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Launch of NASA's Terra satellite December 18th, 1999, 18:57:39 UTC. Story Inside: *MOPITT: Measuring Pollution in the Troposphere for 20 Years*

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CMOS Bulletin SCMO
"at the service of its members / au service de ses membres"

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CMOS exists for the advancement of meteorology and oceanography in Canada.

Le but de la SCMO est de promouvoir l'avancement de la météorologie et l'océanographie au Canada.

Message from the Editor

A Fond Farewell!

As 2019 comes to a close, so does my time as Editor for the CMOS Bulletin. Three and a half years since I began, a different direction is calling to me, and it is with incredible gratitude for all that I have been a part of with CMOS that I take my leave to further travel down that other path.

In my time with the Society I have gotten to know a community of people so dedicated and capable, and also so warm-hearted and kind, that I marvel at for their commitment to their research and to working towards a better understanding of all of the layers of this beautiful planet that we live on. I have spoken to so many of you about what you do, and time and time again, been blown away by your knowledge, curiosity and passion. I have attended congresses and sat with a lump in my throat as Arctic researchers talk about the ice disappearing from the spaces that they have dedicated their life's work to; as Climatologists show where we stand on the line of best and worst case scenarios; as risk and adaptation specialists talk about our lack of preparedness for some of the extreme events that lay ahead.

I have spoken with students working to understand the long-range transport of atmospheric pollutants from their source to Canadian skies; how much mass we are losing from the Greenland ice sheet and at what point it will no longer be able to recover; how the paths of cyclones are changing in response to climate change; and what it all might mean for their future. These young people are willingly embarking into scientific careers that will become increasingly demanding, as the world turns more and more towards science to tell us what is happening: *how much? how soon?* And yet they have spoken to me with heads full of ideas and hearts full of commitment and I have been privileged enough to enjoy the feelings of hope and possibility that arise in me when I stand among them.

But where does that leave them? How heavy is the weight of hope that I place on their shoulders when the task of righting the incredible imbalance of our changing climate is just so enormous?

This is where I see that CMOS is so important. Yes, the work that the senior scientists do and how you share that work with each other is absolutely essential. But without young scientists willing to fall step behind you, learn from you, take up the reigns when you need to hand them over, and come up with incredibly innovative ideas all of their own, where will it all lead? These young people have most of their lives ahead of them, and with so much uncertainty in the air what we are expecting of them should not be undervalued. Your support, as their mentors and friends, is the foundation from which they can spring forward, and the pillow on which they can rest when they need a break.

I hope that in my time as Bulletin Editor you feel that I have been able to support the Society in getting your important work out to the world. Leading the development of the virtual Bulletin was very joyful for me, as I got to imagine how people all over the world would further benefit from what you all had to share. The english Bulletin site gets on average between 600 and 1,000 visitors each month, the french Bulletin site gets between 150-200. The **Future Earth interviews** that I put together for the 2017 Congress with the support of the seven CMOS members that I interviewed now have nearly 190,000 listens! So to every one of you that has written an article for the Bulletin or agreed to be interviewed by me, do know that you have made a difference, and that your word has reached at least some of the ears that need to hear them.

We are currently recruiting a new editor for the Bulletin, and I will be working with that person over the coming months as we slowly make the transition, so I am not going anywhere too quickly! All of you, and the Society as a whole, have grown on me very much, and I will ensure to the best of my ability that whoever takes over is in a position to only help you all progress and grow even more.

A huge thanks to executive director Gordon Griffith, to publications director Douw Steyn, to archivist Bob Jones, to office manager Qing Liao, to the current president Kimberly Strong and all of the past presidents, and to so many others in CMOS, for all of the support and kindness over the last few years.

Best wishes to you all in your scientific endeavors,

Sarah

Sarah Knight, Ph.D., CMOS Bulletin Editor

Mot de la rédactrice

Un adieu chaleureux

Tandis que l'année 2019 tire à sa fin, il en va de même de mon mandat de rédactrice en chef du Bulletin de la SCMO. Trois ans et demi après mes débuts, une autre destination m'appelle. C'est toutefois avec une gratitude inouïe pour tout ce que j'ai pu accomplir au sein de la SCMO que je tire ma révérence afin de suivre cette autre voie.

Au cours de ces années à vos côtés, j'ai rencontré une communauté si dévouée et compétente, et aussi si chaleureuse et avenante, que je m'émerveille de son engagement envers ses travaux et les efforts visant une compréhension accrue de toutes les tranches de la belle planète que nous habitons. J'ai parlé à tant d'entre vous de vos travaux, et maintes et maintes fois, j'ai été époustouflée par vos connaissances, votre curiosité et votre passion. J'ai assisté à des congrès et j'ai eu les larmes aux yeux lorsque les spécialistes de l'Arctique ont parlé de la disparition de la glace de ces lieux auxquels ils ont consacré leur vie; lorsque les climatologues ont montré où nous nous situions par rapport aux meilleurs et aux pires scénarios; lorsque les spécialistes des risques et de l'adaptation ont parlé de notre manque de préparation face à certains des événements extrêmes qui nous attendent.

J'ai parlé à des étudiants qui s'efforcent de comprendre le transport à longue distance des polluants atmosphériques, de leur source jusqu'au ciel canadien; la quantité de masse que perd l'inlandsis du Groenland et le moment où il ne pourra plus se rétablir; la façon dont les trajectoires des cyclones changent en réaction aux changements climatiques; et ce que tout cela signifie pour leur avenir. Ces jeunes se lancent volontiers dans des carrières scientifiques qui s'avéreront de plus en plus exigeantes, tandis que le monde se tourne vers la science pour savoir ce qui se passe : *quand et à quel degré serons-nous touchés?* Et pourtant, ils ont la tête pleine d'idées et le cœur plein d'entrain. Et j'ai eu le privilège de ressentir l'espoir et les possibilités qu'ils m'ont communiqués en les côtoyant.

Mais où cela les mène-t-il? Quel est le poids de l'espoir que je place sur leurs épaules quand la tâche qui leur incombe, redresser l'incroyable déséquilibre des changements climatiques (et de toutes les disparités environnementales et sociales qui s'y rattachent), s'avère si gigantesque?

C'est en ce sens que la SCMO revêt toute son importance. Oui, les travaux qu'entreprennent les scientifiques expérimentés et la façon dont ils partagent ces travaux entre eux sont absolument essentiels. Mais où tout cela mènera-t-il sans les jeunes scientifiques prêts à vous suivre, à apprendre de vous, à prendre les rênes quand il le faut et à trouver eux-mêmes des idées incroyablement novatrices? Ces jeunes ont la vie devant eux, et avec tant d'incertitude dans l'air, nous ne devrions pas sous-estimer ce que nous attendons d'eux. Votre soutien, en tant que mentors et amis, est leur tremplin, et aussi un refuge quand ils en ont besoin.

J'espère que vous avez senti, au cours de mon mandat de rédactrice en chef du Bulletin, que j'ai été en mesure d'aider la Société à diffuser votre important travail au monde entier. Diriger le développement du Bulletin virtuel m'a procuré un grand plaisir, car j'ai pu imaginer comment les gens du monde entier pourraient bénéficier davantage de ce que vous avez tous à partager. Le site anglais du Bulletin reçoit en moyenne de 600 à 1000 visiteurs par mois, le site français en reçoit entre 150 et 200. **Les entrevues sur la Terre du futur** que j'ai organisées pour le Congrès 2017 avec l'appui des sept membres de la SCMO que j'ai interviewés ont été écoutées près de 190 000 fois! Donc, à tous ceux d'entre vous qui ont écrit un article pour le Bulletin ou qui ont accepté que je les interviewe, sachez que votre contribution est précieuse et que vos paroles ont atteint au moins certaines des personnes qui ont besoin de les entendre.

Nous sommes en train de recruter un nouveau rédacteur en chef pour le Bulletin. Je travaillerai avec cette personne au cours des prochains mois, pour une transition en douceur. Je ferai donc encore un bout de chemin avec vous! Vous tous, et la Société dans son ensemble, m'êtes allés droit au cœur, et je veillerai à ce que le candidat qui prendra la relève puisse vous permettre de progresser et de grandir encore plus.

Un énorme merci au directeur général Gordon Griffith, au directeur des publications Douw Steyn, à l'archiviste Bob Jones, à l'administratrice du bureau Qing Liao, à la présidente actuelle Kimberly Strong, à tous les anciens présidents et à tant d'autres membres de la SCMO, pour tout le soutien et la gentillesse dont ils ont fait preuve au cours des dernières années.

Meilleurs vœux à vous tous et bon succès dans vos projets scientifiques,

Sarah

Sarah Knight, Ph.D.,

Words from the President

Welcoming in a Decade for Climate Action

As 2019 ends and we welcome 2020, we have an opportunity to reflect on some of the events of the last year and where we are heading in the year to come, particularly on the topic of climate change, which has been front and centre in the news all year. Progress on climate action this past year was frustratingly slow for many, particularly given the disagreement at the December **COP25 Conference** in Madrid, which resulted in a **weak compromise agreement** on how to meet greenhouse gas emissions reduction targets. However, 2019 saw a massive increase in climate change awareness. Inspired by Swedish climate activist **Greta Thunberg**, there were marches and protests around the globe calling for governments and business to act. Climate change was a key issue in the fall federal election, and the subsequent **Speech from the Throne** recognized this with its emphasis on fighting climate change: "*Canada's children and grandchildren will judge this generation by its action – or inaction – on the defining challenge of the time: climate change. From forest fires and floods, to ocean pollution and coastal erosion, Canadians are living the impact of climate change every day. The science is clear, and it has been for decades. A clear majority of Canadians voted for ambitious climate action now.*"

The Speech from the Throne set an ambitious target for Canada to achieve net-zero emissions by 2050, and just a day later, the European Council endorsed the objective of a climate neutral EU by 2050 with its **European Green Deal**, in line with the objectives of the Paris Agreement. Meanwhile, New Zealand's parliament recently passed a zero carbon bill with cross-party support of 119 votes to one, and subsequently announced that it will now make **all major decisions looking through a "climate lens"**.

The **UN's Intergovernmental Panel on Climate Change** has said that global carbon emissions should be net zero by 2050 if warming is to be held at 1.5□C. While meeting this target is undoubtedly a challenge, for both Canada and the world, failure to rise to this challenge will also be costly. The financial world is taking notice, as seen in the Bank of Canada adding climate change to its **2019 list of risks to Canada's economy and financial system**, the recommendations of the **Canadian Expert Panel on Sustainable Finance**, the **open letter from large investors** representing more than US$34 trillion calling on the G20 to commit to action to achieve the goals of the Paris Agreement, and the **appointment of Mark Carney as the UN special envoy** on climate action and climate finance. We are reminded of the urgency with each extreme weather event in the news, most recently the massive forest fires raging in Australia, and with every new scientific report. In 2019, these included ECCC's ***Canada's Changing Climate Report***, NOAA's ***Arctic Report Card***, IPCC's ***Special Report on the Ocean and Cryosphere in a Changing Climate***, and UNEP's ***Emissions Gap Report 2019***. CMOS's scientific position statements, including our updated statement on climate change, can be found at **https://www.cmos.ca/site/ps_pos_statements**.

This issue of the CMOS Bulletin includes several articles that fit in with the end-of-year theme. Always popular is David Phillips' annual summary of **Canada's Top Ten Weather Stories**. We also have a look back at **summer 2019 Arctic temperatures** and a forecast for the 2019-2020 winter produced by the new **Arctic Regional Climate Centre (ArcRCC) Network**. Across Canada, the **seasonal outlook for winter 2019-2020** is for elevated temperatures in southern and eastern Canada and above normal precipitation for much of the country.

Of particular note, December 18th marked the 20th anniversary of the launch of Canada's MOPITT (Measurement of Pollution in the Troposphere) instrument on NASA's Terra spacecraft. MOPITT was conceived by Professor James R. Drummond to measure carbon monoxide from space, and in this issue, Jim writes about the **history of MOPITT and its continuing importance**. Jim and the Terra satellite team recently received the 2019 William T. Pecora Team Award from NASA and the U.S. Department of the Interior. The citation for this award notes that "*Terra is arguably one of the most successful Earth-sensing satellites ever deployed" and that MOPITT was the first instrument "designed to observe the distribution and transport of tropospheric carbon monoxide and, along with other sensors, has helped advance our understanding of air quality and biomass burning emissions.*" Congratulations to Jim and all past and current members of the MOPITT team on the spectacular success of this instrument and its mission to quantify and track global atmospheric pollution.

As we look ahead to 2020, I'd like to invite our members to submit nominations for **CMOS prizes and awards** (due February 15) and **CMOS Fellows** (due March 15), and to attend the **CMOS Congress in Ottawa in May**.

Words from the President / Mot de la présidente

Finally, I would like to thank Sarah Knight for her outstanding work as Editor of the CMOS Bulletin for the last three and a half years. Sadly for us, **Sarah is leaving to take up new opportunities**. Sarah spearheaded the development of our online version of the CMOS Bulletin, making it an attractive and informative open-access magazine of interest to both CMOS members and the general public. It has been a very great pleasure working with Sarah and I'm sure you all join me in wishing her every success in her future endeavours.

Best wishes for a happy and productive 2020.

Kim

Kimberly Strong, CMOS President and Professor & Chair, Department of Physics, University of Toronto

L'occasion de revenir

Tandis que 2019 se termine et que nous accueillons 2020, nous avons l'occasion de revenir sur les événements de l'an passé et de décider de la voie à suivre cette année. Notamment en ce qui concerne les changements climatiques, qui ont été au centre de l'actualité l'an passé. Le progrès des mesures visant le climat a été au cours de l'année d'une lenteur frustrante pour beaucoup, notamment en raison du désaccord survenu en décembre à Madrid lors de la **conférence COP25**, qui a abouti à un **faible accord de compromis** sur la manière d'atteindre les objectifs de réduction des émissions de gaz à effet de serre. Cependant, en 2019 nous avons été témoins d'une prise de conscience incomparable en matière de changements climatiques. La militante suédoise **Greta Thunberg** a inspiré l'organisation de marches et de manifestations dans le monde entier pour demander aux gouvernements et aux entreprises d'agir. Les changements climatiques ont été un enjeu important des élections fédérales cet automne. Le **discours du Trône**qui a suivi l'a reconnu en mettant l'accent sur la lutte contre les changements climatiques : « *Les enfants et petits-enfants du Canada jugeront cette génération selon ses actions, ou son inaction, à l'égard du plus grand défi de notre époque : les changements climatiques. Des feux de forêt aux inondations, de la pollution des océans à l'érosion côtière, les Canadiens vivent les effets des changements climatiques tous les jours. Les données scientifiques sont claires; elles le sont depuis des décennies. Une nette majorité de Canadiens ont voté pour un plan d'action ambitieux en matière de lutte contre les changements climatiques maintenant.* »

Le discours du Trône fixe un objectif ambitieux pour le Canada : l'atteinte d'émissions nettes nulles d'ici 2050. Le lendemain, le Conseil européen approuve l'objectif d'une Union européenne climato-neutre d'ici 2050, avec son **Pacte vert pour l'Europe**, conformément aux objectifs de l'Accord de Paris. Aussi, le parlement néo-zélandais a récemment adopté **un projet de loi zéro carbone** avec un soutien interparty de 119 voix contre 1. Il a ensuite annoncé qu'il **prendrait désormais toutes ses décisions importantes en tenant compte du climat** (site en anglais).

Le **Groupe d'experts intergouvernemental sur l'évolution du climat de l'ONU** a déclaré que les émissions mondiales de carbone devraient être nulles d'ici 2050 si l'on veut maintenir le réchauffement à 1,5 °C. Bien que la voie vers cet objectif soit semée d'embûches, tant pour le Canada que pour le reste du monde, l'incapacité à atteindre ce but sera également coûteuse. Le monde financier en prend note, comme en témoignent l'ajout par la Banque du Canada des changements climatiques à sa **liste 2019 des risques pour l'économie et le système financier canadiens**, les recommandations pour le Canada du Groupe d'experts sur la finance durable, la **lettre ouverte de grands investisseurs** représentant plus de 34 mille milliards de dollars américains demandant au G20 de s'engager à prendre des mesures pour atteindre les objectifs de l'Accord de Paris, et **la nomination de Mark Carney à titre d'envoyé spécial de l'ONU pour le financement de l'action climatique**. L'urgence nous est rappelée à chaque événement météorologique extrême que rapportent les bulletins de nouvelles, tout

Mot de la présidente

récemment, les incendies de forêt majeurs qui font rage en Australie, et à chaque parution d'un nouveau rapport scientifique. En 2019 ont paru le ***Rapport sur le climat changeant du Canada* d'ECCC**, le ***bilan sur l'Arctique* de la NOAA** (en anglais), le ***Rapport spécial du GIEC sur l'océan et la cryosphère dans le contexte du changement climatique*** et le ***Rapport 2019 sur l'écart entre les besoins et les perspectives en matière de réduction des émissions* du PNUE**. Les énoncés de position scientifiques de la SCMO, y compris notre déclaration mise à jour sur les changements climatiques, se trouvent à **https://www.cmos.ca/site/ps_pos_statements?language=fr_FR&**.

Ce numéro du Bulletin de la SCMO comprend plusieurs articles qui soulignent la fin de l'année. Le résumé annuel de David Phillips des **Dix événements météorologiques marquants au Canada** est toujours très attendu. Nous jetons également un coup d'œil sur les **températures de l'été 2019 dans l'Arctique** et sur les prévisions pour l'hiver 2019-2020 que produit le nouveau **Centre climatologique régional en réseau pour l'Arctique** (site en anglais). Dans l'ensemble du Canada, **les prévisions saisonnières de l'hiver 2019-2020** annoncent des températures élevées dans le sud et l'est du pays et des précipitations supérieures à la normale dans la majeure partie du pays.

À noter, le 18 décembre a marqué le 20e anniversaire du lancement de l'instrument canadien MOPITT (mesure de la pollution dans la troposphère) à bord du satellite Terra de la NASA. Le professeur James R. Drummond a conçu MOPITT afin de mesurer le monoxyde de carbone à partir de l'espace. Dans ce numéro, Jim raconte **l'histoire de MOPITT et souligne l'importance toujours actuelle de l'instrument**. Jim et l'équipe du satellite Terra ont récemment reçu le prix 2019 William T. Pecora de la NASA et du Department of the Interior des États-Unis. La mention accompagnant le prix note que « *Terra est sans doute l'un des satellites de télédétection visant la Terre les plus fructueux jamais déployés* » *et que MOPITT est le premier instrument « conçu pour observer la répartition et le transport du monoxyde de carbone troposphérique et, qu'avec d'autres capteurs, il a fait progresser notre compréhension de la qualité de l'air et des émissions émanant de la combustion de la biomasse.* » Félicitations à Jim et à tous les membres passés et actuels de l'équipe MOPITT, pour le succès spectaculaire de cet instrument et de sa mission, qui consiste à quantifier et à suivre la pollution atmosphérique mondiale.

Tandis que nous arrivons en 2020, j'invite les membres à soumettre des candidatures pour les **prix et récompenses** de la SCMO (jusqu'au 15 février) et pour le titre de **membre émérite de la SCMO** (jusqu'au 15 mars), ainsi qu'à participer au **Congrès de la SCMO à Ottawa**, en mai.

Enfin, je tiens à remercier Sarah Knight pour son travail exceptionnel des trois dernières années et demie à titre de rédactrice en chef du *Bulletin de la SCMO*. Malheureusement pour la Société, **Sarah nous quitte pour profiter de nouvelles occasions**. Elle a été le fer de lance de la version en ligne du *Bulletin de la SCMO* et en a fait une revue attrayante et informative en libre accès, couvrant des sujets qui intéressent à la fois les membres de la SCMO et le grand public. Ce fut un immense plaisir de travailler avec Sarah et je suis certaine que vous vous joignez tous à moi pour lui souhaiter beaucoup de succès dans ses projets.

Meilleurs vœux pour une année 2020 heureuse et productive,

Kim

Kimberly Strong, Présidente de la SCMO et directrice du département de physique de l'Université de Toronto

Canada's Top Ten Weather Stories of 2019

by David Phillips, Environment and Climate Change Canada

(article source: https://www.canada.ca/en/environment-climate-change/services/top-ten-weather-stories/2019.html)

Canadians are experiencing more and more extreme weather, from intense and lengthy heat waves, to suffocating smoke and haze from wildfires, to extreme flooding. Canadian scientists have made a clear link between climate change and extreme weather events. They tell us that while such events can and do occur naturally, much of what we are seeing is driven by human-induced climate change. The effects of climate change are evident in many parts of Canada and are projected to intensify in the future.

As the Top Ten Weather Stories of 2019 illustrate, exceptional weather is becoming ordinary. It is playing out in our backyards, in our communities and across our country. Canadians must become more resilient—not only for what lies ahead but also for the climate that is already here.

Introduction

Canadians had plenty to "weather" in 2019: Winter froze and buried us; summer soaked and frightened us and, occasionally, baked us. It was the shorter spring and fall seasons that brought the most destructive and disruptive weather. Property damage from weather extremes cost Canadians millions and the economy billions of dollars. Based on preliminary estimates collected by the Insurance Bureau of Canada, there were 12 major catastrophic events, each with losses in excess of $25 million. For the eleventh year in a row, the Canadian insurance sector faced billion-dollar losses due to weather-related extremes.

The year 2019 was one of big floods, especially in Ontario, Quebec and New Brunswick. The Ottawa River flood was bigger and worse than the one in 2017. Everything about the flood, including its magnitude, duration and impacts, was unprecedented. For the second consecutive year, the Saint John River flooded in April and became one of the longest flood events in New Brunswick's history. Significant flooding also occurred in central Ontario's cottage country, on the shores of the Lower Great Lakes, and in Quebec's Beauce region.

The absence of spring flooding in Manitoba's Red River Valley made news when the basin was anticipating a major flood that did not materialize, owing to a favourable melt season. In contrast, heavy rain and snow in October resulted in flood warnings and high water advisories for some areas of Manitoba and triggered the latest activation of the Red River Floodway since it began operation.

This year featured several noteworthy storms. One that disappointed millions of children in Ontario and Quebec was the Halloween storm that cut short trick-or-treating, and even delayed it for some. Two early autumn snowfalls shocked residents in Calgary and Winnipeg and further delayed harvesting. During an active Atlantic hurricane season, Canada was touched by four tropical storms and was hit directly by Category-2 Dorian in September. The impacts of Dorian were made worse by the soaking rains and powerful winds from tropical storm Erin just a week earlier. While not as intense as Hurricane Juan of 2003, Dorian's winds, rains and waves destroyed more Nova Scotia physical infrastructure than any storm in the past.

Storms in 2019 caused extensive power outages from coast to coast to coast. Over three million homes and businesses lost power not just for hours but, in some cases, for a week or longer. For British Columbia, the greatest outage in BC Hydro's history occurred during the first week of winter (December 2018). In Manitoba, the public utility also faced the largest outage in that province's history. In Quebec, the Halloween storm took out power for nearly a million customers, the impact second only to the infamous ice storm of January 1998. With Hurricane Dorian, Nova Scotia Power faced the single most damaging storm in its history, with 412,000 or 80% of their customers affected.

The year 2019 presented enormous challenges for food producers and the farming industry across the country. Farming became a year-long challenge for Western farmers and ranchers when it was too cool throughout the growing season and either too dry at the start or too wet in the fall, leaving the harvest (for some) to be completed in 2020. It was the worst-ever harvest for others who managed to complete it. For Eastern farmers, the growing weather was especially disappointing. Some farmers said they could have bought both flood insurance and drought insurance in the same growing season.

Article: Canada's Top Ten Weather Stories of 2019

In 2019, Western Canadians proved their mettle as winter people by beating back a brutal cold spell in February, when the shortest month felt like the longest. Easterners were no less heroic, having to endure lengthy power losses. The forest fire season was generally quiet across Canada in contrast to the last two years. The exceptions were in Alberta and northwestern Ontario, where huge tracts of timber were burned in some of the largest fires on record.

In the rugged but fragile North, 2019 saw the Arctic continue its alarming warming and massive ice melt. Parts of the North experienced southern-like weather, such as heat waves, thunderstorms, tornadoes, wildfires and winter rains. Arctic ice cover shrank to its second lowest minimum extent on record (40 years).

It was another warm year (January to November, inclusive) in Canada. In fact, it was our 23rd "not-cold" year in a row, although it was not as warm as it has been in much of the past 10 years. Almost all of the warm-up was carried by the North, especially the northeastern part of Nunavut, which had its second warmest year in 72 years of record keeping, exceeded only by 2010. For millions of Canadians, it was not that 2019 was so cold—it just wasn't hot. Apart from the Pacific coast of British Columbia, all of southern Canada, from Summerland to Summerside, felt a cooler year with temperatures slightly below normal. Much of the coolness was contributed by a frigid February and a summer that was more a teaser than a pleaser.

The year 2019 concluded the warmest decade on record in Canada. Average temperature for the ten-year period (2010–2019) was 1.42 °C above the long-term conditions (1948–2019). Since the 1970s, each successive decade has been warmer than the last with the warming accelerating after 2000. Globally, 2019 was another warm year, according to the World Meteorological Organization (WMO), on course to be the second warmest year since modern records began 140 years ago, even without the help of a tropical Pacific El Niño. Further, 2019's continued warming ensured the decade was the warmest in modern times.

From a list of 100 significant weather events happenings across Canada in 2019, events were rated from 1 to 10 based on factors that included the degree to which Canada and Canadians were impacted, the extent of the area affected, economic and environmental effects, and the event's longevity as a top news story.

Top Ten Number 1. Another record-setting Ottawa River flood

Nature was all primed for another catastrophic spring flood along the Ottawa and St. Lawrence Rivers—the second record discharge in three years. Flooding on the Ottawa River is often a threat in the spring. In the past century, flooding has exceeded a flow of 8,000 cubic metres per second at Hawkesbury, Ontario, on eight occasions. But only twice, in 2017 and 2019, has the flow peaked above 9,000 cubic metres per second. This year's flood was bigger than the 2017 event that was then considered the flood of the century. On April 5, Hydro-Québec reported that the dam at Chute Bell, Quebec, on the Rouge River (which feeds into the Ottawa River), was exceeding the dam's specifications. The dam, built to withstand a once-in-one-thousand-year flood, saw water gushing over the top and around its sides, at eleven times its normal flow.

Everything about this year's flood, including its size and duration, was unprecedented. All the weather ingredients were in place for a catastrophic event. Seven straight months of below-normal temperatures from October to April ensured the ground froze deeply and thawed late, preventing the infiltration of rain and snowmelt runoff. With little melting by mid-spring, the deep and icy snowpack stayed. In heavily forested areas upstream of the Ottawa River, snowfall accumulation was 50% greater than normal. Adding to this scenario were multiple rounds of heavy spring rains persisting over a five-week period from mid-April to mid-May. This included two storms from the Gulf of Mexico that brought an equivalent of a month's worth of rain and triggered an immediate and lengthy spring flood. In Ottawa, twice the normal accumulation of rain, 150 mm to be exact, fell between April 10 and May 10.

It promised to be a long, drawn-out flood season along the rain-soaked Ottawa and Rideau Rivers and in Quebec along rivers such as the Rigaud, Mille-Îles and des Prairies. In mid-April, 20 to 40 cm of snow still lay on the ground in the northern reaches of the Ottawa River watershed. Incessant rains and warm air from the southwest assaulted the snow pack, causing rapid melting. On May 1, the bloated Ottawa River crested 30 cm above 2017's peak flood levels. Water inundated several riverside communities, including Pembroke, Constance Bay, Fitzroy Harbour, Arnprior and Britannia in Ontario, and Pontiac, Gatineau, Rigaud and Laval in Quebec. Dozens of smaller rivers flowing into the Ottawa River also broke all-time flow records. For the second time in three years, homeowners, municipal workers, volunteers and armed forces personnel worked frantically to fill sandbags, build makeshift walls, pump water from homes, and assist first responders in evacuations. Hundreds of residents from Pembroke, Ontario, to Sherbrooke, Quebec, and on to the Beauce, Quebec, region were forced to leave their homes despite sandbagging efforts. In Ottawa and Gatineau, more than 6,000 dwellings were flooded or at risk. Roads and streets in flooded areas closed for long periods. Several bridges, including the Chaudière between Ottawa and Gatineau, also closed, and many of the ferry services were suspended. Farmland was flooded, delaying fieldwork and planting. Downstream in Montréal, the flood emergency remained until May 8. It took Ottawa more than a month longer to lift their state of emergency. The flood claimed at least two lives: one each in Ontario and Quebec.

Top Ten Number 2. Active hurricane season as predicted

The 2019 Atlantic hurricane season was one of the world's most devastating, with many casualties and widespread destruction in the Caribbean. Post-tropical depression Erin reached the south shore of Nova Scotia on August 29, merging with a trough of low pressure arriving from the west. At its peak, this hybrid storm's rainfall rates exceeded 30 mm per hour, triggering flash flooding with ponding and washouts.

A week later, Hurricane Dorian arrived on the scene. Dorian was the most destructive storm of the season both outside and inside Canada. With winds of nearly 300 km/h, it destroyed parts of Grand Bahama and the Abacos before it crawled adjacent to Florida and Georgia and made landfall in North Carolina. On September 7, a weakening Dorian raced northeastward toward Canada. As it neared Nova Scotia, Dorian transitioned into a post-tropical storm but maintained its Category 2 intensity with sustained winds of 155 km/h before making landfall just west of Halifax after 7:00 p.m. Post-tropical storm Dorian pounded Atlantic Canada with heavy rains, winds, storm surges, and high significant waves over the 24-hour event on September 7 and 8. Some century-old trees in full leaf suffered a swift uprooting, often landing on homes and vehicles. Nearly half a million people were without power across Atlantic Canada. Eighty per cent of Nova Scotia's homes and businesses lost power—the highest number of outages in Nova Scotia Power's history. Dorian seriously hampered crops almost ready for harvesting in what had already been a difficult growing season. Authorities claimed that the physical infrastructure damage across the province of Nova Scotia was unprecedented. As a result of excellent preparation by citizens and emergency managers, there were no serious injuries or direct fatalities. Rain totals were 100 mm in many places, with an observed maximum of 190 mm west of Halifax.

Dorian brought destructive winds to other parts of the Maritimes as well. Storm surges generated extensive flooding in some coastal areas along the Northumberland Strait. In New Brunswick's Shediac region, winds and storm surges lifted dozens of vessels and carried them onto the shore. The Magdalen Islands and Gaspé Peninsula were severely impacted, as homes, cottages and boats were damaged and trees uprooted; in some cases, cottages and outbuildings were blown off their foundations. As Dorian tracked its way to Newfoundland and Labrador, its impacts were mostly from the wind. The western and southwestern parts of Newfoundland and Labrador felt the strongest winds, topping 157 km/h in the Wreckhouse area. Dorian also produced a behemoth 30 m wave just a little ways offshore from Port aux Basques, Newfoundland. Early estimates from the Insurance

Bureau of Canada indicate that Hurricane Dorian caused a trail of damage to insured property estimated at $140 million, with nearly two-thirds of the damage occurring in Nova Scotia.

Other Atlantic tropical storms affected life in Canada. Early in the summer, the remains of Hurricane Barry caused urban flooding in West Toronto. Hurricane Humberto passed through Canadian waters as a post-tropical storm on September 21. Tropical storm Jerry didn't make landfall anywhere in Canada but brought rains in the 40 to 60 mm range on September 24–25 across parts of western New Brunswick, Prince Edward Island and northern Nova Scotia. Parts of Newfoundland and Labrador also got upwards of 100 mm of rain. The rain backed up drains still clogged with debris left over by Dorian. In the last week of October, the remnants of Tropical Storm Olga yielded up to 50 mm of rain and southwesterly winds, raising water levels on some exposed shores of Lakes Erie and Ontario.

Top Ten Number 3. sNo-good Prairie fall

Snow in September is not rare in Calgary, and about two-thirds of its annual snowfall usually occurs in the fall and spring seasons. But for four days at the end of September, Calgary was assaulted by a bout of wintry weather with sub-freezing temperatures and snow. The four-day snowfall totaled 32 cm. While not a record dump, Calgary did see the greatest depth of snow on the ground in 65 years for late September. Over the foothills, heavier snowfalls fell at more intense rates, with upwards of a metre of snow accumulating in the higher terrain of Waterton Lakes, Pincher Creek and Crowsnest Pass.

The heavy, wet snow created huge traffic problems. Several universities and colleges closed, public services shut down, and air travelers faced delays and flight cancellations. Trees still flush with green leaves bowed, sagged and snapped from the weight of sticky snow. Snow accumulation on power lines and branches led to widespread power outages. Outside Calgary, especially to the south and west, farmers and ranchers braced against more killing frost and heavy, wet snow that beat down crops. In southern British Columbia, the early blast of winter also brought 35 to 50 cm of snow across several mountain passes. Eventually, the storm moved eastward, bringing much less snow to southern Saskatchewan and only rains to Manitoba.

Two weeks later, heading into the Thanksgiving Day weekend, Manitobans were still drying out from record September rains, nearly three times the norm. Farmers were especially concerned but, after a relatively dry first week of October, they once again started up their combines and resumed round-the-clock harvesting. They were keeping an eye on a pending well-announced weather system. The storm sat over the region for days. Heavy, sticky snows draped Manitoba from Brandon to Winnipeg from October 10 to 12 and through the Thanksgiving weekend. Historic snowfall totals included 34 cm at Winnipeg over two days, making it the biggest October snowstorm in the city since records began in 1872. States of emergency were declared across the province and in eleven communities, including Winnipeg. More than 6,000 people had to evacuate from a dozen or more First Nations communities. Lengthy and widespread power outages created hardship. Powerful winds exceeding 80 km/h drove the wet snow, creating blinding blizzards and two-metre drifts. In some cases, transmission towers toppled, downing total electrical grids. According to Manitoba Hydro, at the peak of the storm, a quarter of a million people were without power, making it the largest outage in the utility's history. Ten days later, about 5,000 were still without power. By the end of November, there were still some citizens who could not yet return to their homes.

The storm's early arrival in October meant tree branches, still loaded with leaves, were bending. Many of Winnipeg's trees saw damage and loss under the weight of the snow. Over 30,000 trees on public land were affected, with estimates of thousands more on private land. The Manitoba escarpment in Morden, Winkler, and Carberry also saw between 50 and 75 cm of snow.

Top Ten Number 4. A brutal Febrrruary in Canada

The Polar Vortex prevailed across Canada and helped to define a long winter! El Niño was expected to tame winter across North America, but it was late to arrive and its effect on weather patterns was weak. Instead, Arctic weather pushed southward for six weeks, from late January and throughout February, with a continuous supply of cold air.

For half the country, from the Pacific Coast to the Upper Great Lakes, February was the coldest month in at least 70 years. Along the Pacific coast and the BC interior, temperatures were 9 degrees below normal and nearly 1.6 degrees colder than the previous coldest February, in 1949. Calgary had its coldest February in 83 years, and Alberta's Chinook Country was 14 degrees colder than normal. The February mean temperature in Calgary was an astounding 10 degrees below normal—the greatest monthly departure from normal ever for anywhere in the Prairie provinces. Toronto saw a year's worth of snow in the first two months of the year with only 10 days without precipitation in January and February. Montréal saw 9 days of thaws and freezes in February, meaning that liquid on the ground during the day turned to ice overnight, leading to an inordinate number of slips and falls, causing injuries ranging from sprains to concussions. In Atlantic Canada, it was the third coldest February in 25 years. Just too much winter went on without a break!

At the same time, homeless Canadians filled all available spaces in emergency shelters. Often, mail carriers and couriers were unable to carry out their duties. New power consumption records were set, only to be eclipsed the next day. Mechanical problems dogged public transit systems. Buses broke down, often forcing schools to close for several consecutive days. Cities faced hundreds of calls for service on leaky and broken pipes, with frost levels well below pipe depth. For example, Regina reported a record number of water main breaks—fifty-two, compared with the five-year average of seventeen for February. Piercing cold, ferocious winds, ice, and mountains of snow piled up on front yards and even higher along curbs and driveways. The shortest month will be remembered for one of the longest cold snaps in years.

Top Ten Number 5. Record heat continues in Arctic

With many consecutive warm years, the Arctic is seeing less snow, permafrost slumping deeper, sea ice thinning, and high-latitude glaciers retreating. Increasing temperatures above and below the ice caused a further reduction in ice concentrations, from its maximum extent in March to minimum amounts in September. This September, Arctic sea ice reached its annual minimum at 4.15 million square km—the second lowest minimum extent on record, tied with the minima observed in 2007 and 2016, and behind the record set in 2012. According to the Canadian Ice Service, the pattern of reduced ice coverage was observed in northern Canadian waters, with maximum and minimum ice cover attained in mid-May and late September, respectively. Freeze-up in the fall was the latest on record (since 1979), primarily due to the extraordinary warm spell spanning ten weeks starting in early September.

From Alaska to Greenland and in Canada, the North American Arctic experienced above average temperatures at a record level throughout the year. The same July heat wave that originated over North Africa and surged northward to roast Europe continued into the Arctic. Summer temperatures in the High Arctic, according to Environment and Climate Change Canada's trends analysis, ranged between 2.5 °C and 4.5 °C above what is normal for Nunavut, making it the warmest summer in 72 years.

The first half of winter saw very little snow across parts of Nunavut. On the tundra, Indigenous hunters reported that rocks and gravel—typically covered by a hard layer of snow—were exposed. Just days before the first day of spring, southerly winds brought unseasonable warmth and abundant sunshine to the North. The Yukon and Northwest Territories broke more than 90 maximum temperature records over one week in March, with some records eclipsing the previous record by 3 to 6 degrees. By April 11, the ice road connecting Dettah and Yellowknife closed for the season due to rapidly deteriorating conditions when temperatures exceeded 20 °C. It

was the earliest closure of the ice road since 1993. Other ice roads also had to close prematurely. On June 2 around 4 p.m., eyewitnesses spotted an EF-1 tornado near Fort Smith, Northwest Territories. It was the fourth tornado ever confirmed north of 60° latitude in Canada. The Canadian Forces Station Alert, Nunavut—a military outpost and the most northerly permanently inhabited spot on Earth—experienced an "Arctic heat wave" in mid July when temperatures exceeded 21 °C, 14 degrees warmer than normal. It was warmer in Alert that day than it was in Victoria, British Columbia! On the afternoon of August 10, multiple lightning strikes occurred within 500 kilometres of the North Pole in a rare Arctic thunderstorm. Wildfires in the Yukon began early, stayed later, were hotter, bigger and moved more quickly. The total area burned was 2,800 square km, more than double the territory's 10-year average. Wildfires visible from space also occurred north of the Arctic Circle near Inuvik, Northwest Territories.

Top Ten Number 6. On the Prairies…Too dry early, too wet later

Prairie farmers and ranchers had another challenging weather year in 2019. It was too cool and dry in the beginning and too cold and wet at the end. Before the growing season even got underway, ranchers and farmers were facing some of the driest winter-spring conditions in 133 years of record keeping. In some of the southern regions, the amount of moisture and rain had been running low for more than two years. Edmonton, Alberta, experienced its driest spring on record. Regina, Saskatchewan, saw its driest March with just 0.8 mm of precipitation. Saskatoon, Saskatchewan, was even drier in April with 0.4 mm of precipitation. Winnipeg, Manitoba, recorded its driest first half year with only 91 mm of total precipitation; the normal January-to-June total is 235 mm. In those cities, homeowners were seeing their foundations cracking, shifting and sinking in the abnormally dry ground. Record cold, especially in February that continued into March and April, had already delayed seeding and slowed crop growth. The Prairies welcomed scattered rains in July, but pockets of drought continued in the southern area, leading to a shortage of feed resources, which carried over from 2018. Stunted grasses forced ranchers to either sell off part of their herds or start using winter feed, months early.

The much-needed moisture in mid-summer through the fall initially raised spirits among rural Westerners but, unfortunately, the rains didn't stop until the Prairies had gone from dry to drenched. Regina saw nearly 175 mm of rain in August and September, bringing 100 mm more than normal, making it the second wettest August/ September in 136 years. Frequent, heavy rain events often left fields saturated and incapable of handling heavy farm equipment. Residents on the Prairies witnessed double the normal number of severe summer weather happenings with tornadoes, intense rainfalls, windstorms and 2.25 times the usual number of hailstorms, but no place exemplified the summer misery more than Edmonton. Through June, July and August, inclusively, Edmonton's city weather station had 55 days of rain, the second highest number of days since 1881. Further, there were only 18 days in 2019 in which temperatures climbed in a summery way to 25 °C or above.

In central Alberta, crops were drowning, pastures were under water and ditches were full and overflowing. The wetness led to major crop losses, especially hay. Farmers were desperate for warmer, windier and sunnier weather to dry things out so that they could begin harvesting. Instead, they got overcast skies, cold temperatures, and continuous showers with more hail. The stress and strain reached the breaking point for thousands of producers, their families and communities. As rains persisted in September and October, farmers grew even

more anxious. Huge tracts of land received double the average August-to-October precipitation. The historic mid-September snowfall that struck Alberta and western Saskatchewan, followed by more snows and rains in October, caused the majority of the Prairie crop still in the fields to deteriorate and prices to fall. Grains began to show sprout and mildew. Never had so much crop—from canola to potatoes to sugar beets—been out so late.

Top Ten Number 7. Weather witch stole Halloween

The forecasts for the evening hours of October 31 are scrutinized more than most other evenings. For millions of children and their parents, the weather forecast on Halloween night is used to make decisions from what to wear to what route to take and for how long. This year, with notice of a significant Halloween storm coming several days in advance, some municipal leaders contemplated whether or not to postpone Halloween.

Following rain showers the previous day, a second round of more intense rainfall moved through Central Canada on Halloween and into Atlantic Canada through the morning of November 1. At the same time, snow fell on the northern side of the system, stretching from Northeastern Ontario to north-central Quebec and across to Labrador, with powerful winds across the East.

Twenty Quebec municipalities postponed trick or treating until the next day. Millions of children exchanged an evening of trick or treating in the rain for high winds blowing them around in total darkness the following evening, after damaging winds accompanied plunging temperatures as the heavy precipitation came to an end.

Winds at Port Colborne, Ontario, peaked at 129 km/h. Along the shores of eastern Lake Erie and Lake Ontario, high waves and storm surges caused extensive property damage. Montréal, Trois-Rivières and La Pocatière, Quebec, recorded gusts over 104 km/h. Halifax, Nova Scotia, recorded a wind gust of 102 km/h. Newfoundland winds intensified on November 1 and sped along at 107 km/h at Wreckhouse and 100 km/h at St. John's.

The strong winds downed power lines and trees, causing the lights to go out for nearly two million Quebecers on November 1. It was the biggest service interruption in the province in more than 20 years. Power outages were especially widespread in Montréal, the Montérégie, the Laurentians, the Eastern Townships, Lanaudière, and the Beauce–Québec City region. Soaking rains also triggered flooding in the downtown core of several communities, including Sherbrooke, where more than 100 mm of rain swelled the Saint François River by more than seven metres, prompting evacuations from 250 buildings. The cities of Granby, Sherbrooke, and Drummondville appeared to take the brunt of the storm's wrath, with both the greatest rainfall and strongest winds centred in that region of southern Quebec. Property losses totaled several million dollars from downed trees and damaged roofs and siding. Authorities confirmed four deaths in Quebec.

For much of Eastern Canada, the Halloween storm was also a season-changer, as it ended what had been a warm fall, ushering in lasting November cold and winter's first snowfalls.

Top Ten Number 8. Spring missing in the East

Following one of the coldest Februaries in decades, Canadians were ready for spring. Yet "real" spring was more winter-like across Eastern Canada. The culprit was the dreaded Polar Vortex that lingered well past April. Persistent northerly and westerly winds kept spring air cold with ample overcast skies, cold rain, and even snow at times. Spring was colder than normal from Alberta to Atlantic Canada.

Over the Great Lakes and St. Lawrence Basin, spring was the second coldest in 22 years. Simply, most Canadians had to wait until summer for spring's arrival. The lack of sun and warmth and weeks of continuous rains caused concern among farmers, gardeners and golfers: spring might have been the cruelest season ever

this year. On the first day of summer, many fields and golf greens in the East were either under water or still saturated from non-stop rains. Standing water covered swaths of recently planted corn and soybeans. Farmers could only watch as the plants rotted. Some growers were set back weeks, some never caught up and some scrambled to choose a different crop. In the East, it was one of the latest planting seasons ever. By the long weekend in May, less than 5% of Ontario's crop was in the ground. Some seeds were sown but nothing was growing except grass. The agriculture-rich Annapolis Valley of Nova Scotia recorded nearly triple their April rainfall and suffered the coldest soil temperatures in 20 years.

May was also colder than normal, which meant less evaporation and drying. In Moncton, New Brunswick, May's average temperature was 7.6 °C, significantly below the normal of 10 °C. Heat for growing food and flowers was less than 40% of normal in May, disappointing many farmers and gardeners. The 2019 planting season was the latest in 40 years, some three weeks behind schedule, raising concerns for crop damage from an early frost and/or high ground water content at harvest. The weather being the farmers' worst enemy in the spring, it turned out to be their best ally in the fall with enough sunny, warm and dry weather to save what could have been a disastrous crop.

Cities were impacted by the lack or delay of spring. Sports fields were drenched, forcing thousands of practices and games to be rescheduled. Golf courses opened late but stayed empty throughout spring: some golf superintendents lamented the conditions, calling them the worst in at least 15 years.

Top Ten Number 9. Saint John River floods again

At the beginning of March, provincial river forecasters in New Brunswick were on watch. In the northwest of the province, where it had been snowing since late October, the snow pack was much deeper than average and ahead of last year's amount by nearly 20%, when the river recorded a record flow in some places. Further, the frozen ground was unable to absorb spring rain. Spring weather is really the big flood determinant—a cold stretch slowing snowmelt, followed by sudden warming and rapid, round-the-clock thawing, compounded by heavy spring rains, often create significant flooding. With that weather outlook in hand, residents in dozens of communities close to the Saint John River spent Easter preparing for the worst.

The weather in April indeed brought on the flood. In Fredericton, precipitation was nearly double April's average with six more wet days than normal and twice the number of heavy rain days. From mid-to-late April, a series of storms brought mild temperatures and significant rains that worsened the prospects for flooding. From April 18 to 28, up to 130 mm of rain fell along the Saint John River. The snowpack in New Brunswick and Maine melted rapidly. On April 22, the Saint John River at the Maine–New Brunswick border had its largest peak streamflow in 67 years. Farther downstream, the peak river level in Fredericton was 8.37 m, surpassing 2018's water level and making it the second highest level on record behind 1973. Other stations downriver from Fredericton came close to exceeding historical levels. The river, at many locations, remained near or above flood stage for about two weeks, making it one of the longest flood events in history.

The Saint John River ran cold and fast and carried waste and debris. Thousands of riverside residents scrambled to protect their properties. The military was called upon to help emergency crews and volunteers fill sandbags, build retaining walls, and help first responders with 1,500 evacuations. In the end, more than 16,000 properties were impacted by floodwaters. More than 145 roads were closed, including a portion of the Trans-Canada Highway between Fredericton and Moncton for seven days, requiring a 90-km detour. Schools and offices were also closed. New Brunswick has battled three major floods over the past 11 years, including this year's and one last year that would once have been called hundred-year floods. More advanced warning, preparations and lessons learned from 2018 helped lessen the flood impacts and costs in 2019.

Top Ten Number 10. Fewer fires, more burning

Statistics from the Canadian Interagency Forest Fire Centre revealed a relatively quiet fire season in 2019. The number of fires nationally was down by 2,600, or 40%, compared with a record in 2018, but the number of burned hectares of woodlands was only 20% less than last year. Despite fewer fires, they burned more on average than last year's infernos. Mitigation work, such as ridding the forest floor of dead brush, helped to prevent more fires from taking hold.

A notable exception to the quiet wildfire season was Alberta. The number of fires was on par with 2018, but the area that fire consumed was nearly 14 times greater, making it the second worst season on record. In May, the "Spring dip", when trees and grasses have low moisture content, was underway, and hot, very dry, strong gusty winds came early. Around mid-May, the Chuckegg Creek fire erupted near the town of High Level, in far northwestern Alberta. Four thousand residents were evacuated as a result of the fire. By the end of May, 10,000 Albertans were out of their homes. Smoke from northern fires caused poor air quality and reduced visibility in parts of Alberta, northern British Columbia, and the Yukon. In particular, skies in Calgary and Edmonton were an eerie-grey-orange and air quality was very poor. By June 3, the Chuckegg Creek fire had grown to 280,000 hectares and was not considered held until the end of July, making it one of the longest wildfires on record. Fires in Alberta burned 883,000 hectares this year, making it the second greatest area burned in 60 years, and four times the 25-year average.

In northwestern Ontario, a dry May contributed to prime forest fire conditions near the community of Pikangikum in the early summer. Heavy smoke from wildfires affected air quality in several First Nations communities for nearly two weeks, prompting the evacuation of 2,500 residents. Another blaze in early July, dubbed Red Lake Fire 23, occurred near the community of Keewaywin, forcing over 400 residents to be flown to rescue centres as far away as Regina. Forest fires in Ontario were half the number compared with the 25-year average, but they burned twice the average area.

In contrast, British Columbia, whose last two wildfire seasons featured in Canada's Top 10 Weather Stories, got a bit of a break this year. In the spring, there was concern over the province's winter snows that were about half their normal quantity, their lowest in 40 years. A record number of lightning strikes in summer across the province were also of concern. In total, 422,000 lightning strikes occurred, compared with the average of 266,000. Thankfully, the lightning was accompanied by considerably wet weather. A dry spring initially led to an early start to the fire season. Fortunately, less extreme temperatures and frequent cool, damp and cloudy weather worked against short heat bursts and dry spells to squelch fires. Wet weather in July was the saving grace, with up to double the rainfall in places. In the end, the area consumed by wildfires was about 0.02% of the area burned in each of the past two summers. The fire season was so slow that fire crews from BC were redeployed to help extinguish fires elsewhere in Canada.

Regional weather highlights

Atlantic Canada

- New Year's Day takes Newfoundland by storm
- January maritime storm included every type of weather
- Winter storm forces Moncton residents outside
- February storm causes road closures in Labrador
- Pre-Valentine's storm across the Maritimes
- March starts out stormy in Nova Scotia
- Newfoundland's icebergs please tourists and locals
- Nain cut off by August fog
- October "weather bomb" drops lots of rain

Quebec

- Cold and snow close Montréal festival celebrating …cold and snow
- Miserable Valentine's Day weather
- Made in Texas "bomb cyclone" explodes over Quebec
- Double storm leads to major spring flooding in Montréal
- Freezing April showers darken Quebec
- Two July tornadoes hit campgrounds
- Beauce flooding
- September tornado maple blowdown
- October nor'easter (weather bomb) brings outages and uprootings
- Remembrance Day record snow dump

Ontario

- Never too cold to snow
- February cold-melt-flash freeze in southwestern Ontario
- Toronto's rare "snow day"
- Nasty winter storm closes Hwy 400
- Two rainstorms lead to major spring flooding along the Grand River Basin
- Record snows in Sudbury
- Great Lakes record high water flooding
- Historic Muskoka flooding
- Ottawa's second tornado in nine months
- Ontario's hot and humid summer day
- Lake Erie inland flooding caused by swollen Great Lakes
- Remembrance Day pre-winter storm

Prairie Provinces

- Winnipeg's February snow scare
- Alberta March fog delays flights
- Biggar wildfire burns popular nature area
- Red River flood risk downgraded by "slowest melt ever"
- April whitewasher welcomed by farmers closes the Trans-Canada Highway
- Saskatchewan welcomes rain – most plentiful in three years
- Saskatchewan park tornado
- Rescue rains in Manitoba
- Eston Saskatchewan thunderstorms
- Winnipeg's deadly heat
- Alberta's overactive tornado and thunderstorm season
- Hailer of a year in Alberta
- Bummer of an Edmonton summer
- September monsoon floods Manitoba

British Columbia

- British Columbia winter windstorms
- Record rains and snowfalls lead to flooding
- Winter's snow all in February – Victoria and Vancouver
- British Columbia's March heat wave
- Snow drought lessens flood risk
- The Eagle Bluff fire – BC's big one
- Record lightning but fewer fires
- Waiting to squeeze Okanagan grapes
- Two-week drought in Vancouver
- "Pineapple express" brings warm rains to the West Coast

The North

- Iqaluit windstorm delays Prime Minister's trip
- Territorial heat wave in March
- February in August?

Article: MOPITT Celebrates 20 Years

MOPITT: Measuring Pollution in the Troposphere for Twenty Years

By Prof James Drummond, FRSC
Department of Physics and Atmospheric Science, Dalhousie University

Most scientific projects run for a few years and then the people involved move on to something else. The Measurements Of Pollution in The Troposphere (MOPITT) project has been running for over 30 years and on December 18th, 2019 we are celebrating the 20th anniversary of the launch of the MOPITT satellite instrument.

You cannot get close to the rocket on the launchpad so everyone watched the final seconds on the monitors. Credit: Jim Drummond

This is a Canadian story since the instrument was designed and built in the country. It was then passed to NASA who put it into the Terra satellite and launched it on December 18th, 1999, 18:57:39 UTC.

On that day we had all hoped that ten years of planning were going to successfully pay off. There were five instruments on the satellite, ASTER (Japanese), CERES, MISR, MODIS and MOPITT (Canada). The mission was expected to last five years – and I have always wondered whether the planning people were Trekkies ("These are the voyages of the Starship Terra. Its five-year mission: to explore strange new worlds….").

There was anxiety about the launch because we had aborted a countdown the previous day, and this was now the last launch window until after the year-end. The entire range was going to stand down for "Y2K" (remember that?). So on this final window "5..4..3..2..1.main engines start….and lift-off!"

And we were away.

Twenty years later MOPITT is still producing data every day.

Left: The payload is winched up to the onto the rocket. Credit: NASA; Middle: The rocket and its payload ready to go. Credit: NASA; Right: Launch! (There are no re-dos!). Credit: Jim Drummond

Article: MOPITT Celebrates 20 Years

A few numbers: The Terra mission has made over 100,000 orbits, MOPITT has made more than 1.3 billion measurements resulting in over 470 publications. For the engineering aficionados: some of the mechanisms have undergone more than 20 billion cycles.

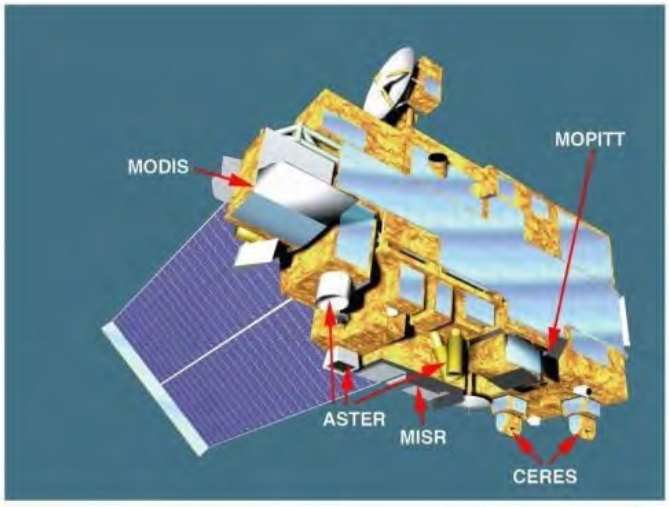
I still have the original proposal for MOPITT from 1989. It is a bit embarrassing to show it to people because some of the science was sketchy by our current understanding and our computers were so limited that many things had to be simplified. But using that proposal, MOPITT was submitted in a competition with nearly 100 from around the world – and we were selected!

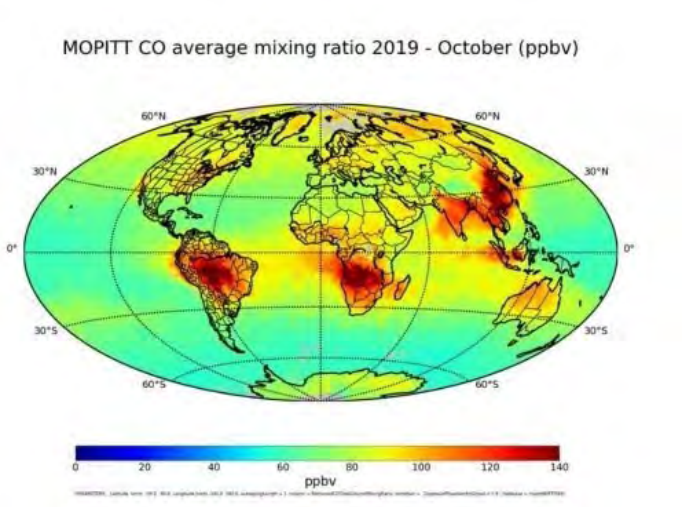
The Canadian Space Agency (CSA) has supported and financed the MOPITT project throughout its 30 years. MOPITT actually pre-dates the CSA – the project was started in a division of the National Research Council. The Canadian Space Agency Act came into December 14, 1990 and MOPITT was transitioned to the agency.

COMDEV was the prime contractor for the instrument and I commuted very many times to Cambridge, Ontario as development progressed. After we built the instrument, we had to characterise it. That was performed in the basement in the Physics Department of the University of Toronto. We had a long integration and testing time at Valley Forge near Philadelphia. Then finally to Vandenberg Airforce Base, California, and then on to space.

Then there are the people who made it possible over the years. I cannot give a total number of the people involved, but there were the engineers and technicians who made the instrument, the calibration team that worked in the basement of the University of Toronto, the programmers and scientists who make the measurements and other scientists who assess the quality of the measurements. I still meet people today who tell me that their careers were changed by their involvement in the MOPITT project. These people are all over the world now: Russia, China, USA, France and of course many in Canada. And of course, they are now senior people. Sadly, we have lost some people: John McConnell was part of the first proposal; Diane Michelangeli was part of one of the science team at the first modelling on MOPITT; and Eric Deys and Dennis Henry worked on design and construction of the instrument.

There are many stories about the instrument and the people who made it possible. One major incident I remembered show the spirit of the team: The instrument had a problem during the testing at Valley Forge and we had to bringing it back to Canada, open it, fix it and then retest it in the basement of the University of Toronto. Both the engineers from COMDEV and the university worked through the nights and weekends to keep the schedule together. Someone seemed to always be in the clean room or the control room. But then back to Valley Forge and onto the satellite – and it worked!





Left: A schematic of the Terra spacecraft and the five instruments. Mass: 5,190 kg, Size: 6.8 m (length) x 3.5 m (diameter) Power: 2.5KW (~7.5KW peak) Data Rate 18.5 Mbit/s (~100 Mbit/s peak). Credit: NASA; Right: A month (October 2019) of data of MOPITT showing hot-spots of CO in the amazon, South Africa and China. Credit: MOPITT Team

When a satellite and a dataset is so long, there are new ideas and the science progresses, and these reflect enhancements to the entire dataset. The massive power of computers that has enabled us to use techniques that were impossible in 20-30 years ago. However, the ability of progress of computers and understanding allows us to go through the entire dataset, and many times we have upgraded the measurements. There are so far eight revisions from our colleagues at the National Center of Atmospheric Center (NCAR) and a ninth one is being planned.

So, what is important about MOPITT?

- MOPITT measures carbon monoxide (CO) in the troposphere (that is the region from the ground up to about 15km). It is important to point out that this is carbon monoxide, not carbon dioxide. A prominently conservative commentator took some early MOPITT measurements and wrote a long polemic about carbon dioxide and its changes and therefore proclaimed that global change was a hoax. He had missed the point that MOPITT measures carbon monoxide, not dioxide, and they are very different animals!

- MOPITT produced the first continuous global tropospheric chemical measurements from satellite. We intended that the major focus was on processes for carbon monoxide, such as intercontinental transport and regional biomass events, but as the dataset grew we have been able to look at regional and global trends too. It shows a slight but steady decrease of CO in many areas.

- MOPITT produced maps of pollution transport. When I saw the first results I was astounded at how much pollution we could see from the satellite. We can see enormous fires in Indonesia, Africa, South America as well as Russia and North America. We actually had to rework some of the algorithms of the retrievals because we never expected to see such large amounts of CO. We could also see major industrial areas such as in East Asia and watch the changes as economic activity grew.

- MOPITT has grown up contemporaneous with chemistry climate models and MOPITT has been able to verify and refine the models as they have ben matured. Synergies between MOPITT and models have allowed “inverse modelling” to delineate the areas of the land which are producing or destroying the CO.

- MOPITT and models are now able to help with predictions of pollution by assimilating MOPITT measurements into a model in a real-time prediction. This was science fiction or a “gleam in our eye” when we designed the instrument, but today you can get predicted CO fields for tomorrow on your laptop in the internet (two other innovations that did not exist when we began!).

- MOPITT has the unique ability not only to measure horizontally, but also can provide vertical profiles where we can see the transport of CO in the upper troposphere. Using this we can see particularly how transport interacts with monsoons and the upper level jets. It is the upper winds that allow pollution to be transported from one continent to another. MOPITT’s global maps show that chemical changes (pollution) are global rather than regional or local. We can see that pollution from Asia is exported into North America and then again exported/imported into Europe and so on. Before MOPITT there was no real strong understanding that local pollution is a global problem.

- It is important to know that this is a Canadian instrument; conceived, designed and constructed in Canada. An instrument that has operated for 20 years – the computer has never crashed in that time. Although we never stuck a Maple flag onto the instrument (we would have needed a lot of paperwork) maybe we should have done! Canada rocks!

Have there be any problems? Definitely. A year after the launch, we had a problem in the cooler systems and half the instrument went dead. We were looking at the end of the instrument, but a ”tiger team” worked prodigiously and came up with a solution which allowed us run the instrument and produced data that are almost as good before the problem.

There was also a methane channel built in, and we have not been able to retrieve results from the instrument so that has been a disappointment so unless someone has a brilliant idea, unfortunately those results will never come.

Personally, I have been amazed at how much support I have found from many people during the last three decades. Looking back I wonder how we managed to do it – but we did it with the help of a lot of people.

So, to everyone who made a contribution to this success and today, to our 20th year in orbit – thank you.

MOPITT Resources:

- MOPITT webpages at:

https://mopitt.physics.utoronto.ca/

https://www2.acom.ucar.edu/mopitt

- The MOPITT data are publicly available at:

https://eosweb.larc.nasa.gov/project/mopitt/mopitt_table

- MOPITT near real-time maps are at:

https://worldview.earthdata.nasa.gov/

- MOPITT contributes to the Copernicus chemical forecast at:

https://atmosphere.copernicus.eu/charts/cams/carbon-monoxide-forecasts

About the Author

Prof. James R. Drummond, M.A., D.Phil. FRSC graduated from the University of Oxford in England, was a faculty member of the Department of Physics, Toronto University for 27 years and then a Canada Research Chair in Remote Sounding of Atmospheres in the Department of Physics and Atmospheric Science at Dalhousie University until his recent “retirement”. He is the currently the Principal Investigator for the Measurements Of Pollution in The Troposphere (MOPITT) instrument on the Terra satellite; a Co-Investigator for the instruments on the Canadian SciSat satellite; Principal Investigator of the Polar Environment Atmospheric Research Laboratory (PEARL) at Eureka, Nunavut; the founding president of the Canadian Network of Northern Research Operators (CNNRO); the Chair of the Forum of Arctic Research Operators (FARO); and the Canadian representative to several international organisations.

Report: ArcRCC Consensus Statement Part 1: Temperature

Arctic Regional Climate Centre Consensus Statement: Temperature / Déclaration de consensus du Centre climatologique régional de l'Arctique : Température

Gabrielle Gascon[1], Katherine Wilson[1], Marko Markovic[1*], Adrienne Tivy[1], Bill Appleby[1], Vasily Smolyanitsky[2], Valentina Khan[3], Helge Tangen[4], Eivind Stoylen[4], Lene Ostvand[4], Johanna Ekman[5], Arun Kumar[6] and Shanna Combley[6]

2019 Arctic Summer Seasonal Summary and 2019-2020 Arctic Winter Seasonal Outlook for Temperature

Arctic temperatures continue to warm at more than twice the global mean. Annual surface air temperatures over the last 4 years (2014-2018) in the Arctic have been the highest on record since 1900. The extent of winter sea-ice is at record low levels, and the volume of Arctic sea-ice present in the month of September has declined by more than 50% compared to the mean value for 1979-2018 . To support Arctic decision makers in this changing climate, the new Arctic Regional Climate Centre (ArcRCC) Network now provides climate consensus statements in May prior to summer thawing and sea-ice break-up, and in October before the winter freezing and the return of sea-ice. The role of the ArcRCC is to collaborate amongst Arctic meteorological and ice services to synthesize observations, historical trends, forecast models and fill gaps with regional expertise to produce these climate consensus statements. These consensus statements provide a review of the major climate trends of the previous season, and outlooks for the upcoming season for temperature, precipitation and sea-ice. They are released at Arctic Climate Forums (ACFs) with Arctic users in May, and through a virtual on-line ACF in October.

Highlights

A strong persistent high-pressure system over the Arctic region between June and August 2019 contributed to the above normal surface air temperature observed in the region. Above normal temperatures and drier than average conditions are forecast for all Arctic regions between November 2019 and December 2020.

The summer 2019 (JJA: June, July, August 2019) average surface air temperatures were above normal for most of the Arctic domain, with Eastern Siberia experiencing its warmest JJA on record. Exceptions are north central Canada and the northwestern part of Russia, where average surface air temperatures were below normal. Above normal temperatures are expected to continue across the majority of the Arctic regions between November 2019 and January 2020.

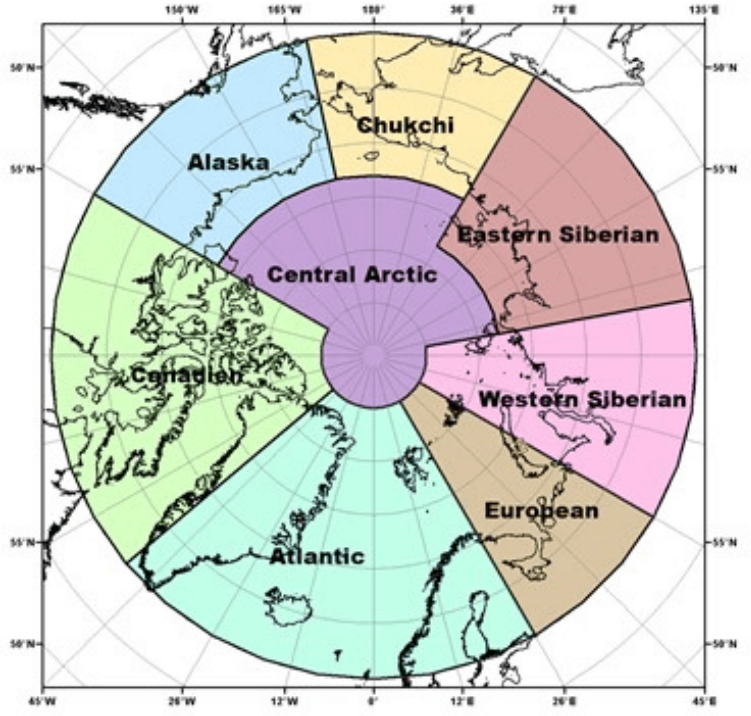


Figure 1: Regions used for the seasonal summary and outlook of temperature and precipitation.

Understanding the Consensus Statement

This consensus statement includes a seasonal summary and forecast verification for temperature for previous 2019 Arctic summer season. This statement also includes an outlook for the upcoming 2019-2020 Arctic winter season. Figure 1 shows the regions that capture the different geographic features and environmental factors influencing temperature.

The temperature forecast is based on thirteen WMO Global Producing Centers Long-Range Forecasts (GPC-LRFs) models. In terms of models' skill (i.e. the ability of the climate model to simulate seasonal climate), a multi-model ensemble (MME) approach essentially overlays all of the separate model performances. This provides a forecast with higher confidence in the regions where separate models agree (regions where models have same result), versus a low confidence forecast in the regions where the models don't agree. The multi-model ensemble approach is a methodology reputed as providing the most reliable objective forecasts.

Temperature Summary for Summer 2019:

The June, July and August (JJA) 2019 average surface air temperatures in the Arctic north of 65°N were above normal in most regions, with the exception of north central Canada and the northwestern part of Russia (Figure 2). Eastern Siberia saw their warmest JJA since the start of the record in 1936, while most of the Chukchi, Central Arctic, and Alaskan regions saw their second warmest JJA on record. Using data from NCEP/NCAR reanalysis to rank the average surface air temperature, the JJA period ranged from the top 10 warmest over parts of Alaska, Chukchi, the northern Canadian Arctic, and most of Eastern Siberia, to the 10th coldest in small areas of the western Canadian Arctic and northwestern Russia regions since the start of the record in 1949 (not shown).

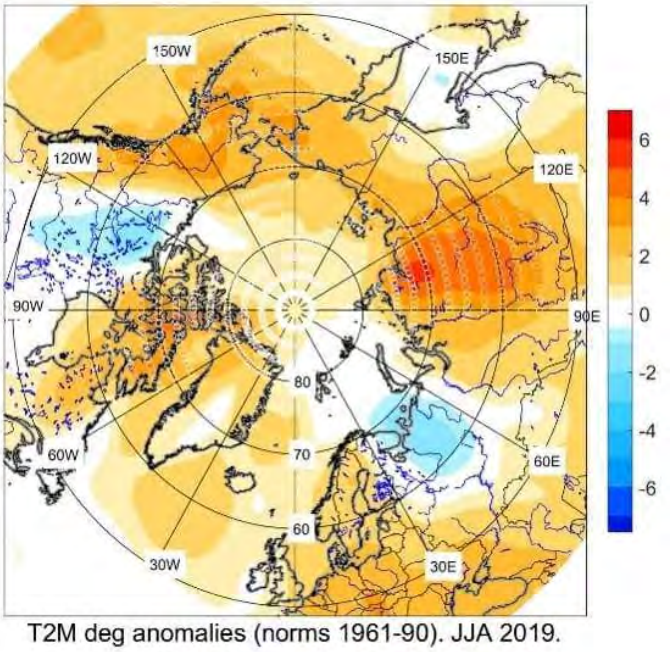


Figure 2: June, July and August (JJA) 2019 temperature anomaly relative to the 1961-1990 reference period. Red indicates warmer temperature and blue indicates cooler temperatures. Map produced by the Hydrometcenter of Russia https://meteoinfo.ru/. Data source: NCEP(NCAR Reanalysis https://www.esrl.noaa.gov/.

The Summer 2019 temperature forecast was verified by subjective comparison between the forecast (Figure 3, left) and re-analysis (Figure 3, right), region by region. A re-analysis is produced using dynamical and statistical techniques to fill gaps when meteorological observations are not available.

Above-normal surface air temperatures over western Alaskan, western Siberia, and the Chukchi region, were accurately forecast for the JJA 2019 season (Figure 3, Table 1). The above normal surface air temperature forecast for the northern Canadian region was also accurate. Over the Atlantic region, the forecast accuracies were variable but above-normal temperatures over the ocean for the region were accurately forecast. The observed below temperatures over eastern Alaska and the European region (blue areas in Figure 3, left) were not accurately forecast. Additional areas with an incorrect surface air temperature forecast included most of the Eastern Siberia, the southwestern parts of the Canadian Arctic, and eastern Alaska. As a general conclusion, the multi-model ensemble forecast was accurate for approximately 50-60% of the Arctic territory.

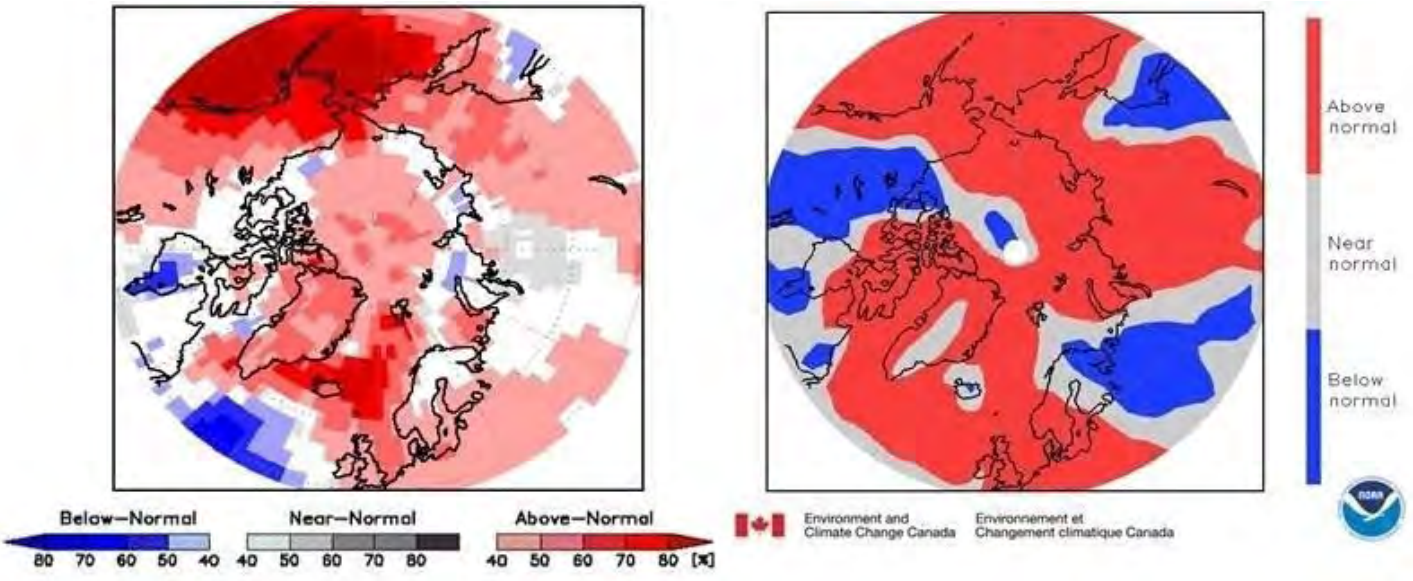


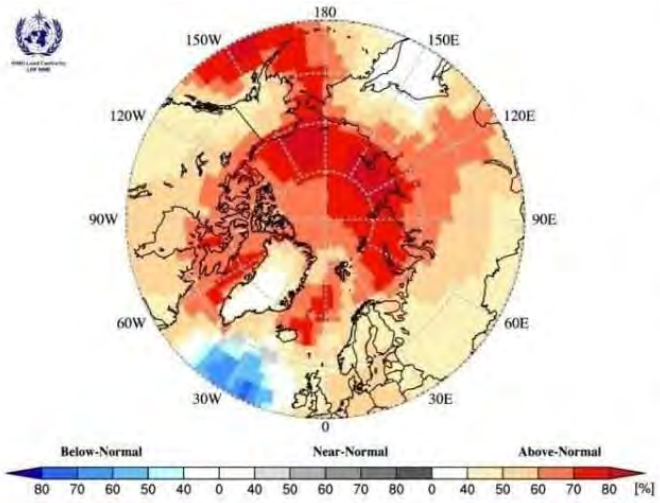
Figure 3: Left) Multi-model ensemble (MME) probability forecast for Surface Air Temperatures: June, July, and August 2019. Three categories:below normal (blue), near normal (grey), above normal (red); no agreement amongst the models is shown in white. Source: www.wmolc.org. Right): NCAR (National Center for Atmospheric Research) Climate forecast System Reanalysis (CFSR) for air temperature for June, July, and August 2019.

Regions (see Figure 1)	MME Temperature Forecast Agreement	MME Temperature Forecast	Observed Temperature	MME Temperature Forecast Accuracy
Alaska	High	Above normal	Above normal	High (west only)
Chukchi	High	Above normal	Above normal	High
Eastern Siberian	Moderate	Near normal	Above normal	Low
Western Siberian	Low	Above	Above normal	High
European	Low	Above to near normal	Below normal	Low
Atlantic	High	Above normal	Above normal	High
Canadian	Low	Above to near normal	Above to below normal	High (north only)
Central Arctic	Moderate	Above normal	Above normal	Moderate

Table 1: Summer 2019: Regional Comparison of Observed and Forecasted Arctic Temperature.
High=80%+, Moderate=50-70% and Low=<40%

Temperature Outlook for Winter 2019-2020:

Surface air temperatures during winter 2019-2020 (NDJ: November 2019, December 2019, January 2020) are forecast to be above normal across the majority of the Arctic regions (orange and red areas in Figure 4). The confidence of the forecast is moderate to low over most of the southern Arctic, especially over the southern continental Alaska, Canadian, European, Chukchi, Western and Eastern Siberian regions. (yellow and orange areas in Figure 4, Table 2). Forecast confidence increases with latitude from low/moderate to moderate/high for all regions (dark red areas in Figure 4, Table 2). The multi-model ensemble did not agree over southern Greenland (white areas in Figure 4).



Region (see Figure 1)	MME Temperature Forecast Agreement	MME Temperature Forecast
Alaska	Low and high	Above normal
Chukchi	Low to high	Above normal
Eastern Siberian	Moderate to high	Above normal
Western Siberian	Low to high	Above normal
European	Low to high	Above normal
Atlantic	Low to high	Above normal
Canadian	Low to high	Above normal
Central Arctic	Low to high	Above normal

Left) Figure 4: Multi model ensemble probability forecast for surface temperature for November 2019, December 2019 and January 2020. Three categories: below normal (blue), near normal (grey), above normal (red) and no agreement amongst the models (white). Source: www.wmolc.org
Right) Table 2: Winter (NDJ) 2019-2020 Outlook: Regional Forecasts for Arctic Temperatures

Report: ArcRCC Consensus Statement Part 1: Temperature

Background and Contributors

This Arctic seasonal climate outlook was prepared for ACF-4. Contents and graphics were prepared in partnership with the Russian, United States, Canadian, Norwegian, Danish, Finnish, Swedish, and Icelandic meteorological agencies and contributions of the Expert Team on Sea-ice, an expert team of the Joint WMO/IOC Technical Commission on Oceanography and Marine Meteorology, CCl/CBS Joint Expert Team on Regional Climate Centres, the Global Cryosphere Watch, the International Ice Charting Working Group, and with input from the Arctic Monitoring and Assessment Programme (AMAP).

The ArcRCC is in demonstration phase to seek designation as a WMO RCC-Network, and products are in development and are experimental. For more information, please visit **www.arctic-rcc.org**.

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***About Marko Markovic, Corresponding Author:**

Marko completed his PhD in atmospheric science at UQAM (2011) under the supervision of Dr. Hai Lin (RPN, Environment Canada). His PhD research encompasses seasonal forecasting and the research of low frequency atmospheric variability. After completing his doctoral degree Marko joined Consortium Ouranos as a postdoctoral fellow working on climate change related projects. Between 2012 and 2014, as a Consortium Ouranos employee, Marko has worked on the representation of the Arctic climate simulated by the latest generation of global climate models.

Marko joined ECCC in 2014 and his current work is focused on production and evaluation of seasonal forecasts, issued by Canadian Seasonal to Interannual Prediction system. Marko's office is in Canadian Meteorological Centre (CCMEP) located in Montreal/Dorval.

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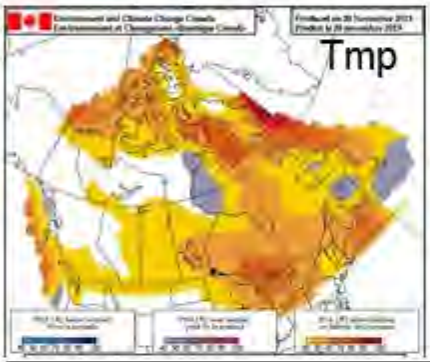
Canada

Seasonal Outlook for the winter 2019/2020 (DJF) based on the official CanSIPS forecast issued on the 30th Nov. 2019

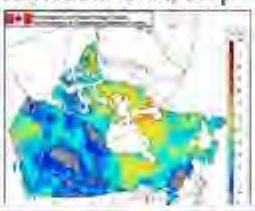
Marko Markovic , Bill Merryfield and Marielle Alarie

Temperature: Elevated probabilities for warmer than normal are expected across southern and eastern Canada. The highest probabilities for such a forecast are expected over the Great Lakes region (>70%), southern and Central Ontario (>60%), southern QC(>60%) and the Maritimes (50-60%). Central Canadian prairies and southern BC are expecting weaker probability for above normal winter of 40-50%.

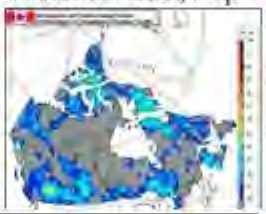
Modest chance of above normal precipitation over the southernmost Ontario and BC? There is a 40-50% probability for this outcome in southern and central continental BC. Above normal precip. is also most likely over northern AB, MB and northwestern QC (>40%). Below normal precipitation is likely at 40-50% over Labrador and eastern parts of the Maritimes. White areas on the map mean equal chances are expected for precipitation this winter.

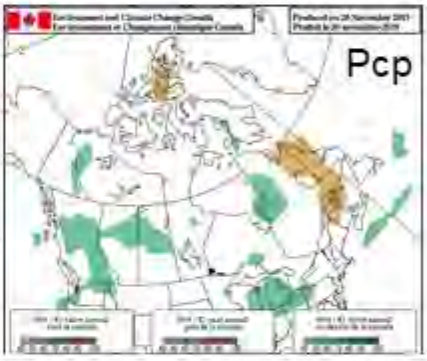


Historical Skill, Tmp



Historical Skill, Pcp





CanSIPS DJF19/20 forecasted Indices:
Nino3.4 = 0.35 (neutral conditions)
PDO = -0.15 (weak negative phase)

What will influence the next season? It is highly likely that a neutral ENSO will occur in the equatorial Pacific this winter. ECCC predicts this neutral condition to persist into the following spring. According to the longer lead seasonal forecast issued by International Research Institute (IRI), there is a probability of ~60% that a neutral ENSO will prevail this winter and of ~70% to continue in spring. **PDO** index is expected to remain weak this winter, with a very limited influence to the coastal areas. **PNA** index will remain positive for the first part of December after which the skill is low. Historically, positive PNA is related to below normal temperatures over NE Canada. Besides neutral ENSO conditions, currently there are no major low frequency anomalies that may influence Canadian winter. Positive SST anomalies observed in the north Pacific ocean, off the coast of BC, are likely caused by the atmospheric ridging in the region and can potentially bring some warm air in the coastal region as a consequence of downstream advection.

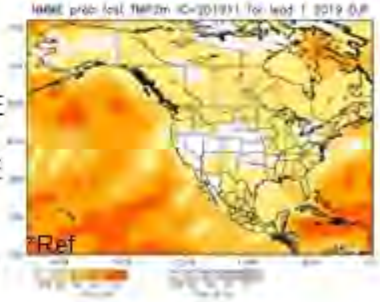
SON19 Obs. Categories

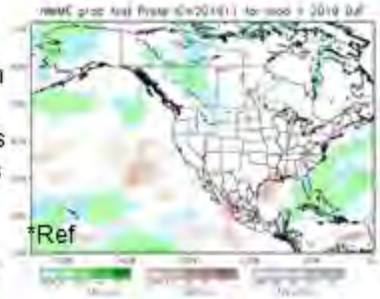
SON19 CanSIPS Catgs.

Verification SON19, Percent Correct, Temperature: 53%. The CanSIPS forecast did not predict the very cold weather in much of the southern Canada in the first part of November 2019.

Seasonal forecast by other centers: Temperature: There is a good agreement between NMME (longer lead forecast) and CanSIPS seasonal forecasts. According to the NMME (North American Multi Model Ensemble) (lead 1 month), probability of above normal temperatures (>40%) is expected over the entire North American continent. Regions with the highest probabilities are southern British Colombia and northern Quebec (>50%). The two systems also agree on the equal chance possibilities over northern Alberta.

Precipitation: There is an agreement between CanSIPS and a longer lead forecast from NMME (lower figure), over the BC and AB where NMME is forecasting this precipitation zone more to the east. There is also agreement over north-western QC where both systems forecast probabilities of 40% or more. Difference between the two systems is seen over the NFLD, Maritimes and over the Great Lakes region. NMME is forecasting equal precip. chances over these three regions.





*Ref: http://www.cpc.ncep.noaa.gov/products/NMME/

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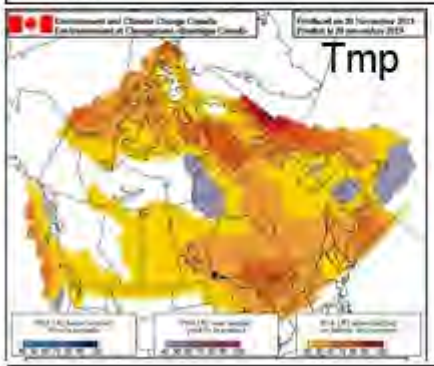
Prévision saisonnière pour l'hiver 2019-2020 (DJF) basée sur la prévision officielle de SPISCan, émise le 30 nov.2019

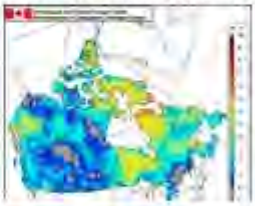
Marko Markovic , Bill Merryfield et Marielle Alarie

Températures: On s'attend à des probabilités au-dessus des normales dans le sud et l'est du Canada. Les probabilités les plus élevées pour ces conditions sont attendues dans la région des Grands Lacs (>60 %), la majorité de l'Ontario (>50 %), plusieurs régions du Québec (>50 %) à l'exception de l'est, et les Maritimes (50 à 60 %). Les Prairies canadienne et le sud de la C.-B. s'attendent à une faible probabilité d'un hiver au-dessus de la normale de > 40%.

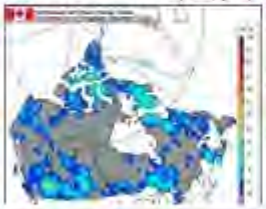
Faible probabilité de précipitations supérieures à la normale sur l'extrême sud de l'Ontario et de la C.-B. ?
La probabilité de ce scénario est de >40 % dans le sud et le centre de la C.-B. continentale et le sud de l'ON. Des précipitations supérieures à la normale sont aussi très probable sur le nord de l'AB, la SK et le nord-ouest du Québec (>40 %). Des précipitations sous la normale sont prévues du Labrador vers le secteur nord des Maritimes (40-50%). La zone blanche sur la carte signifie que des chances égales sont attendues pour les précipitations cet hiver.

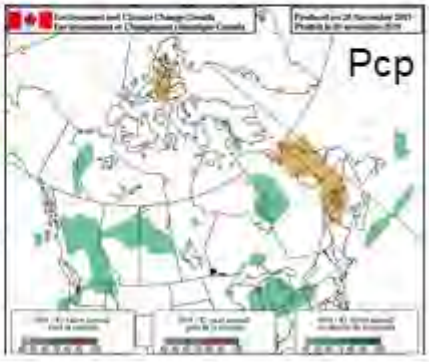


Habileté historique, tmp



Habileté historique, pcp





Indices climatiques prévus par SPISCan pour DJF 19/20
Nino3.4 = 0.35 (conditions neutres)
PDO = -0.15 (phase négative faible)

Qu'est-ce qui influencera notre saison? Il est fort probable qu'un ENSO neutre aura lieu dans le Pacifique équatorial cet hiver. ECCC prévoit que cet événement neutre persistera jusqu'au printemps suivant. Selon les prévisions saisonnières à plus long terme publiées par l'Institut international de recherche (IRI), il y a une probabilité d'environ 60 % qu'une ENSO neutre prévaudra cet hiver et d'environ 70 % pour le printemps. L'indice **ODP (PDO)** devrait rester faible cet hiver, avec une influence très limitée sur les zones côtières. L'indice **PNA** restera positif pendant la première partie du mois de décembre, après quoi, l'habileté a le prévoir sera faible. Historiquement, un indice **PNA** positif est lié à des températures inférieures à la normale dans le nord-est du Canada. Outre les conditions neutres de l'ENSO, il n'y a actuellement aucune anomalie majeure qui pourrait influencer l'hiver canadien. Les anomalies positives de la TSM observées dans l'océan Pacifique Nord, au large de la côte de la Colombie-Britannique, sont probablement causées par la formation de crêtes atmosphériques dans la région et peuvent potentiellement apporter de l'air chaud dans la région côtière à la suite de son advection en aval.

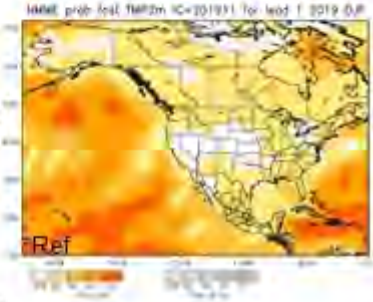
SON19 Catégories observées

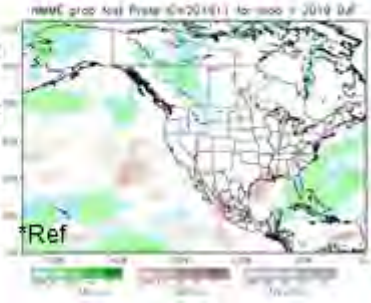
SON19 Catgs. prévues CanSIPS

Vérification SON19; poucentage correct pour tmp : 53%.
Les prévisions de SPISCan n'ont pas anticipé le temps très froid observé dans une grande partie du sud du Canada au cours de la première partie de novembre 2019.

Prévisions saisonnières des autres centres.
Températures:
Bonne similarité entre les prévisions NMME (émises au début du mois de nov.) et les prévisions saisonnières de SPISCan. Selon le NMME (North American Multi Model Ensemble), la possibilité d'observer des températures supérieures à la normale (>40%) est prévu sur tout le continent nord-américain. Les régions ayant les probabilités les plus élevées sont le sud de la Colombie-Britannique et le nord du Québec. (>50%). Les deux systèmes de prévisions s'entendent également sur les possibilités d'égalité des chances dans le nord de l'Alberta.

Précipitations:
Il y a un accord entre SPISCan et la prévision émise au début du mois de nov. par le NMME (image inférieure) pour la C.-B. et l'AB; cependant le NMME prévoit cette zone de précipitations légèrement plus à l'est. On s'entend également sur le nord-ouest du Québec, où les deux systèmes prévoient des probabilités près de 40 % ou plus. La différence entre les deux systèmes s'observe au Labrador, sur l'est du QC, les Maritimes et dans la région des Grands Lacs; le NMME prévoit des chances égales de précipitations sur ces régions.





*Ref: http://www.cpc.ncep.noaa.gov/products/NMME/

Searching towards creating a sustainable integrated mesonet for the Canadian Prairie Provinces

By Jeannine-Marie St-Jacques[1], Aston Chipanshi[2], Trevor Hadwen[2], Allan Friesen[1], and David Sauchyn[3]

[1]Geography, Planning and Environment, Concordia University, Montréal, Québec; [2]Agricultural and Agri-Food Canada, Regina, Saskatchewan; [3]Prairie Adaptation Research Collaborative, University of Regina, Regina, Saskatchewan

Due to the continental nature of the Canadian Prairie Provinces, their weather and climate are characterized by extremes. With this reality, the Prairie Provinces should benefit from high resolution weather monitoring from an integrated weather mesonet. A mesonet consists of any number of automated weather stations with an average spacing of 1 to 50 kilometers. This station spacing is much denser than that of the Environment and Climate Change Canada weather stations and can therefore capture local weather conditions in a much more detailed fashion. There have been efforts by Agriculture and Agri-Food Canada (AAFC) to use all the available weather data from the Canadian Prairie Provinces to form an integrated mesonet from federal, provincial and private weather networks. Due to large weather station gaps across Canada, the National Agroclimate Information Service (NAIS) has made special arrangements with various weather providers, including private ones, over the years to use their data to produce occasional value-added weather products for Canada's agricultural regions. However, there has been little momentum to legally formalize data sharing agreements to create a permanent integrated mesonet that can guarantee a continuous, regular availability of weather data to various stakeholders. Our study's ultimate goal is to show the potential benefits of including multiple weather networks in a Prairie

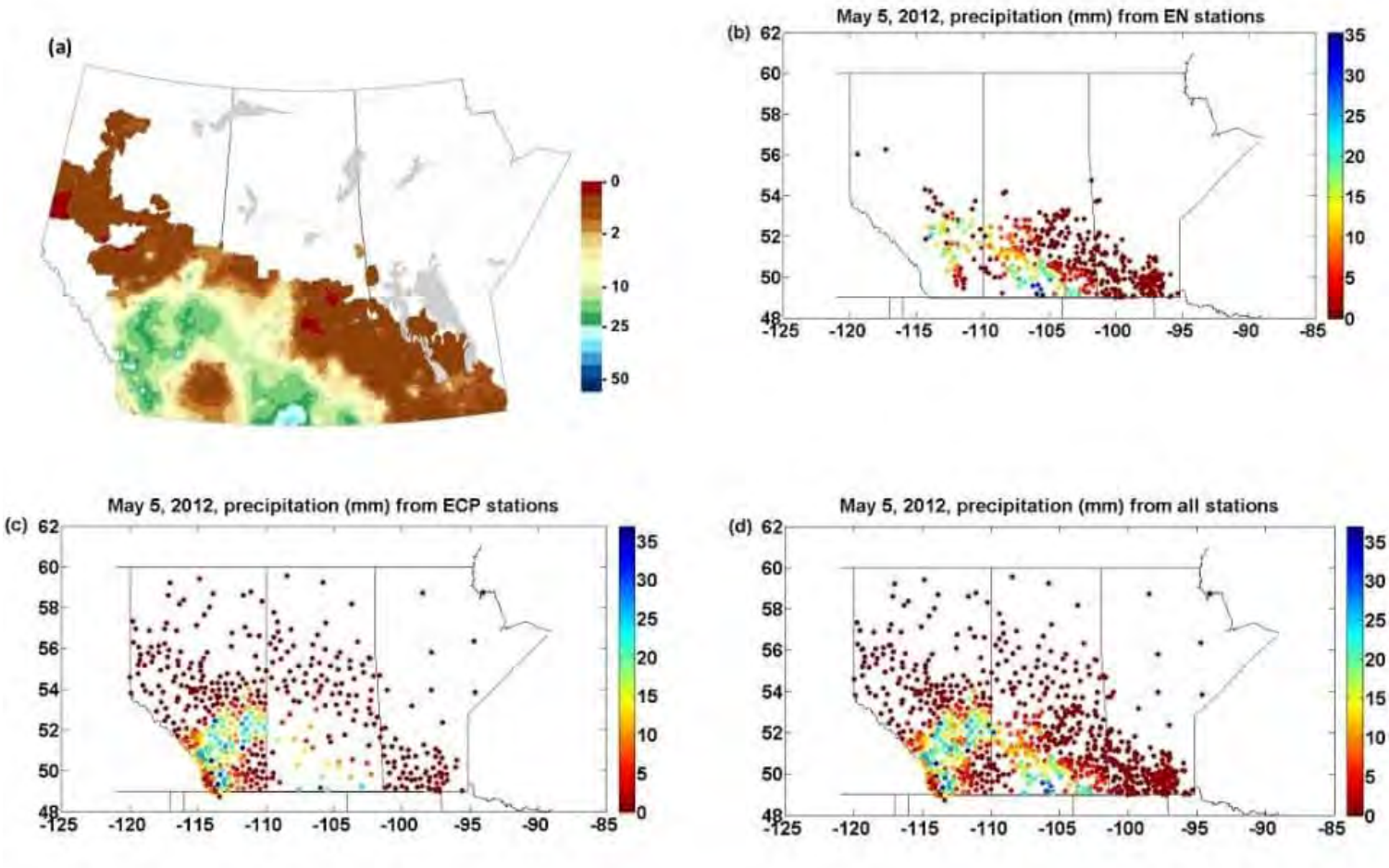


Fig. 1. Map of precipitation (mm) from the storm of May 5, 2012, (a) provided by Agriculture and Agri-Food Canada's National Agroclimate Information Service (NAIS) as an occasional value-added product using all available weather data, (b) from all 798 Earth Networks (EN) stations located on the Prairies, (c) from all 668 Environment and Climate Change Canada and provincial (ECP) stations located on the Prairies, and (d) from all Prairie EN and ECP stations combined as they would be in an integrated mesonet.

Article: Sustainable Integrated Mesonet for Prairies

Provinces integrated mesonet to improve data coverage, since any one network may not be enough to support the sensitive economic sectors found here. We propose that such a comprehensive mesonet can provide more detailed weather information at finer space and time scales and reduce the cost of data collection and distribution for any one governmental agency.

We met this goal by assessing how temperature and precipitation are captured temporally and spatially on the Canadian Prairies by the weather stations of a private provider network, Earth Networks (EN), relative to stations operated by federal and provincial governments. Specifically, we examined how weather events during the 2012 growing season were captured by the high-resolution, non-World Meteorological Organization (WMO) standard EN network, relative to the WMO standard weather stations operated by federal and provincial governments. In particular, we tested how storm events from the study area were captured by each weather network. We found that there was a large amount of missing EN data. There was a significant pattern of the EN stations having higher hourly temperature values later in the day and higher daily minimum temperatures than their nearest neighboring governmental stations did. There also was a significant pattern of the EN stations having less daily and hourly precipitation than their nearest neighboring governmental stations did. This is possibly due to the non-WMO siting of some of the EN stations. However, overall, the EN stations and the various governmental stations were complimentary, often with one network being denser where the other one was sparse and vice-versa; thereby giving a more spatially detailed picture of five storms of the 2012 growing season (Fig. 1). Hence, we show the benefits of including this high-resolution EN weather data, together with government station data, in a permanent, formally established integrated mesonet for the Canadian Prairies, with a much higher spatial and temporal resolution than the individual contributing networks.

LINK TO THE FULL ARTICLE RECENTLY PUBLISHED IN ATMOSPHERE-OCEAN

About the Author

Dr. Jeannine-Marie St-Jacques has been an assistant professor in the Geography, Planning and Environment Department of Concordia University in Montreal, Quebec, since 2013.

Prior to this, she spent nine years at the Prairie Adaptation Research Collaborative at the University of Regina, Saskatchewan as a post-doctoral fellow and research associate. Her research interests are climatology, hydrology, paleoclimatology, paleo-environmental reconstructions, tree-ring studies and climate modelling.

Register for CatIQ's Catastrophe Conference

Start the year off well by joining experts in your industry and other sectors in Toronto for Canada's premier catastrophe conference! CatIQ's highly anticipated 5th annual Canadian Catastrophe Conference is taking place February 3-5, 2020 at the Metro Toronto Convention Centre.

The conference workshop, hosted by the Canadian Red Cross, will contribute to their report on the role of a national flood insurance program in assisting individuals and small businesses affected by disasters.

Get an overview of insights in the insurance, DFA and construction industries, as well as case studies and pain points AND provide your own feedback on the catastrophic recovery ecosystem. The feedback and recommendations from the workshop will be cited in the Canadian Red Cross' report.

For more details, please visit **https://connect.catiq.com**

CMOS SCMO

54th CONGRESS
54e CONGRÈS

Canadian Meteorological and Oceanographic Society (CMOS) Annual Congress

Congrès annuel de la Société canadienne de météorologie et d'océanographie (SCMO)

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cmos.ca / scmo.ca

In case you missed it...

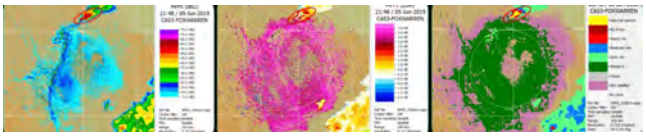
From CMOS Bulletin Volume 47, Number 5:

Message from the CMOS President: Communication, Partnership and Change

Comparison of Wind Forecasts and Observations at Lake St. Charles, Quebec: Results from 2018
by Richard Leduc

Radar Events Initiative
by Phil Chadwick

Revitalization of UQAM Atmospheric Science Undergraduate Programme
by René Laprise and Julie Mireille Theriault



Replacement of the Canadian Weather Radar Network
by Sylvain Laramée and Qian Li

Book Review: The Weather Machine: A Journey Inside the Forecast
Book by Andrew Blum, Review by Bob Jones

Book Review: Burning Souls
Book by David Chernushenko, Review by Frank Johnson

Members Updates
Meeting Notifications, Books for Review, and more

These articles, and more, in the online CMOS BULLETIN.

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http://bulletin.scmo.ca (français)

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Canadian Meteorological and Oceanographic Society
La Société Canadienne de Météorologie et d'Océanographie

CMOS BULLETIN
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After 45 years in print, the Bulletin of the Canadian Meteorological and Oceanographic Society (CMOS) has gone virtual. See bulletin.cmos.ca for articles, news, events and updates from Canada's top meteorologists, climatologists and oceanographers.

Après 45 années de publication papier, le Bulletin de la Société canadienne de météorologie et d'océanographie (SCMO) passe en mode virtuel. Consultez le site bulletin.scmo.ca pour lire des articles, des nouvelles, des annonces d'événements et des faits nouveaux que partagent les éminents météorologues, climatologues et océanographes du Canada.

http://bulletin.cmos.ca
http://bulletin.scmo.ca

CMOS congratulates Robie Macdonald and Eddy Carmack, recent Order of Canada recipients

Created in 1967, the Order of Canada honours people whose "service shapes our society, whose innovations ignite our imaginations, and whose compassion unites our communities."

Amongst the 120 recipients are CMOS members Robie Macdonald and Eddy Carmack, who played a strong and active role in CMOS in the past. Robie was appointed Officer of the Order for having identified the effects contaminants have on northern marine ecosystems and on nearby Indigenous communities. Eddy was also appointed Officer of the Order for his contributions to climate oceanography and for expanding our understanding of the Arctic Ocean and its role as an exemplar for climate change.

Robie Macdonald, pictured at the 47th CMOS Congress in Saskatoon, May of 2013

We also offer our congratulations to all of the other recipients, amongst whom were several other significant figures in Canadian earth, atmosphere and ocean science.

For a full list of award recipients visit https://www.cbc.ca/news/politics/order-of-canada-full-list-2019-1.5409612

Congratulations to Dr Xiaolan Wang, Recipient of the 2019 PIPSC Gold Medal Award

(L to R): Nancy Hamzawi ADM Science and Technology, ECCC; Dr. Xiaolan Wang; Debi Daviau PIPSC (presenter)

Since 1937, the Professional Institute of the Public Service of Canada (PIPSC) has awarded a Gold Medal every year to a professional public service employee who has made a significant contribution in a field of pure or applied science, and whose outstanding work has led to the improvement and enhancement of public well-being.

This year's recipient of the Gold Medal Award is Dr. Xiaolan Wang, a senior Research Scientist in the Atmospheric Science & Technology Directorate. Dr. Wang received her award on November 8 at the PIPSC Annual General Meeting. Dr. Wang is an internationally regarded climate scientist with expertise in the development of methods for creating multidecadal to centurial climate data records and on the quantitative characterization of historical and future climate. Dr. Wang's research on data homogenization has led to the development and release of multiple derived historical Canadian climate datasets, which are essential for studying and monitoring changes in the Canadian climate. Her statistical methods and associated software have changed the approach to assessing climate trends and variability used by scientists worldwide. Her studies on extreme wave heights have enabled the assessment of the potential impact of climate change on coastal/offshore design and operations.

Dr. Wang has also substantially influenced the planning and execution of research in her division and has managed collaborative research with a wide range of scientists from Canadian and international institutions. She has and continues to co-lead several international projects and committees under the auspices of the World Climate Research Programme, the World Meteorological Organization's Commission for Climatology, and the Joint Technical Commission for Oceanography and Marine Meteorology. Since 2017, Dr Wang has served as the president of the PIPSC Research (RE) Downsview Sub-Group and became a PIPSC steward in 2018.

CMOS News

CMOS Membership Renewal Time!

Every year at this time, we send you reminders to renew your membership. Please help the Society save money on postage and renew online. Outstanding invoices will be mailed out if required.

I trust you will continue to be part of the CMOS community. Take the time to renew online at **http://www.cmos.ca/**. When doing so please consider making a voluntary donation to one of the CMOS funds – your generosity will greatly enrich our CMOS activities. In addition, please continue to use our web-site as a useful resource of our events, publications, news and announcements.

Thank you for being a member of our Canadian Meteorological and Oceanographic Society. I hope to see you at our 2020 Congress in Ottawa, ON. I speak on behalf of our Society to thank you and express my appreciation of your active participation in our community!

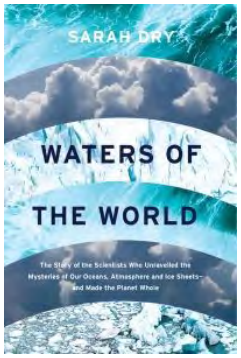
Renouveler votre adhesion!

Chaque année, à cette époque, nous vous invitons à renouveler votre adhésion. S'il vous plaît, aidez la Société à économiser sur les frais des timbres et à renouveler en ligne. Les factures en suspens seront expédiées si nécessaire.

J'espère que vous continuerez à faire partie de la communauté de la SCMO. Prenez le temps de renouveler votre adhésion en ligne à : http://www.scmo.ca/. Merci de considérer de faire un don à l'un des fonds de la SCMO — votre générosité enrichira considérablement les activités de la SCMO. De plus, merci de continuer à utiliser notre site Web en tant que ressource utile pour en savoir plus sur nos événements, publications, nouvelles et annonces.

Merci d'être membre de la Société canadienne de météorologie et d'océanographie. J'espère vous voir à notre congrès de 2020 à Ottawa. Au nom de notre société, je vous remercie de votre participation active au sein de notre communauté !

NEW Books Available for Review



Winds, Waves and Warriors: Battling the Surf at Normandy, Tarawa, Inchon, 2019. By Thomas M. Mitchell, Lousiana State University Press. ISBN 978-0-8-71-7223-0 (Cloth), 168 pages, $39.95 USD (2020-1)

Waters of the World: The Story of the Scientists Who Unraveled the Mysteries of Our Oceans, Atmosphere, and Ice Sheets and Made the Planet Whole, 2019. By Sarah Dry, University of Chicago Press. ISBN 978-0-226-50770-5 (Cloth), 368 pages, $30.00 USD (2019-4)

Other recent titles still available for review by a CMOS member:

- **An Introduction to Tides**, 2019. By Theo Gerkema, Cambridge University Press, ISBN 978-1-108-46405-5 (Paperback), 211 pages, $51.95 USD (2019-3)
- **A Bright Future: How Some Countries Have Solved Climate Change and the Rest Can Follow**, 2019. By Joshua S. Goldstein and Staffan A. Qvist, Hachette Book Group, ISBNs 978-I-5417-241O-5 (hardcover), 978-1-5417-2409-9 (e-book), 288 pages, $34.00. (2018-9)
- **Tropical Extremes: Natural Variabilities and Trends**, 2019. Edited by V. Venugopal, Jai Sukhatme, Raghu Murtugudde, Remy Roca, Elsevier Inc. ISBN 978-0-12.809248-4, 333 pages, US$110 (2018-11)
- **World Seas, An Environmental Evaluation. VOLUME III: Ecological Issues and Environmental Impacts**, Second Edition, 2019. Edited by Charles Sheppard, Elsevier Inc. ISBN 978-0-12-805052-1, 633 pages, US$250. (2018-12)
- **Rainbows: Nature and Culture**, 2018. By Daniel MacCannell, The University of Chicago Press and Reaktion Books Ltd, ISBN 9781780239200, 208 pages, US$24.95 (2018-4)
- **The Deep Pull: A Major Advance in the Science of Ocean Tides**, 2018. By Walter Hayduk, FriesenPress, ISBN 9781525518706 (hardcover) $35.49, 9781525518713 (softcover) $27.49, 9781525517820 (eBook) $11.99, 251 pages. (2018-7)

Never reviewed a book before? No problem! Check out some of these past reviews for ideas: Ice: Nature and Culture; Weather in the Courtroom; Convenient Mistruths: A Novel of Intrigue, Danger and Global Warming; Weather, A Very Short Introduction; Nonlinear and Stochastic Climate Dynamics.

If you a review a book it is yours to keep! Contact the Editor to get involved.

54th Annual CMOS Congress – Abstract submissions are now open!

The Canadian Meteorological and Oceanographic Society (CMOS) will host its 54th Congress from May 24-28, 2020 at the Delta Hotel by Marriott Ottawa City Centre, Ottawa, Ontario, Canada. More detailed information will be posted as it becomes available on the Congress website at **http://congress.cmos.ca**.

The theme of the congress is Building Societal Resilience to Changing Weather, Climate, Oceans and Environment. For more information go to **http://congress.cmos.ca**.

Please submit abstracts electronically via the link: **https://congress.cmos.ca/site/abstract/call_for_abstract** before February 14, 2020. You will be asked to select a specific Session if possible. If you cannot find a relevant session please choose a "General" session and your paper will be assigned to a session later. Please indicate your preference for oral or poster presentation.

A non-refundable fee of $70.00 is required to complete your submission. Your abstract will be evaluated by the Science Program Committee and you will be notified by the end of March 2020 of the presentation details, including if your presentation is to be oral or by poster.

Student CMOS members are encouraged to participate and to apply for a Student Travel Awards. When submitting an abstract a student can apply for a Student Travel Award (maximum to $500) at the time of abstract submission by completing the online form. Please note that only abstracts submitted by the submission deadline of February 14, 2020, will be considered for the award.

Note that an abstract submission does not constitute congress registration. Registration will be open in early 2020.

Sincerely,
Gordon McBean and Leonard Barrie, Scientific Program Committee Co-Chairs
Bruce Angle, Local Arrangements Committee Chair

Le 54e Congrès de la SCMO – La soumission de résumés est maintenant ouverte!

Le 54e Congrès de la Société canadienne de météorologie et d'océanographie (SCMO) aura lieu du 24 au 28 mai 2020, à l'hôtel Marriot Delta Centre Ville Ottawa (Ontario), Canada. Dès que disponibles, de plus amples renseignements paraîtront sur le site Web de la SCMO à l'adresse https://congress.cmos.ca/index.html?language=fr_FR.

Le thème général de ce congrès est: « Bâtir une résilience sociétale face à l'évolution du temps, du climat, des océans et de l'environnement »

Veuillez soumettre vos résumés électroniquement via le lien https://congress.cmos.ca/site/abstract/call_for_abstract avant le 14 février 2020. Vous devrez sélectionner la séance qui correspond le mieux à votre communication (veuillez voir Descriptions des séances). Si aucune séance ne semble correspondre, sélectionnez une des séances «générale» et votre communication sera assignée ultérieurement à une séance pertinente. Indiquez aussi votre préférence pour une présentation orale ou par affiche.

Des frais de soumission non remboursables de 70$ sont exigés. Le comité du programme scientifique évaluera votre résumé. Vous recevrez une réponse d'ici la fin mars 2020 concernant les modalités de présentation, y compris le type de présentation assigné (oral ou par affiche).

Nous encourageons les membres étudiants de la SCMO à participer, et à solliciter une subvention de voyage. Lorsqu'un étudiant soumet un résumé, il peut demander une subvention de voyage (maximum de 500 $), au moment de la soumission du résumé, en remplissant le formulaire en ligne. Seuls les résumés soumis avant la date limite du 14 février 2020 seront évalués quant à la subvention.

Notez qu'une soumission de résumé ne constitue pas une inscription au congrès, qui elle sera offerte au début de 2020.

Sincèrement,
Gordon McBean et Leonard Barrie, Co-Présidents du Comité du programme scientifique
Bruce Angle, Président du Comité des arrangements locaux

CMOS INVITES:

2020 Fellows Nominations

March 15th is the deadline to recognize your colleagues by nominating one or more of them to be a CMOS Fellow or CMOS Honorary Fellow. It may seem far away, but it always arrives faster than we expected.

The titles "CMOS Fellow" and "Honorary CMOS Fellow" may be granted for exceptional long term service and support to the Society and/or outstanding contributions to the scientific, professional, educational, forecasting or broadcasting fields in atmospheric or ocean sciences in Canada.

Nominations can originate from non-members of the Society, as long as at least one Sponsor is a Member. Please take a moment to visit **http://www.cmos.ca/site/fellows** for information about these designations and instructions on how to submit a nomination. Don't wait – do it now!

Any inquiries and all nominations are to be forwarded to the CMOS Awards Coordinator (Denis Bourque) at **awards-coord@cmos.ca** .

Photo shows 2019 CMOS Fellow Richard Boudreault on left, being presented with his certificate by then CMOS president Paul Kushner

CMOS Scholarships Applications

CMOS offers undergraduate and graduate scholarships to students in atmospheric sciences, meteorology, climate, oceanography and related fields (e.g., mathematics, hydrology, limnology).

The undergraduate scholarships offer $1,000 and $1,500. The graduate scholarship is $5,000 (with an option for a 2nd year).

Information about these scholarships and how to apply can be found at **http://www.cmos.ca/site/scholarships**. You do not have to be a member of the Society to receive a scholarship.

The application deadline for the undergraduate scholarships is March 15th. The application deadline for the graduate scholarship is April 20th.

CMOS Award Nominations

CMOS AWARDS Nominations Deadline: Feb 15.

February 15th is the deadline for nominations for the CMOS Prizes and Awards.

Please take a moment to visit **http://www.cmos.ca/site/awards** for a list of the eight awards, for instructions on how to make a nomination and then submit something on behalf of one of your colleagues or students.

CMOS has a rich history recognizing deserving persons (members and non-members) through its awards programs. But regrettably, there are many deserving candidates who go unrewarded each year because we were too busy to work up a nomination. Don't wait – do it now!

Note that any inquiries and all nominations are to be forwarded to the CMOS Awards Coordinator (Denis Bourque) at awards-coord@cmos.ca.

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ROUTLEDGE

Edited by
GUOQI HAN, HAI LIN and DOUW STEYN

Council / Conseil d'administration

CMOS Bulletin SCMO at bulletin.cmos.ca

This publication is produced under the authority of the Canadian Meteorological and Oceanographic Society. Except where explicitly stated, opinions expressed in this publication are those of the authors and are not necessarily endorsed by the Society.

CMOS Bulletin SCMO at bulletin.scmo.ca

Cette publication est produite sous la responsabilité de la Société canadienne de météorologie et d'océanographie. À moins d'avis contraire, les opinions exprimées sont celles des auteurs et ne reflètent pas nécessairement celles de la Société.

Thank you to Bob Jones for his continued editorial assistance and guidance.

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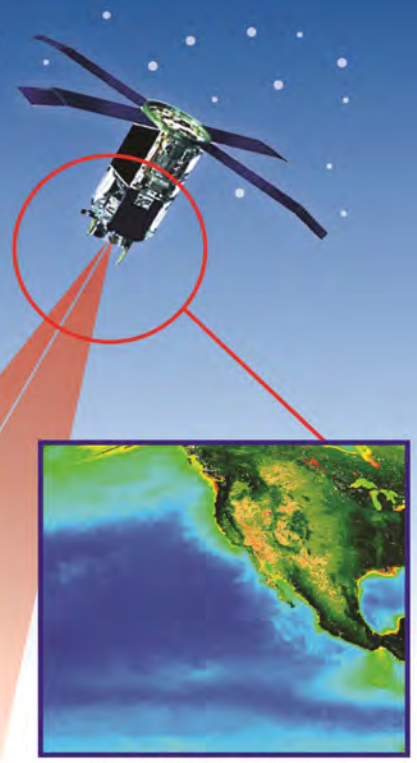
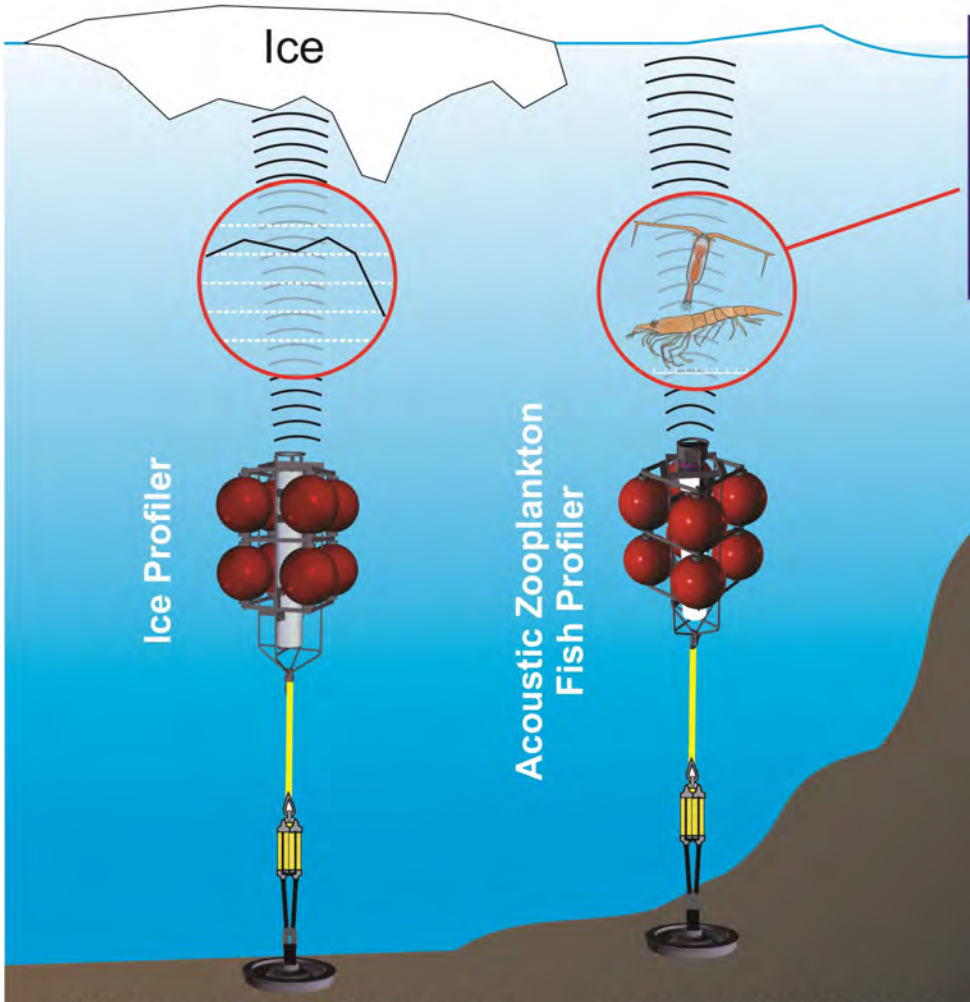
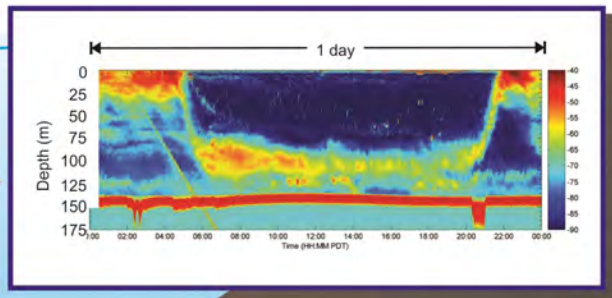


Ocean colours are chlorophyll concentrations and land colours are NDVI





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