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La Société canadienne de météorologie et d'océanographie

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Photo: aAron munson. Story inside, page 7.

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"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.

Words from the President / Mot du président

Advocating for Science

In my previous messages as CMOS President I have spent quite a lot of time promoting the strong advocacy role that CMOS can and should play in the development and implementation of public science and technology policy, as well as the development of new business ventures related to weather, oceans, atmosphere and climate. I would like to give a shout out to our Vice President, Paul Kushner, for his advocacy effort with many colleagues and Evidence for Democracy (E4D), regarding federal climate science funding. A letter signed by 250 scientists around the world has generated awareness of the funding situation for climate science. Articles have appeared in Le Devoir, the Globe & Mail and internationally, in the Guardian. The Globe and Mail has also weighed in with a main page editorial (https://www.theglobeandmail.com/opinion/editorials/globe-editorial-science-loving-government-cuts-funding-for-science/article37711890/).

I was fortunate to meet Dr. Mona Nemer, Canada's new Chief Science Advisor, who spent an hour with the Partnership Group for Science and Engineering (PAGSE) in late January. I knew our last Chief Science Advisor, Dr. Arthur Carty, and worked with him and his staff during their short-lived tenure. I would like to take this opportunity on behalf of CMOS to congratulate Dr. Nemer on her appointment and to wish her great success as she provides advice to the PM and federal departments, and develops her "role" and "voice" for science and technology in Canada. As I have noted in past messages, there is a dearth of S&T capacity across the senior management cadre of the federal government, and little to no effort has been made by either the Government or the Privy Council Clerk to ensure S&T funding and expertise is nurtured and wisely managed. I believe that Dr. Nemer has a monumental task ahead.

I have had very positive feedback from many of you regarding our efforts with the all-electronic CMOS Bulletin. Thank you for your support. Keep up your excellent contributions and let's keep promoting the great work of CMOS members.

Wayne Richardson, P.Eng.
CMOS President

Un plaidoyer pour la science

En tant que président de la SCMO, j'ai pris le temps, dans mes messages précédents, de promouvoir le rôle important que notre organisation peut jouer dans l'élaboration et la mise en œuvre de politiques publiques en matière de sciences et de technologie, ainsi que dans le développement de nouvelles entreprises commerciales liées à la météorologie, aux océans, à l'atmosphère et au climat. J'aimerais souligner le travail de sensibilisation qu'a accompli notre vice-président, Paul Kushner, auprès de nombreux collègues et d'Évidence pour la démocratie concernant le financement fédéral de la science du climat. Une lettre qu'ont signée 250 scientifiques du monde entier a fait prendre conscience de la précarité du financement de cette discipline. Des articles ont paru dans *Le Devoir*, *The Globe & Mail* et, à l'étranger, dans *The Guardian*. *The Globe & Mail* a également publié cet éditorial : https://www.theglobeandmail.com/opinion/editorials/globe-editorial-science-loving-government-cuts-funding-for-science/article37711890/.

J'ai eu la chance de rencontrer la nouvelle conseillère scientifique en chef du Canada, madame Mona Nemer, qui a passé une heure avec des membres du Partenariat en faveur des sciences et de la technologie (PFST), à la fin de janvier. Je connaissais son prédécesseur, monsieur Arthur Carty, pour avoir travaillé avec lui et son équipe pendant leur court mandat. Au nom de la SCMO, je profite de cette occasion pour féliciter madame Nemer pour sa nomination. Je lui souhaite beaucoup de succès en tant que conseillère du premier ministre et des ministères fédéraux. Et puisse-t-elle développer son « rôle » et sa « voix », afin de soutenir les sciences et la technologie au Canada. Comme le mentionnent certains de mes messages précédents, les compétences en science et technologie restent lacunaires dans l'ensemble de la haute direction du gouvernement fédéral. Le gouvernement ou le greffier du Conseil privé n'ont déployé que peu d'efforts, et encore, pour garantir que le financement et l'expertise en S et T soient judicieusement soutenus et gérés. J'entrevois pour madame Nemer une tâche colossale à accomplir.

Plusieurs d'entre vous m'ont transmis des commentaires très positifs concernant le bulletin électronique de la SCMO. Je vous remercie de votre soutien. Continuez à nous envoyer vos excellentes contributions et ainsi à promouvoir l'excellent travail des membres de la SCMO.

Wayne Richardson, ing.
Président de la SCMO

Climate Clock: Running out of Time?

By Samantha Mailhot, Human Impact Lab, Concordia University, Montreal

Snapshot of the Climate Clock (climateclock.net) taken at 11:52 (EST) on January 16th, 2018.

Samantha Mailhot pictured with the Climate Clock at Formula E in Montreal, in July 2017. Formula E is a race series for electric cars. The Human Impact Lab had a booth at the event where they showcased the Climate Clock.

Time is something we all understand. As each of us go about our daily lives, worrying about more immediate and personal issues, climate change is progressing at an accelerating rate. While many areas around the world have begun to feel the effects of climate change via extreme weather events, floods or wildfires, the majority of the global population has likely not seen any major effects of climate change on our day-to-day lives. This incomplete perception of risk is compounded by low awareness and understanding of the potential consequences of climate change, and is exacerbated further by the outright denial of the problem as currently demonstrated potently (though not exclusively) in US politics. The result is that we have not yet fully embraced the need for immediate and stringent action to decrease greenhouse gas emissions and eliminate our dependence on fossil fuel energy.

The Climate Clock was developed by the Human Impact Lab in collaboration with Concordia University in Montreal to bring the climate challenge out of the abstract sphere of science and politics, and into the public consciousness. Framing the problem in units of time, makes it something that we can intuitively understand; the clock acts as a line in the sand that we can identify with, and that can track our progress towards meeting the goals of climate mitigation.

Given current global and national ambition to limit global warming to no more than 1.5 to 2°C above pre-industrial averages, the Climate Clock shows our best estimate of when global temperature will reach 1.5 and 2 °C above these temperatures, assuming global CO_2 emissions continue to increase following the observed trend of the past five years. The clock shows three numbers: (1) “Tonnes of CO_2 emitted”, which represents the total accumulated CO_2 emissions from fossil fuel burning, cement manufacture and land-use change since 1870; (2) “Global warming to date”, which represents the human contribution to global temperature increases since 1861-1880, based on a recently-developed Global Warming Index that estimates the portion of observed temperature change that can be attributed to all human drivers of climate change; and (3) “Time left to 2 °C”, which is based on extrapolating the most recent 5-year trend of global CO_2 emissions (which increased by 0.56% per year during 2012-2017)

until we reach the total allowable emissions of 3500 billion tonnes of CO_2 emissions; and (4) “Time left to 1.5 ° C”, which identifies the time that 1.5°C is crossed on the trajectory towards the 2°C climate threshold. As of December 2017, we have 15 years remaining until we reach 1.5°C of global temperature increase, and 27 years remaining to 2°C. With each year’s new emissions data, we will update the clock, allowing us to evaluate our progress or lack of progress in efforts to curtail climate change.

In 2017, I carried out an undergraduate research project, entitled Running out of time: Using a climate clock to communicate the urgency of climate change. I was concerned with the general lack of concern about climate change that I have perceived in the people around me. My research project aimed to bridge science and community knowledge in order to understand: (1) how aware people are on the subject of climate change and why they are not more concerned about it; (2) to what extent people engage in environmentally-friendly behaviours and what barriers are the most important in preventing climate action; and (3) how effective the climate clock is as a tool for communicating the urgency of climate change to a broad range of people. My research found that some of the barriers to sufficient concern for climate change among respondents were inadequate climate communication, a perceived consensus gap among scientists, confusion about the severity of climate change and its anthropogenic causes, and most importantly, a lack of understanding of what they can do in their own lives to mitigate climate change. The majority of my respondents reacted very strongly when shown the Climate Clock, revealing emotional responses that included fear, shock, anger and sadness; yet they did not know how to do their part for climate action. Many felt lost.

The Climate Clock is therefore an extremely powerful communication tool, providing a visceral view of the progression of time towards the climate targets that we are trying to avoid crossing. The clock shows us the urgency of climate action, but it is up to us to find ways to implement the action that is needed. We need to educate ourselves on what we can do personally, as well as on how we can use our own personal and professional spheres of influence to motivate change in those around us. Every single human being on Earth will be affected by climate change. To avoid the more serious consequences on the horizon, we need to act now, together.

About the Author

Samantha Mailhot holds an honours degree from the Department of Geography, Planning and Environment at Concordia University, where she worked with Dr. Damon Matthews, Professor and Concordia University Research Chair in Climate Science and Sustainability.

Her interest in environmental issues began at the beginning of her university degree, and has grown significantly as she progressed in her education and research. She plans to continue studying climate science and communication as a graduate student and hopes to contribute to our understanding of what science communication strategies are most effective to motivate climate action.

Isachsen – An Artist's Exploration of Isolation Through the Eyes of his Father at a Remote Arctic Weather Station

Interview with Doug Munson and aAron munson by Sarah Knight, CMOS Bulletin Editor

In 1974 Doug Munson, just 19 years old and fresh off 8 months of surface weather and upper air courses, was posted to the remote Isachsen weather station in the Canadian Arctic for a full year. Isachsen was operated on Ellef Ringnes Island from 1948-1978, and for those living there contact with the "outside" world was minimal – via a monthly air supply and the nearest settlement 300 miles to the southeast. At nearly 79 degrees North, the winter brings a 3 ½ month long night, temperatures below -50 degrees C, and extreme winds.

As a weather observation technician with Environment Canada, Doug's time at Isachsen would leave a lasting impression on him. Little did Doug realize that this extreme and snowy landscape would also make a big impression on his future son, and that 40 years later aAron munson would return to this place, camera in hand, to explore this piece of his father's history.

aAron's photographs made a strong public impression when they were recently displayed as part of an experiential multimedia exhibit at the dc3 Art Projects gallery in Edmonton, Alberta. I caught up with both aAron and Doug just as the exhibition was coming to a close, to ask them about their experiences, reflections, and the impact of the project.

Photos of the abandoned Isachsen station, supplied by aAron munson.

How did you end up at Isachsen and what was it like?

Doug: "After I finished high school I took a 4 month surface weather course in Ottawa, and then a 4 month upper air course in Scarborough, Ontario. As part of the training I had to spend a year in service at a remote weather station, and I was sent to Isachsen. I was there for 12 months, from May 1974 to May 1975, along with nine other men. A supply plane would come once a month, and one or two people would change out.

"I went with an open mind and a sense of adventure! But flying in to the place it seemed so small, just a little 'embattled outpost of technology' – to quote Farley Mowat. And once there it was confining – unless there was a very good excuse you couldn't leave. Really it was like a prison with no walls, with the nearest settlement 300 miles away! Distance defined the prison's walls. But after a while I just accepted it. Apart from the work there were a few diversions. We had a ham radio, some movies and books, and plenty of hockey games, so I just had to survive the best I could on the life support system that was out there."

How did it affect you?

Doug: "The isolation and the 3 ½ months of darkness was tough, psychologically and physically. And there were times when I did wonder if I would make it out. The darkness was the worst, and it felt like we were all just going through the motions waiting for the light at the end of the tunnel. We didn't talk to each other about how we felt, so I wrote in my journal a lot."

After you left, did you ever go back?

Doug: “They asked me to go back, I say ‘No!’. I moved on to Cape Parry, on the Dew Line, at 70 degrees North. But 17 years later when I was working as an Inspector I ended up in the nearby settlement of Paulatuk, and some of the local Inuit hunters recognized me! Together, we had had a run-in with a polar bear, back in the winter of 1975-76.”

Photos supplied by Doug Munson from his time at Isachsen, 1974-75. Left: Isachsen weather station (notice the two huskies sunning themselves in the centre left of the picture). Centre: Doug’s co-worker Marvin Maronda releasing a weather balloon. Right: Barrels were likely once for (aviation) gas or similar and collected to be crushed and shipped out.

aAron, what was it like to be up there? Were you prepared for it?

aAron: “I was greeted by the wind! I have been to some extreme places but that was the first time I thought I might be in over my head. It was just me, the guide, and a bunch of bags, dumped at the station for a week. The plan had been to sleep outside, but I wasn’t prepared for the wind.”

What prompted you to do it?

aAron: “As a child I was aware that my mother suffered from depression and I suspect that my father did too. He didn’t talk about Isachsen much, but when I read his diary I saw that he was one man before he went there, and that he came out a changed man. I wanted to know more about what my dad experienced there and how it affected him.”

How has this project affected the relationship with your father?

aAron: “At the exhibit the visitor would enter and first read a diary entry from my dad. So you walk in and imagine what it is like to be so isolated. On paper it might have sounded like an interesting experience, but in reality it carried a huge weight. He could hardly contact his family – even when I was there I could call anyone I wanted from my satellite phone. So it definitely gave me a big sense of empathy, as being up there the only thing that separated he and I was time. My dad only ever spoke about the experience superficially, but going through 3 months without sunlight and living in such isolation must have taken a toll.

“It warmed my heart at the exhibit to see my dad proud of his own experience, and also that the whole thing was received as well as it was and that people were interested in this part of his life. I think it allowed my dad to relive the experience and maybe see how it has shaped him. Some of his friends came, and it opened them up to talk about their experiences.”

What was it like for you to have aAron make the trip up there, and then to revisit the experience through the exhibit?

Doug: “My own dad passed away two years ago, and it was only in the last few years of his life that he talked about his life, so I learned more in those last couple of years than I had in all of the 40 previous years about him. So I was surprised that aAron would be interested, and it’s really nice that we can talk about my experiences now. Going to the exhibit didn’t really bring back the feelings of that time, so much as it revived the good memories of my time there. One tends to remember the positive happenings from the past more so, don’t you think?”

What environmental, intellectual or emotional messages were you trying to get across with your work?

aAron: “The environmental part of the project is more of an aside, but it is there, you can’t ignore it. I think it makes people think about the geography of our country, what the Arctic represents, who lives there, and what happens there. The Arctic is the canary in the coalmine in regards to climate change and shining the light on places like Isachsen can help people think about, and talk about, the Arctic.

“But really this project was more about presenting an experience that makes people think about the impacts of isolation and depression, in experiences and in everyday life. I wanted to recreate Isachsen and the experience of

isolation and depression, in experiences and in everyday life. I wanted to recreate Isachsen and the experience of it, as without the experience there can be no empathy. So I tried to put visitors in the headspace of what it was like there, and hopefully that will translate to helping people have more conversations about depression."

What are the impacts of isolation and depression on individuals and society?

aAron: "We are so well connected through the internet and social media, the world is at our fingertips, but an entirely new form of isolation seems to be emerging from our immersion in this digital world. I think projects like this work against a stigma, and help us work towards having conversations about these issues. The response to the exhibit so far has been overwhelmingly positive."

Photos of the abandoned Isachsen station, supplied by aAron munson.

How did the experience affect your perspective on the relationship between nature and human endeavour?

aAron: "It was a reminder that no matter what we build, given enough time, nature will wipe the slate clean. I wanted to capture the snow taking over the space and creating incredible sculptures – as far as nature is concerned it has all the time in the world to do this. Being up there reminded me that for all our endeavours we won't matter in the end, and I find this humbling."

Doug: "After the Isachsen experience, it seems that we are so small, just a pinpoint, we aren't very significant. Earth is beautiful on its own. We really are just so infinitesimally small. I am reminded of the 1957 movie 'The Incredible Shrinking Man'. The main character realized that we are ever so small. God still sees us where we are, and that's a comfort!"

What is your own personal connection to art, people and nature?

aAron: "Everything that I do starts from a place of wanting to connect with people. Art creates the conversation for me. For me, words are often a shallow interpretation of what I really want to convey, and art can do so much more. I too often find that contemporary art is so self-serving, which is exactly the opposite of what needs to happen – art should be a means to communicate and connect with each other. You can take a concept that is extremely convoluted but if it is executed well you can make almost anything accessible.

"With the prevalence of social media in our society, I think that we are losing some ability to effectively communicate with each other, in words and in many unspoken ways. All of the complexities that happen in face to face interactions…what if we lose it? Can we still know how to be present in a moment, with so much constantly grabbing for our attention? The power of the gallery is its ability to force people to be present, and to open a channel of communication with them as you have their full attention.

"Up North, with my guide, it was so interesting to observe the way that he was experiencing the land. The way in which he could read the land could only be developed through many years of experience. I think that in some ways we are regressing as a species. We're losing so much knowledge that we spent thousands of years developing – how we relate to nature and to each other. The rapid progression of technology is incredible but seems to be developing faster than our ability to adapt to it, often leaving us scatterbrained. Through art, I am interested in exploring the impacts of this new reality on us, and also how much we can absorb by simply being present."

Photographs and information on the dc3 Isachsen exhibit can be seen at http://www.dc3artprojects.com/isachsen/. For more information on aAron munson's work see aaronmunson.com.

MOPITT, Atmospheric Pollution, and Me: A Personal Story

By Jim Drummond, Principal Investigator for the Measurements Of Pollution in The Troposphere (MOPITT) instrument on the Terra satellite

It's 1987 and I have just bought my first personal computer – an IBM PC clone running at a stunning 8MHz! I'm also on sabbatical at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, when one of those cafeteria conversations start with John Gille who asks: "You can measure composition in the stratosphere with correlation radiometers, could you do it for the troposphere?". Being on sabbatical it seemed like an interesting problem to look at, so I worked on it and wrote a short paper on an instrument known as the "Length Modulated Correlation Radiometer", which had the properties needed for such measurements. Little did I know that this would be the beginning of a thirty-year saga that has engaged my attention for much of my career.

In 1988, an International Announcement of Opportunity came out from NASA for the Earth Observing System and a series of Polar Orbiting Platforms that would monitor the state of the planet over a fifteen-year time frame with three successive copies of each instrument involved. These instruments were to be mounted on enormous, school bus size, Polar Orbiting Platforms (POP). With a bit of encouragement we brought together an international science team and proposed, along with over 100 other proposals from around the world, an instrument that we dubbed MOPITT for "Measurements Of Pollution In The Troposphere" to measure carbon monoxide in the lower atmosphere (troposphere) over the entire planet. We always aimed to get around to choosing a better acronym, but we never did.

Why did we choose carbon monoxide as our target gas? There are three reasons. The first is that carbon monoxide is an important lower atmosphere (tropospheric) pollutant produced largely by incomplete combustion, both natural and anthropogenic. The second reason is that it participates in atmospheric chemistry, so measuring it gives us a window into lower atmospheric chemistry. The third reason is that it has a lifetime of about a month in the atmosphere, and so is transported on a regional to global scale thus allowing us to monitor the spread of pollution.

Our application for the MOPITT instrument was supported by the Space Division of the National Research Council of Canada, and to our immense satisfaction it was chosen to move forward into the next phase of development. Our contractors were COMDEV of Cambridge, Ontario and the design proceeded. As with most space instruments, this one involved a lot of new technology and so was very difficult for the industry and academic teams to bring it from the concept stage to something that might be realised in hardware. We were using cooled detectors with a mechanical Stirling Cycle Cooler and the Length Modulated Radiometer, which was all new technology. We had to produce an instrument that would last at least five years in orbit and meet a myriad of requirements from the spacecraft. In parallel with this hardware activity, NASA supported our partners at NCAR to develop the data processing and retrieval software.

The MOPITT instrument undergoing test at the University of Toronto around 1995. (Photo credit: COMDEV)

The Earth Observing System was also undergoing changes due to changing priorities and budget constraints at NASA. After many iterations and down-scaling MOPITT survived as an instrument on the first of three smaller platforms, which became known as Terra, Aqua and Aura. Each of these smaller platforms was "only" the size of a small school bus.

In Canada the Canadian Space Agency (CSA) was formed, and the MOPITT project transitioned there. Test facilities were built at the University of Toronto and by 1996 the instrument was mostly completed and ready to undergo testing. First in Canada, and then when integrated onto the Terra spacecraft at Valley Forge, Pennsylvania, the MOPITT instrument underwent a gruelling test schedule and was finally ready for launch in 1999.

Article: MOPITT and Me

Remember Y2K? There was a lot of nervousness around technical projects at that time and the Terra launch was scheduled for late December 1999 from Vandenberg Test Range in California. We all went down for the launch on December 17th, but a procedure problem meant the launch had to be aborted. We had a last attempt on December 18th. Failure to launch then would mean waiting until after the New Year to avoid any Y2K problems. Seconds before the end of the launch window at 18:57:39 UTC, Terra launched, and I watched much of my career flying towards the heavens on a very large rocket. Even then boosting the spacecraft to final orbit was delayed until after Y2K.

We made it into the final orbit and started analysing the measurements. Our first attempts involved showing that carbon monoxide was “high” or “low” in various places but things rapidly improved, and after a year the instrument seemed to be working well. Almost immediately we realised that carbon monoxide was a global phenomenon, not just a local or regional one, and that global focus has stayed with the mission ever since then.

Left: The Terra spacecraft at the integration facility in Valley Forge, PA ready for integration into the rocket nosecone on the left. (Photo Credit: NASA)
Centre: The Terra spacecraft launch showing the Atlas IIAS lift-off on 18th December 1999 (Photo credit: Jim Drummond)
Right: Some of the COMDEV and University of Toronto MOPITT team at the launch (Photo credit: Rosemarie Drummond)

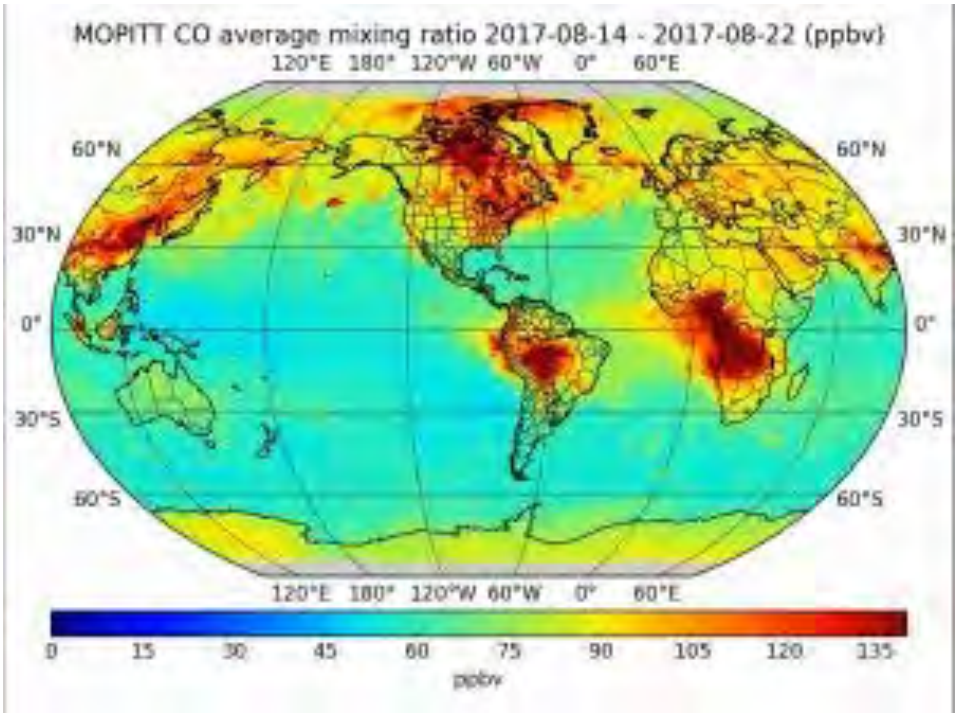
No one likes getting phone calls in the middle of the night, but the one that says, “your instrument is showing an anomaly” is definitely not welcome. On May 7th 2001 that was what happened. Half of our cooling system had failed, and it looked as though the mission was over. But a lot of people did a lot of hard work and found that if we reconfigured the cooling system a bit we could get half the instrument working again, and if we reconfigured the operational part of the instrument we could still get pretty well all of the science. So, after a lot of testing and review, we re-activated the instrument several months later on August 23rd and it has been operating in that mode ever since.

Five years came and went, then ten years, then fifteen years, and we – especially the NCAR team – have gotten better and better at interpreting the data from the instrument. A NASA employee reminded me recently that our original objective was a fifteen-year dataset, which we had now achieved with only a single instrument instead of the three copies originally envisaged.

Of course, MOPITT is a team effort, and includes an industry team at COMDEV who built the instrument with involvement from staff and students at the University of Toronto (some of those students have gone on to careers in academia, industry and the CSA), the CSA who financed and supported the whole project, the instrument team who still monitors MOPITT’s health daily, the NASA team who keep the spacecraft running and the NCAR team who process the data. All the MOPITT data are freely available from the Langley Atmospheric Science Data Center (https://eosweb.larc.nasa.gov/project/mopitt/mopitt_table)

On December 18th 2017, we passed 18 years from launch, and we now have an 18 year data record of carbon monoxide over the planet. The NCAR team have taken the analysis software to version 7. The whole Terra mission has been a great success. A recent review stated that Terra’s impact on progress in many earth science disciplines has been staggering …. Several subcommittee members convincingly argued that Terra is perhaps the single most important NASA Earth Science Mission ever. (NASA, 2017) There are now over 400 scientific papers referencing MOPITT data from over 250 institutions in over 40 countries. MOPITT data have been used to estimate surface emissions, measure trends and with carbon dioxide measurements have extended our

understanding of the carbon cycle. We have made over 1.3 billion measurements and in October 2018 the spacecraft will complete 100,000 orbits of the planet. This causes a little problem, because the data specifications only allow 5 digits for the orbit number!



MOPITT map of carbon monoxide (CO) over the planet for 14-22 August 2017 with interpolation to fill data gaps. The CO outflow from the summer forest fires in Western Canada covers much of Canada and there are several other centres of CO production visible. (Credit: MOPITT)

Where will it end? Assuming no catastrophic failures, the spacecraft will run out of the fuel needed to maintain its precision orbit in the early 2020s, but after that it can fly ballistic for several decades. How long will MOPITT last? The limit will be the longevity of the sample gases we carry in the radiometer cells. Although these sample gases are slowly disappearing, we should be good for at least another decade or two.

So, after thirty years, the echo of that cafeteria conversation is still with me, and I suppose I am now in a position to answer the question: Yes, John, we can do these measurements in the troposphere.

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.

Article: Top Ten Weather Stories of 2017

Canada's Top Ten Weather Stories of 2017

By David Phillips, Environment and Climate Change Canada

Our climate is changing, and it's happening here and now

Worldwide changes in extreme precipitation and temperature are consistent with what we anticipate from global warming. Science is linking climate change with increased risk of forest fires, floods, heavy rains, and the most powerful hurricanes. Canadians experienced many of these extremes in 2017.

Canadians had plenty to "weather" in 2017. Property damage from weather extremes cost Canadian insurers and governments millions of dollars. Between the few floods, the many wildfires and record dry temperatures, 2017 was a year of too much— too dry, too hot, too fiery, too wet, too cool, but not too cold. It was the eighth warmest period in 70 years of reporting weather, with temperatures averaging 1.4°C above normal. This year also marked the 21st consecutive year warmer than normal, matching the trend for the rest of the world.

From a list of 100 significant weather events that occurred across Canada in 2017, we picked the top ten weather stories that were the most significant. These stories were selected based on the degree of impact on Canadians, the size of area affected, the economic and environmental effects and how long it remained a top news story in Canadian media. As the *Top Ten Weather Stories of 2017* confirm, our communities must become more resilient – not only for what lies ahead, but for the changing climate that is already on our doorstep.

1: British Columbia's longest and most destructive wildfire season

In 2017, across the southern British Columbia (BC) interior, an extraordinary weather change occurred – the region's wettest spring was followed by its driest summer ever. The result was the longest, most disastrous wildfire season in the province's history. A province-wide state of emergency, the first in 15 years and the province's longest one, began on July 7 and lasted until September 15. Aggressive wildfires forced 50,000 British Columbians to leave their homes.

A growing snowpack and heavy rains in May kept BC wildfire staff busier helping with flood relief than firefighting. But excessive spring rains mixed with mild temperatures helped vegetation growth that quickly turned into kindling when a hot and dry start to summer didn't let up. Occasionally, low pressure systems brought gusty, erratic winds, dry lightning and low humidity but no long, sustained soaking rains to quell the inevitable flames.

One of the earliest and largest fires burned west of Kamloops in the Ashcroft-Cache Creek-Clinton area. In the Interior, Ashcroft recorded only a thimble-full of rain over 13 weeks, while Kamloops and Kelowna had even less. In the end, fires burned over 300 structures as well as hundreds of power poles and transmission towers. Ranchers in cattle country returned to scorched fields, dead livestock and burned fences.

In total, the BC Wildfire Service reported 1,265 fires that scorched 1.2 million hectares of timber, bush and grass-land (an area twice the size of Prince Edward Island), smashing the previous record for burned land by 30%. Total firefighting costs exceeded half a billion dollars and insured property losses reached close to $130 million.

2: Dry and hot in the West

A massive dome of heat set the stage for record-breaking summer temperatures across the Canadian West. As a result, southern regions between the British Columbia (BC) Interior and the southeastern Prairies faced their driest summer in 70 years, with many areas recording less than half their normal rainfall during the growing season.

In Calgary, the average temperature between May and August was 16.4°C, making it the warmest May to August since 1881. Other hot spots included Medicine Hat, with 34 days without rain in July and August hotter than 30°C, as well as Kamloops with 42 days without rain.

Across the West no other summer as far back as 1948, had been so dry. The record dryness was centered on Regina and Moose Jaw and between Kamloops and Kelowna. Total rainfall in Regina from April to October was 119.3 mm compared to the previous record of 151.5 mm in 1961. In Kelowna, it was not only the warmest August on record, it was also the driest. Just two-tenths of a millimeter of rain fell in the city compared to the 32.1 mm it usually receives in August; in July there was no rain at all. Attendance at outdoor attractions dropped, golf courses struggled to keep their greens green, low river flows and heated water harmed fish, and rising temperatures pushed summer electricity use to all-time highs. Hot days were also dry ones.

Credit must be paid to growers of any product that made it to market, with the heat and drought impacting crops across the board. Livestock also suffered, as watering holes and grazing land dried up, with hundreds of cattle dying from dehydration. The only positive outcome from the persistent dry heat was a reduction in mosquitoes.

3: Spring flooding in Quebec and Ontario

At the beginning of May, flood forecasters across Quebec and eastern Ontario were concerned. In the previous month, several major, slow-moving weather systems had soaked the region with record rains. Over half the snow pack, loaded with water, still needed to melt, and the 7-day forecast called for more showers falling on the partly frozen ground. Instantly, bloated rivers and streams overflowed, and sewers backed up. Several rivers exceeded the maximum amount water released in the past and overflowed from Gananoque to Gaspésie.

The Quebec government claimed the spring downpour was the worst ever recorded in the province over the past 55 years. In Montréal, April rains totaled 156.2 mm − the second wettest in 147 years. Both Ottawa and Montréal had their wettest spring in history – 400 mm or more with records dating back to the 1870s. Spring flooding occurred in hundreds of communities, forcing 4,000 people to leave their homes. Dozens of towns and cities declared states of emergency, including Gatineau, Laval and Montréal. Up to 2,300 Canadian military personnel were brought in to assist with flood preparations and rescue relief.

According to the Insurance Bureau of Canada, spring flooding in April and May resulted in 15,750 claims and $223 million in property damages. In total, more than 5,000 residences were flooded, 550 roads were washed or swept away from floods or landslides, and – tragically – on May 6, two people were swept away by the swollen Sainte-Anne River in the Gaspé region.

4: British Columbia's cold and snowy winter

Winter was mild across Canada − the seventh warmest in 70 years – with only British Columbia (BC) experiencing colder-than -normal temperatures. Meanwhile, residents west of the Rockies struggled to cope with their second coldest winter in 25 years.

In early January, winter across much of BC went from mild to wild and stayed that way until two weeks before spring. What made the winter memorable was not the amount of snow but the duration, frequency and length of snowfall, as well as the amount of snow on the ground. In addition, there were several days with sub-freezing temperatures – more than any other winter in 25 years.

Too much winter for too long had enormous impacts on the Lower Mainland and parts of Vancouver Island. Community centres became warming centres. Retailers couldn't keep up with the demand for snow tires, snow shovels and road salt. Ski conditions were fantastic but getting to mountain resorts was, at times, an issue. On roads and walkways, frequent bouts of freeze and thaw made for especially icy, slippery surfaces with numerous potholes.

The long winter kept landscapers and gardeners a month behind schedule, and at times heavy, sticky snow crushed blossoms and dropped bushes.

Article: Top Ten Weather Stories of 2017

5: Another Windsor flood: two storms of the century in a year

Less than a year after a record $153 million flood hit Windsor and Essex County, another downpour with equally heavy rains and damage flooded the same area.

Light rain began falling before noon on August 28. It continued with heavier amounts in the early evening. Storms kept happening overnight. The next day intense thunderstorms re-occurred and remained stationary. In less than 48 hours, 222 mm of rain fell in southwest Windsor and 140 to 200 mm in Riverside-Tecumseh.

However, it was the nearby community of LaSalle that was hit the hardest with 125 mm of rain on August 28. Another 160 mm fell the next day. In total an incredible 285 mm fell in 32 hours. This was one of the wettest moments in Eastern Canadian history. Flood waters filled thousands of basements to the rafters and stalled vehicles on waist -high flooded streets. The scene was a repeat of September 2016, when curbs were piled high with soaked carpets, rotten furniture, broken appliances and drenched personal belongings. Insurance payouts totaled $154 million – the most expensive single-storm loss across Canada in 2017.

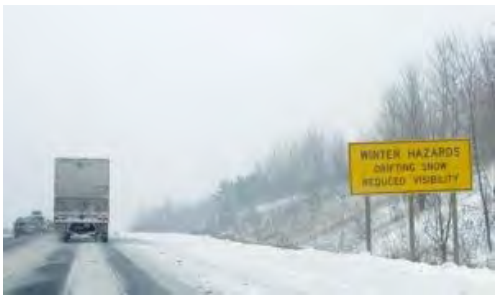
6: Central Canada's missing summer

Ontario and Quebec residents knew it was going to be hard to beat last summer's hot days, record-warm lake water and a season-long stretch of delightful vacation weather. But no one could have predicted what a bummer of a summer 2017 would turn out to be. Total rainfall from April to July was well above normal in most places, including the Great Lakes and St. Lawrence River Basin, where it was the wettest in 70 years of observations. Cool, overcast weather and frequent spring showers continued throughout the summer. The seasons changed but not the jet stream, stubbornly hanging out south of the Great Lakes for weeks on end. As a result, mid-latitude weather systems continually crossed the region two to three times a week. Every day had a constant and frustrating suite of cool air, endless hours of rain, and an absence of sunshine and continued warmth. Any small break in the cloud cover or occasional warm day raised false hopes that summer had finally arrived.

Farmers who had faced dryness in 2016 were now cursing 2017's super saturation that left them once again fearing the loss of their crops. By mid-June corn should have sprouted, the first hay should have been cut and baled, and soybeans should have been planted, but agricultural activities remained weeks behind until September. Even the poor bees, who should have been busy pollinating, were kept hive-bound by the cool, wet weather.

Rain, rain, and more rain filled up every nook and cranny, including waterways like Lake Ontario that reached a record 75.9 metres above sea level in May – the highest it has been since at least 1918. Its rising waters blocked access to the Toronto Islands from mid-May to the end of July, keeping the popular summer destination off limits for both city residents and tourists.

7: A new storm of the century



The winter's worst storm stretched across Eastern Canada striking parts of Ontario on March 13, before moving towards the East into Quebec and Atlantic Canada over the next two days.

The storm led to a multi-car pile-up in whiteout conditions in Brockville that involved 15 transport trucks and other vehicles on Highway 401. Officials closed the highway in both directions as twisted metal covered the road and a highly toxic acid spill polluted the air. The storm then moved into Quebec, where it dumped 50 cm of snow at over half the weather reporting stations across the south. No previous storm had beaten so many snowfall records in Quebec, with some stations reporting more than a metre of snow. In Gaspésie, winds reaching 175 km/h caused total whiteouts. In addition, a storm powered by 100 km/h winds along the St. Lawrence River had tragic consequences. The monster storm took five lives and left hundreds of people stranded in a multitude of accidents across the south. On one stretch of highway in Montréal, 300 people spent the night stranded in their cars. Moving further east on the Ides of March, the storm still packed enough punch to cripple parts of Atlantic Canada.

Article: Top Ten Weather Stories of 2017

8: Summer in September

Fall officially arrived on September 22 at 16:02 EDT.

The next day marked the beginning of the warmest period in 2017 across Eastern Canada. From September 22 to 27, over a thousand heat records fell as humidex values shot up close to or above 40, prompting a week-long stretch of heat warnings.

In the lead up to the five-day scorcher, there were two weeks of delightfully sunny, warm and rain-free weather. It was the most beautiful stretch of summer weather in the entire year. The welcomed warmth went into October with southern Quebec experiencing its warmest month since at least 1870. The unusual heat across the eastern half of North America was due to a strong ridge of high pressure south of the Great Lakes that caused a large northward bulge in the jet stream.

It's likely that the four major hurricanes – Harvey, Irma, Jose and Maria – that happened earlier in the season shook up the atmosphere, enabling summer temperatures to arrive eventually, even though it was after the autumnal equinox.

Dozens of cities across eastern Canada had their warmest September and October on record. For some places, September 25 was the hottest day of the year and the hottest fall day on record, with peaks between 30° and 35° C. Everywhere you looked there were full patios, people strolling in the sun and crowded beaches without lifeguards. The abundant dry-warm days were a blessing for farmers harvesting crops and vintners picking grapes. In Annapolis Valley, apple growers had to turn on overhead sprinklers.

To everyone's dismay, the fall heat wave finally came to an end on September 27 when a cold front swept across the south and brought a much cooler air mass to the region.

9: Newfoundland's Brier blast

The traditional winter months of November through February were not too demanding across Newfoundland and Labrador. However, when a series of powerful and impactful winter storms hit the province in March and early April, the "soft winter" turned hard. Slow-moving blizzards racked the province with some of the toughest weather in years, featuring shrieking gales, humongous snows and freezing rain. Hurricane-force winds ravaged Newfoundland on March 1 and 2, but it was the "Brier blast" on March 11 that defined the rest of winter and spring.

On the last Saturday of the Canadian curling championship, curlers, spectators and locals in St. John's faced the usual Newfoundland mix of rain, freezing rain and snow in near-zero visibility. However, it was the winds that stirred the snowstorm into one of the fiercest storms the province had seen in more than a decade. Wind gusts in the Avalon Peninsula peaked at a hurricane-force of 190 km/h at Bay de Verde, leaving over 70,000 residents and visitors in the dark. It was said that wind speed and storm damages exceeded those from Hurricane Igor in 2010. Winds pulled trees out of the ground, brought down traffic lights and power lines, blew away entire roofs and overturned vehicles. In some cases, strong winds ripped the second story floor off houses.

In total, the brutal storm cost almost $60 million in insurance losses from 4,500 claims.

10: New Brunswick's glaze storm

A long-lasting mix of rain, snow, freezing rain and ice pellets dangerously impacted portions of Quebec and Atlantic Canada during the last week of January. This led to the deaths of two people, dozens of injuries, and more than 30 individuals being sick from carbon monoxide poisoning.

At the peak of this event, power lines that were stressed by wind and heavily coated in ice, snapped. This left close to 300,000 residents in the dark and cold. About one in three New Brunswick residents had their lives turned upside down. Power remained off in some communities for up to 12 days as entire hydro grids were rebuilt. Northern Acadian communities

were especially hard hit. Schools were closed for up to four days and public transit was shut down. Canadian Armed Forces were deployed to help with the ongoing emergency response. According to New Brunswick Power, the province endured four major storms in the last two years compared to only two extreme storms in the previous twenty years. Storm surges came ashore in Quebec and there was local flooding in the Gaspé region. In Halifax, strong winds from the East, gusting close to 100 km/h scattered construction debris and tore down power lines.

Regional weather highlights

Atlantic Canada
Two January nor'easters cripple Newfoundland
Four February storms in 10 days
Gander disappears under snow
New Brunswick spring flooding
Record wet May in Cape Breton Island
Rock-tossing storms in Acadia
Big year for icebergs
Hurricane Gert − no Harvey, Irma or Maria
Labrador's miserable summer weather
October blows across the East

Ontario
Year of the pothole
Ontario-wide SAD
January-thaw through February
Short skating season on the Rideau Canal
Ottawa – truly the world's snowiest nation's capital
Major property losses from strong March winds
June thunder flood
Canada 150 celebration soaker
Huntsville tornadoes
Leamington and Hawkesville tornadoes
Microburst ends September heat wave
Hurricane Nate arrives for Thanksgiving
Tropical storm Philippe and more Ottawa rains
Ottawa's year-long big wet

British Columbia
Year of avalanches
Damaging April wind storm
Wet and gloomy weather delays spring planting
Okanagan spring flooding
Trio of October windstorms
Snow-vember in Vancouver/Victoria

Quebec
Preference for snow not freezing rain
Quebec's new single-day snowfall record in Gaspésie
Open and soft winter
Maple sap runs early
Father's Day tornadoes
Major hailers in July
Beauce tornado in August
Quebec's major microburst
Quebec's summer of contrasts
Suspicious-looking tornado in October
Pre-Halloween weather bomb

Prairie Provinces
Mackenzie clipper brings cold to the Prairies
Bonspiel January thaw
Alberta's metre-sized snowfall
Nature warms hearts on Valentine's
March storm buries Churchill
Red River non-flood
Still harvesting last year's crop
Big May blow across the West
Summer of Saskatoon hailers
Hailers and plough winds in Red Deer
Calgary Stampede – hot and dry except for one day
Early July supercells in Saskatchewan
"Pudding-cup" hail and floods across central Alberta
Costly July storms in Alberta Foothills
Manitoba forest fire season more active than usual
Winnipeg … the best weather this summer?
Forest fires in Alberta
Powerful winds too strong for trains

The North
Northern ice roads later and later
Early winter low snowfall in Northwest Territories
Arctic heat wave
Arctic sea ice going, going…
Fierce September gales
Weather delays Halloween
Warm November gales

About the Author

David has been employed with Environment Canada's weather service for more than 45 years. His work activities relate to the study of the climate of Canada and to promote awareness and understanding of meteorology. He has published several books, papers and reports. He is the originator and author of the Canadian Weather Trivia Calendar, the most popular calendar sold in Canada, and now in its 30th year. David is the recipient of three honorary doctorates from the universities of Waterloo and Windsor and Nipissing University. In 2001, David was named to the Order of Canada.

In case you missed it...

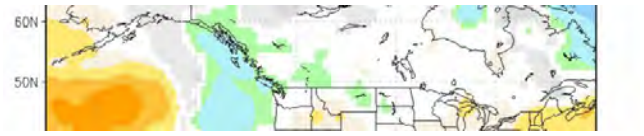
From CMOS Bulletin Volume 45, Number 6, ARCTIC SPECIAL ISSUE:

Canada Needs Sustained Climate Research Funding
by Jon Abbatt, Jim Drummond, Roger Francois, Paul Kushner, Paul Myers, Kimberly Strong, Laxmi Sushama, Phillipe Tortell

PEARL at the Pole: An Update on Canada's Polar Environment Atmospheric Research Laboratory
by the PAHA team

Photo Story: "A Day in the Life" at PEARL, The Polar Environment Atmospheric Research Laboratory at Eureka
by Dan Weaver

Arctic Science Events in Canada and Beyond
Compiled by Helen Joseph



Seasonal Outlook for the winter 2017/18 (DJF) based on CanSIPS forecast 30th November 2017
by Marko Markovic and Kevin Gauthier

Book Review: Nonlinear and Stochastic Climate Dynamics
Review by André April

Book Review: Weather in the Courtroom
Review by Daryl O'Dowd

Message from the CMOS President as 2017 Draws to a Close

These articles, and more, in the new, online 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.

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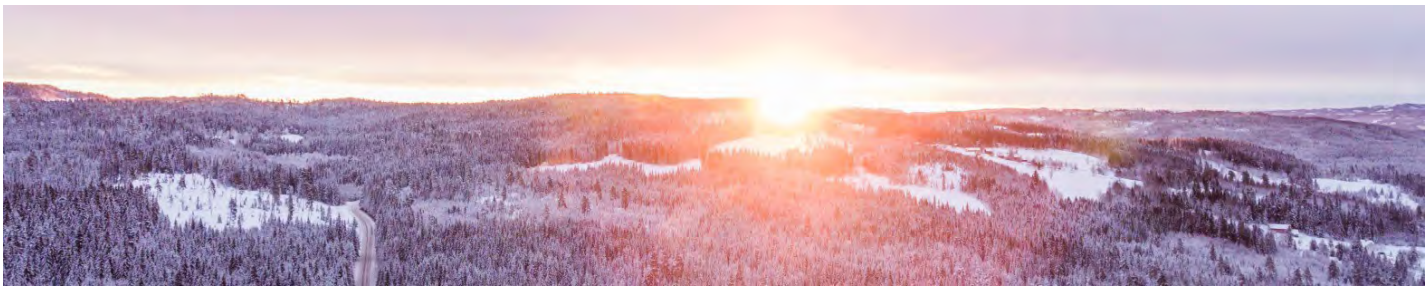
http://bulletin.scmo.ca

CMOS Helping Scientists to be Heard

By Paul Kushner, Department of Physics at the University of Toronto and Vice-President of CMOS



Media coverage of climate change plays a significant part in shaping public perceptions and attitudes, and in garnering support for continued scientific research into this pressing, global issue. As such, it is crucially important that facts and legitimate expert opinions are readily available, which means that climate scientists are finding themselves, more and more often, having to step in to advocate for climate science research and for serious consideration of its implications.

Over the past eight months the CMOS executive have worked with colleagues supported under the Climate Change and Atmospheric Research (CCAR) Program to fight for continued federal government funding of the globally important work that is being conducted through this program. Because of their perseverance, and the lobbying efforts being conducted through Evidence for Democracy (E4D), there have been some wins, such as continued funding for PEARL. But the struggle continues to secure funding for the bulk of the CCAR program.

As such, it is no small victory to get national media coverage, as this advocacy effort managed to achieve in the Globe and Mail last month as a feature editorial piece. In it, the case for CCAR is strongly supported:

"…it's hard to understand why Ottawa isn't renewing the Climate Change and Atmospheric Research program, the only dedicated federal program that funds long-term, large-scale research into the effects of climate change.

The $35-million program expires this year, after funding seven major projects over five years, most of them in the Arctic. So far no one in the government has explained why this is happening. Tellingly, though, last fall Ottawa gave the most high-profile CCAR-funded project, the Polar Environment Atmospheric Research Laboratory (PEARL) in Eureka, Nunavut, an 18-month extension."

CMOS will continue to look for ways to make our advocacy effective, in partnership with other organizations, and in consultation with you, its hardworking membership. Canadian research in atmosphere/ocean, climate, and related sciences provides a great foundation, and work like this ensures that our voices will be heard.

See more on the recent media coverage here:

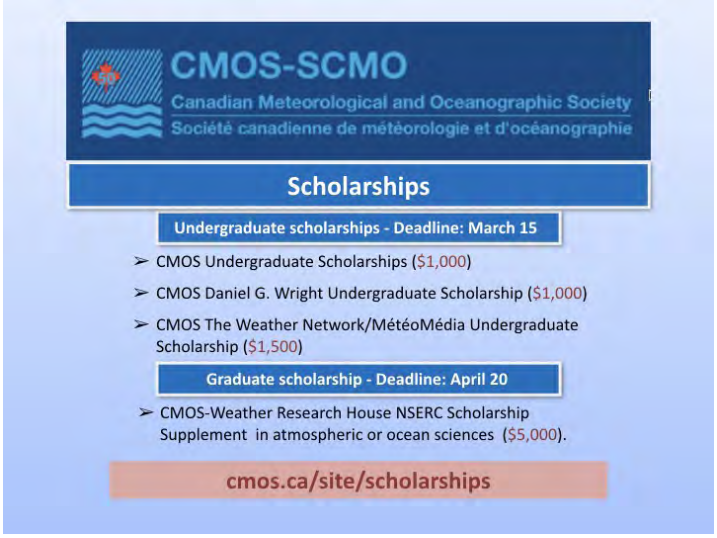
International scientists call on Trudeau to re-invest in climate science, Evidence for Democracy (E4D). Retrieved from: https://evidencefordemocracy.ca/en/content/international-scientists-call-trudeau-re-invest-climate-science

Scientists urge Trudeau to restore or replace key climate research fund (22 January 2018), The Globe and Mail. Retrieved from: https://www.theglobeandmail.com/news/national/scientists-urge-trudeau-to-restore-or-replace-key-climate-research-fund/article37679386/

Canadian climate science faces crisis that may be felt globally, scientists warn (22 January 2018), The Guardian. Retrieved from: https://www.theguardian.com/world/2018/jan/22/canada-climate-science-faces-looming-crisis

Ottawa abandonne un programme scientifique sur l'Arctique (23 January 2018), Le Devoir. Retrieved from: http://www.ledevoir.com/societe/environnement/518218/climat-ottawa-abandonne-un-programme-dans-l-arctique

Globe editorial: Science-loving government cuts funding for science (23 January 2018), The Globe and Mail. Retrieved from: https://www.theglobeandmail.com/opinion/editorials/globe-editorial-science-loving-government-cuts-funding-for-science/article37711890/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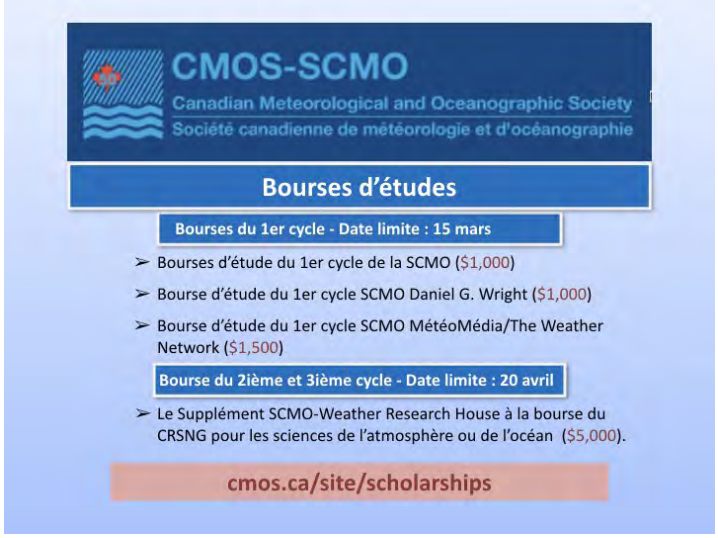
Undergraduate scholarships - Deadline: March 15
CMOS Undergraduate Scholarships ($1,000)
CMOS Daniel G. Wright Undergraduate Scholarship ($1,000)
CMOS The Weather Network/MétéoMédia Undergraduate Scholarship ($1,500)
Graduate scholarship - Deadline: April 20
CMOS-Weather Research House NSERC Scholarship Supplement in atmospheric or ocean sciences ($5,000).
cmos.ca/site/scholarships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Bourses d'étude du 1er cycle de la SCMO ($1,000)
Bourse d'étude du 1er cycle SCMO Daniel G. Wright ($1,000)
Bourse d'étude du 1er cycle SCMO MétéoMédia/The Weather Network ($1,500)
Bourse du 2ième et 3ième cycle - Date limite : 20 avril
Le Supplément SCMO-Weather Research House à la bourse du CRSNG pour les sciences de l'atmosphère ou de l'océan ($5,000).
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Books in search of a Reviewer*:

(2017-3) *Eustasy, High-Frequency Sea-Level Cycles and Habitat Heterogeneity*, 2017. By Mu Ramkumar and David Menier, Elsevier Inc, ISBN 978-0-12-812720-9, Paperback, 102 pages, $60 US

(2017-4) *Minding the Weather: How Expert Forecasters Think*, 2017. By Robert R. Hoffman, Daphne S. LaDue, H. Michael Mogil, Paul J. Roebber, and Gregory Trafton, The MIT Press, ISBN 978-0-262-03606-1, Hardcover, 469 pages, $66.69

(2017-5) *Risk Modelling for Hazards and Disasters*, 2017. By Gero Michel, Elsevier, ISBN 9780128040713, paperback, 338 pages, US$100.00

(2017-6) *Introduction to Satellite Remote Sensing; Atmosphere, Ocean and Land Applications*, 2017. By William Emery and Adriano Camps, Elsevier, ISBN 9780128092545, 860 pages, US$130.00

(2017-7) *Remote Sensing of Aerosols, Clouds and Precipitation*, 2017. By Tanvir Islam, Yongxiang Hu, Alexander Kokhanovsky and Jun Wang, Elsevier, ISBN 9780128104378, 364 pages, US$120.00

(2017-8) *Mixed-Phase Clouds: Observations and Modeling*, 2017. By Constantin Andronache, Elsevier, ISBN 9780128105498, 300 pages, US$89.95

(2018-1) *Synoptic Analysis and Forecasting, An Introductory Toolkit*, 2017. By Shawn Milrad, Elsevier, ISBN 9780128092477, 246 pages, US$125.00

(2018-2) *Ice Caves*, 2017. Edited by Aurel Persoiu, Elsevier, ISBN 9780128117392, 752 pages, $225.00

You review it, yours to keep!

Other News

CWRA National Conference, 28th May to 1st June 2018, Victoria, BC.

The 71st annual Canadian Water Resource Association national conference is fast approaching. Hosted in Victoria, British Columbia, between May 28th and June 1st, 2018,"Our Common Water Future: Building Resilience through Innovation" will bring water resource professionals and others together to help chart the path to that safe, sustainable and resilient water future. Conference topics cover transboundary water management, policy and governance, First Nations and water, flood and drought management, ecosystems, science, technology and more. Events will include technical sessions, social/networking events, selected tours and plenary speakers from around North America. Register through the [CWRA website (conference.cwra.org)!](conference.cwra.org)

DATA, MODELS AND ANALYSIS

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GUOQI HAN, HAI LIN and DOUW STEYN

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The CMOS Bulletin has moved on-line to http://bulletin.cmos.ca. Please continue to send articles, notes, workshop reports and news items to bulletin@cmos.ca. We will be accepting, reviewing, and publishing content on an on-going basis.

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Le *Bulletin de la SCMO* se trouve maintenant en ligne à http://bulletin.scmo.ca/. N'hésitez pas à soumettre notes, rapports d'atelier et nouvelles à l'adresse bulletin@scmo.ca. Nous accepterons, réviserons et publierons vos contenus sur une base continue.

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 and Paul-André Bolduc, for their continued editorial assistance and guidance.

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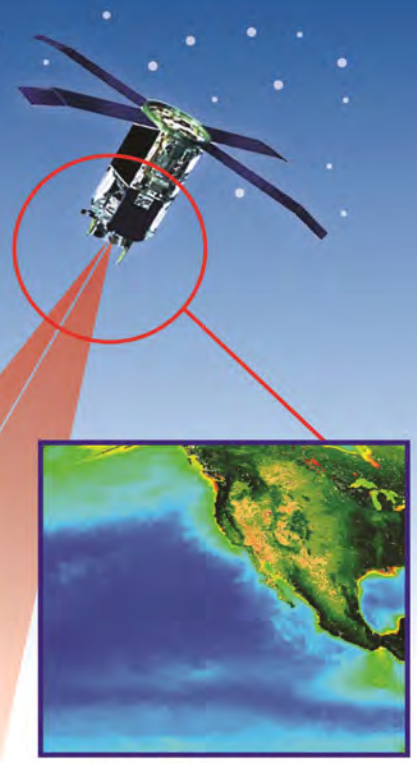
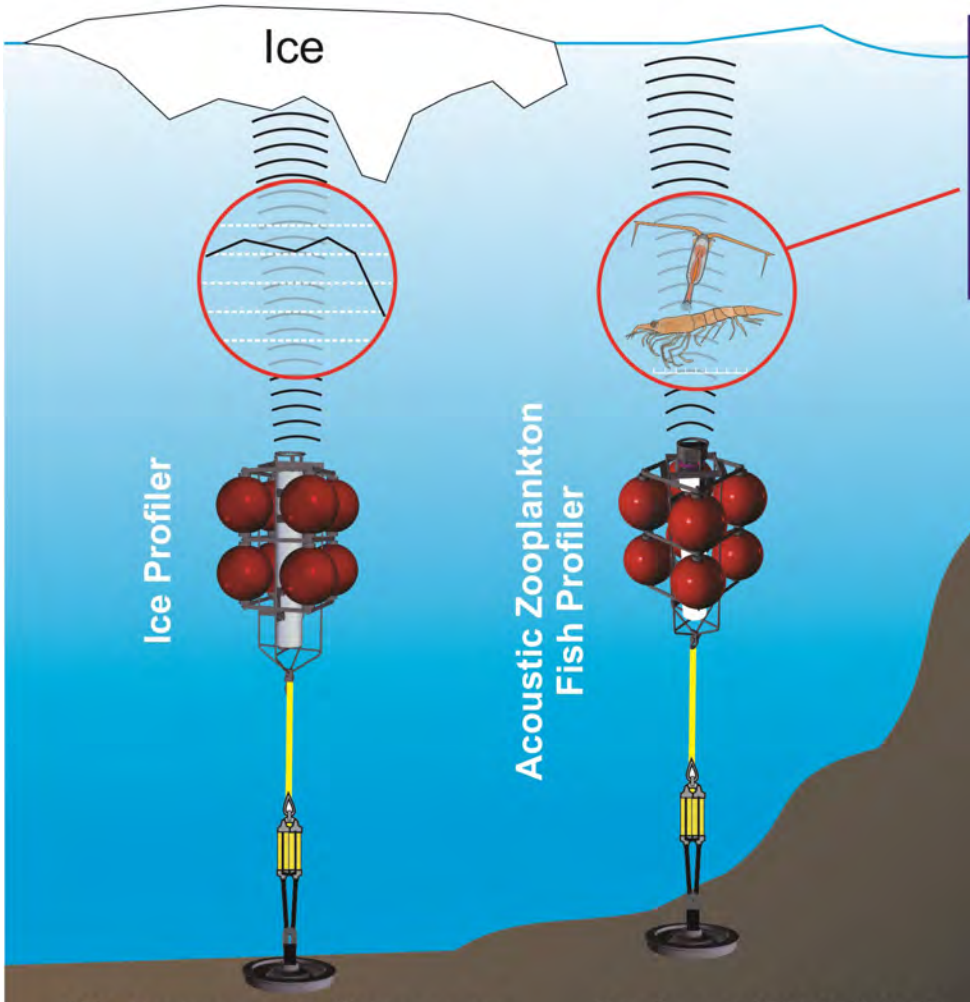
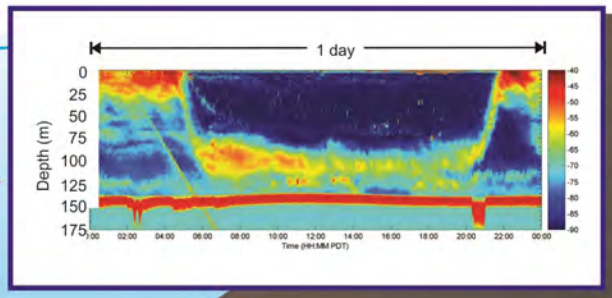


Ocean colours are chlorophyll concentrations and land colours are NDVI





ASL offers:

Ice Profiler and SWIP
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