuku-ku, Tokyo, Japan.

USMAN, A., “The study of exclusive pion electroproduction reaction from the Kaon-LT experiment at Jefferson Lab Hall C”, (G. Huber), Research Facilitator, Natural Science and Engineering, at the University of Regina, Regina, SK, Canada.

UNIVERSITY OF SASKATCHEWAN

AKINPELU, A., ”Exploration of High-Pressure Electride, Polymorphic Transformations and Superconducting Clathrate Frameworks”, (Y. Yao), November 2025, Postdoctoral Fellow at Queen's University, Kingston, ON, Canada.

HOSSEINZADEH FAHIM, B., “Aspects of Black Holes in Extended Theories of Gravity”, (M. Ghezelbash), June 2025, Instructor at Red Deer Polytechnic, Red Deer, AB, Canada.

LETROS, D., “Remote Sensing of Atmospheric Aerosols with the Aerosol Limb Imager”, (A. Bourassa, D. Degenstein), June 2025, Mission Scientist, Canadian Space Agency, Montréal, QC, Canada.

LI, S., “Precision Calculations in Theoretical Particle Physics and the Search for New Physics”, (T. Steele), June 2025, Postdoctoral Fellow at Johannes Gutenberg University of Mainz, Mainz, Rhineland Palatinate, Germany.

YOUSEFI SIGARI, Y., “Coherence Control and Measurement at the CLS Using X-Ray Interferometry”, (M. Boland, J. Vogt), June 2025, Postdoctoral Researcher at TRIUMF, Vancouver, BC, Canada.

UNIVERSITY OF TORONTO

ALKHATIB, I., “Analysis of signals in semiconductor cryogenic dark matter search detectors and new constraints on interactions of light dark matter with electrons”, (M. Diamond), September 2025.

ANGULO MURCILLO, D., “Can a photon spend a negative amount of time in an atom cloud?”, (A. Steinberg), May 2025, Quantum Computing Educator at Xanadu, Toronto, ON, Canada.

BOSE, A., “Proximate Quantum Spin Liquids in Frustrated Magnets”, (A. Paramekanti), September 2025, Grant-Funded Researcher (A), Adelaide University, Adelaide, Australia.

BROWN, G., “On the long-term stability of the solar system”, (H. Rein), May 2025, Software Developer, Xanadu Quantum Technologies Inc., Toronto, ON, Canada.

CHURCHILL, D., “Manifestations of Frustration in Quantum Materials”, (H. Y. Kee), May 2025, Software Developer at Accommodations Plus International, Toronto, ON, Canada.

COTE, K., “Beyond the lab: Investigation of novel optical clock concepts for field applications”, (A. Vutha), May 2025.

COX, A., “A Few Insights Into the Confinement Problem and Other Non-perturbative Questions About Gauge Theories”, (E. Poppitz), September 2025.

DESROCHERS, F., “Exploring Fractionalization in Quantum Spin Ice”, (Y. B. Kim), September 2025, Postdoctoral Researcher at Harvard University, Cambridge, MA, USA.

DUFF, A., “Microscopic treatment of charge and spin response to electromagnetic fields”, (J. Sipe), September 2025, Postdoctoral Fellow at University of Toronto, Toronto, ON, Canada.

FLOOD, V., “Using ground-based infrared spectroscopy, satellite measurements, and models to understand short-lived climate forcers and wildfire emissions over Canada”, (K. Strong), May 2025, Short-term contract Postdoctoral Fellow at University of Toronto, Toronto, ON, Canada.

FOO, J., “Search for Vector-like Quarks in the All-hadronic Decay Channel using the ATLAS Detector”, (P. Sinervo), May 2025.

FRONTINI, F., “Resonant inelastic X-ray scattering studies of strongly correlated rhenium based double perovskites”, (Y. J. Kim), September 2025.

GEMMELL, C., “Making a Map of Shadows and Stars: Astrophysical Probes of Dark Sectors”, (D. Curtin), September 2025, Postdoctoral Researcher at the University of Wisconsin–Madison and the Wisconsin IceCube Particle Astrophysics Center (WIPAC), Madison, WI, USA.

GERRY, M., “Using fluctuations to probe structure and assess methods in nanoscale open systems”, (D. Segal), September 2025.

GILLESPIE, L., “Measuring Methane Emissions in the Urban Environment”, (D. Wunch), September 2025.

HAAS-NEILL, L., “Molecular Dynamics of Protein Perturbations: Structure, Dynamics, and Function”, (S. Rauscher), May 2025.

HAGAN, M., “A Quantum Mechanical Analog of Hamiltonian Monte Carlo”, (N. Wiebe), September 2025, Postdoctoral Fellow at the Pacific Northwest National Lab, Richland, WA, USA.

HOGAN-LAMARRE, P., “Serial Electron Crystallography for High-Resolution Structure Determination of Radiation-Sensitive Materials”, (D. Miller), September 2025.

IYENGAR, S., “Perturbation responses of complex stochastic biological systems”, (A. Hilfinger), September 2025.

JAIN, S., “X-ray investigation of average and local crystal structure in functional materials”, (Y. J. Kim), May 2025.

KELL, B., “Limits of control and robustness in biochemical reaction networks”, (A. Hilfinger), September 2025, Postdoctoral Fellow at Developmental Biology Unit, European Molecular Biology Laboratory, Heidelberg, BW, Germany.

KNIGHT, T., “Searching for dark matter through events with large missing transverse energy recoiling from hadronically decaying vector bosons with the ATLAS detector”, (R. Teuscher), September 2025.

MACDONALD, E., “Climates of Synchronously Rotating M-Earths with Dayside Land”, (K. Menou), May 2025, Postdoctoral Fellow at the University of Vienna, Vienna, Austria.

PLOTNYKOV, M., “Interior structure inference of low-mass exoplanets: investigating planet to star composition correlation”, (D. Valencia), September 2025.

SATTARI JAVID, A., “Compton Scattering Calibration For Cryogenic Semiconductor Crystal Detectors”, (M. Diamond), May 2025.

TIWARI, P., “Transport studies of perovskite correlated electron systems under pressure”, (S. Julian), May 2025, Cryoengineer at Bluefors, Brooklyn, NY, USA.

XIE, F., “Dynamically Downscaled Climate Change Impacts in the Great Lakes Basin of North America and the Mediterranean Basin and Northern Africa of Europe”, (R. Peltier), September 2025.

ZHANG, E., “Light Dark Matter Constraints from a SuperCDMS Cryogenic Silicon Detector with Single-Charge Sensitivity”, (M. Diamond), January 2025.

UNIVERSITY OF VICTORIA

CARLSON, E., “Searching for Long-Lived Supersymmetric Particles Using Displaced Vertices and Missing Transverse Energy with the ATLAS Detector”, (I. Trigger, R. Kowalewski), May 2025, Process Engineer at nLIGHT, Vancouver, WA, USA.

GENNARI, M., “Electroweak Radiative Corrections in Super-Allowed Beta Decays from *Ab Initio* Theory”, (P. Navratil, R. Kowalewski), November 2025.

HOULT, R., “Causal Theories of Relativistic Hydrodynamics”, (P. Kovtun), November 2025, Postdoctoral Fellow at the University of Victoria, BC, Canada.

HUBER, A., “Optical, mechanical, and detector developments for the Prime-Cam 850 GHz module”, (S. Chapman, J. Albert), May 2025, Postdoctoral Fellow in the CCAT group at the University of British Columbia, Vancouver, BC, Canada.

KUMAR, T., “On-sky Applications of Adaptive Optics: Performance Measurements and Globular Cluster Photometry”, (D. Andersen, K. Venn), November 2025.

SHROFF, M., “Effectively Exploring New Physics: A first EFT interpretation using the WZ→lvll process with the ATLAS detector at the LHC”, (R. McPherson, R. Keeler), November 2025, Postdoctoral Fellow at McGill University, Montreal, QC, Canada

SPEEDIE, J., “Planet Hunting and the Dynamical Structure of Planet-forming Disks”, (R. Dong), November 2025.

UNIVERSITY OF WATERLOO

ANDERSEN, N., "Statistical Mechanics of Finite Length Semiflexible Wormlike Polymers", (J. Chen), October 2025.

ARQAND, A., “Information-Theoretic Tools for Analyzing Non-IID Structures in Quantum Key Distribution", (N. Lutkenhaus), June 2026.

BHATTACHARYA, D., "Quantum Fields in Curved Spacetimes: From Detector Entanglement to Black Hole Thermodynamics", (R. Mann), June 2026.

BORISSOVA, J., "Theory and phenomenology of area-metric gravity”, (B. Dittrich), June 2026.

BUKHTEEVA, I., "Biophysical study of the effect of lithium isotopes from cells to ion channels, towards uncovering quantum phenomena in neuroscience", (Z. Leonenko), June 2026.

CHEN, J., "Control and Characterization of the Central Spin System", (D. Cory), June 2026.

CRESTO, N., "Asymptotic Higher Spin Symmetries: Noether Realization & Algebraic Structure in Einstein-Yang-Mills Theory", (L. Freidel and R. Myers), June 2026.

DAILEY, C., "On the Initial Boundary Value Problem in Numerical Relativity", (N. Afshordi, E. Schnetter), June 2026.

GUPTA, N., "Time-resolved and equilibrium resonant X-ray studies of nematicity in cuprate superconductors", (D. Hawthorn), June 2026.

HICKEY, A., "Fluctuation-induced order and thermal transport in frustrated quantum magnets", (A. Burkov, M. Gingras), June 2026.

KAPAHI, C., "Structured Wavefunctions for Precision Quantum Metrology", (D. Pushin, D. Cory), June 2026.

LI, M., "A Multi-Phase Analysis of Gas Dynamics and Perturbations in the Galaxy Cluster Cores", (B. McNamara), June 2026.

LIU, S., "Learning the Quantum, Scrambling the Universe", (Y. Beni, R. Myers), October 2025.

LU, M., "Explorations in Generalized Quasi-topological Gravities", (R. Mann), June 2026.

MacLELLAN, B., "Machine learning for quantum sensing", (R. Melko), June 2026.

MAY, T., “Black hole perturbations beyond the leading order", (L. Lehner, W. East), June 2026.

MERALI, E., "Quantum Monte Carlo Simulations of Rydberg Atom Arrays", (R. Melko), October 2025.

MERINO, Z., "Simulated spin qubits in silicon quantum dots and enhancement of InGaAs photodetectors", (J. Baugh), October 2025.

ROHANIZADEGAN, Y., "A Neural-network-based Solver for the Three Dimensional Shape of Vesicle Membranes", (R. Mann), June 2026.

SWANSON, S., "Characterization of prostate tumor spheroid growth and response to treatment using dynamic optical coherence tomography", (K. Bizheva, E. Osei), October 2025.

TEOH, Y., “Autoregressive Generative Models for Many-body Physics", (R. Melko, R. Islam), October 2025.

VINET, S., "Towards satellite-assisted quantum communication with reconfigurable networks and frequency-bin qubits", (T. Jennewein), June 2026.

WESTERN UNIVERSITY

EKERUCHE, C., “Ion Beam Synthesis and Irradiation for Si-Based Photonic Materials and Nuclear Waste Management, (L. Goncahrova, P. Simpson), October 2025, Research Consultant at Chinenye Ekeruche Consulting, London, ON, Canada.

McFADDEN, L., “Meteor Acoustics and Hydroacoustics”, (B. Chronik), June 2025, Risk Management Consultant at RBC Capital Markets, London, ON, Canada.

PASCUAL GOMEZ-CUETARA, M., “Cosmology in Light of Quantum Gravity”, (F. Vidotto), October 2025.

PERRON, S., “Pulse Sequence Development and Accelerated Imaging for Low Field Hyperpolarized 129Xe MRI”, (A. Ouriadov), June 2025, Postdoctoral Fellow at Western University, London, ON, Canada.

SUFFAK, M., “Be Stars in Misaligned Binary Systems”, (C. Jones), June 2025, Postdoctoral Fellow at University of Calgary, Calgary, AB, Canada

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l'Association canadienne des physiciens et physiciennes :
La Physique, une communauté






How are we a community?

Focus on Equity, Diversity & Inclusion in Physics
Annual Congress - Community Partnerships
Lecture Tours - Professional certification
Networking - Conferences - Scholarships
Awards and Medals - Science Policy and Advocacy
Resources - Read & Publish in *Physics in Canada*
Employment Board Postings - Advertising
Recognitions Program - Art of Physics
Reciprocal Agreements - Group Insurance





Comment sommes-nous une communauté ?

Priorité à l'équité, à la diversité et à l 'inclusion en physique
Congrès annuel - Partenariats communautaires
Tournée de conférenciers - Certification professionnelle
Mise en réseau - Conférences - Bourses
Prix et médailles - La politique scientifique et du plaidoyer
Ressources - Lire et publier dans *La Physique au Canada*
Offres d'emploi - Publicité
Reconnaissances professionnelles - L'Art de la physique
Accords de réciprocité - Assurance collective





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