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Photo: Dan Weaver

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CMOS Bulletin SCMO

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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.

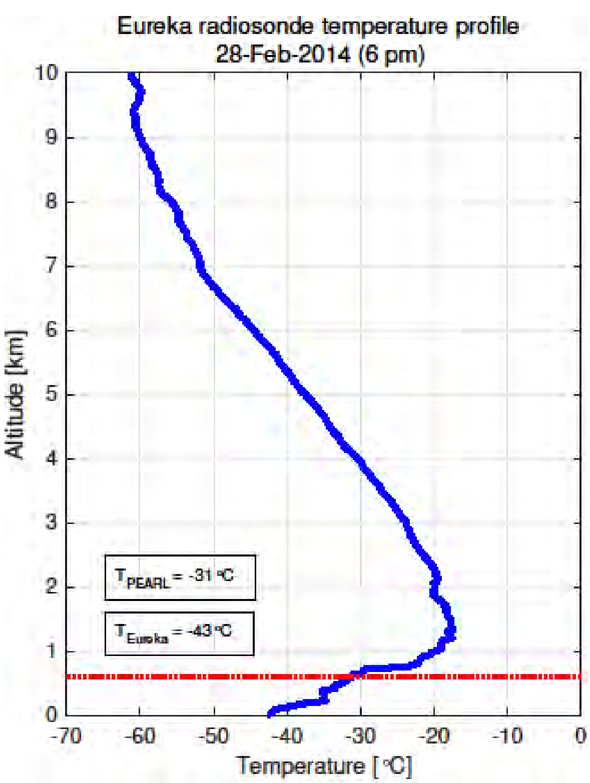
Cover Page / Page couverture

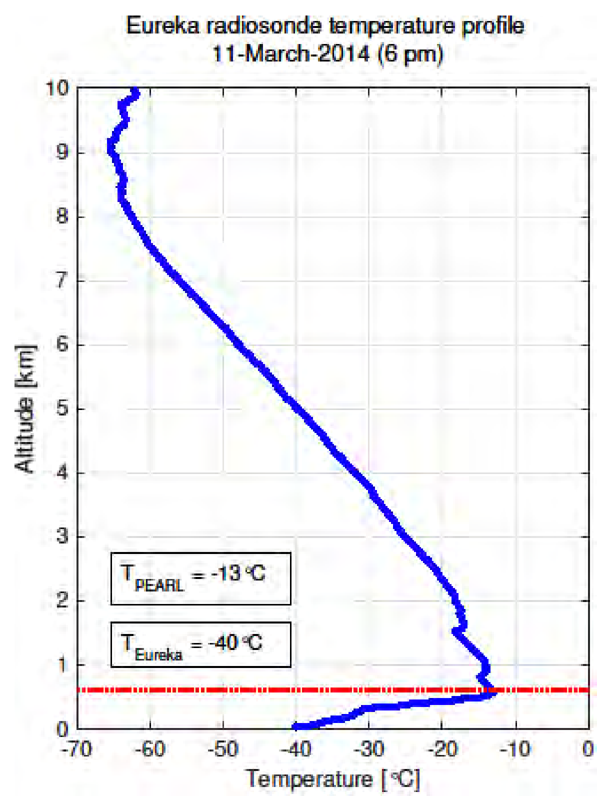
The photo on the cover was taken by University of Toronto Ph.D. student Dan Weaver. He captured this moment during a satellite validation measurement campaign on February 28, 2014, at the Polar Environment Atmospheric Research Laboratory (PEARL) on Ellesmere Island (80N), near Eureka, Nunavut. The team of researchers from U of T, York U, and U of Saskatchewan were installing a ground-based version of an instrument (MAESTRO) also aboard the Atmospheric Chemistry Experiment (ACE) satellite. People visible in the photo are: Prof. Tom McElroy (York U), Zahra Vaziri (York U), Paul Loewen (campaign operator, U of Saskatchewan), and Dr. Sophie Tran (U of T).

Dan is pursuing his doctorate at the University of Toronto Physics Department, with Prof. Kim Strong's experimental atmospheric physics group. His work primarily revolves around measurements taken at PEARL, which have applications for research into climate, ozone depletion, atmospheric dynamics, and air quality.

Dan, pictured here, hiking north of PEARL along a ridge (March 11, 2014), at an altitude that was in a temperature inversion layer. At a relatively balmy -20 °C (much warmer than the -40 °C in Eureka), Dan removed his hat and hood long enough for this photo to be snapped.

Dan, qu'on voit ici, est en randonnée au nord du PEARL, le long d'une crête (11 mars 2014), à une altitude qui se trouvait sous une inversion de température. Par une journée relativement chaude (-20 °C tandis qu'Eureka était à -40 °C), Dan a retiré son chapeau et son capuchon le temps d'une photo.





The temperature profiles from the Eureka Weather Station's radiosonde data on the dates mentioned here. The temperature and altitude of the PEARL Ridge Lab (610 m) is indicated by the dotted red line.

Le profil de température à la station météorologique d'Eureka provient des données de radiosondage enregistrées à la date figurant ici. La ligne rouge pointillée indique la température et l'altitude de la crête où se situe le laboratoire PEARL (610 m).

Cover Page / Page couverture

La photo de couverture a été prise par Dan Weaver, étudiant au doctorat de l'Université de Toronto. Il a capturé ce moment au cours d'une campagne de mesure visant à valider des données de satellite, le 28 février 2014, au Laboratoire de recherche atmosphérique dans l'environnement polaire (PEARL), sur l'île Ellesmere (80° N), près d'Eureka (Nunavut). L'équipe de chercheurs des universités de Toronto, de York et de la Saskatchewan installait une version terrestre d'un instrument (MAESTRO) aussi embarqué sur le satellite ACE (Atmospheric Chemistry Experiment). La photo montre le professeur Tom McElroy (York), Zahra Vaziri (York), Paul Loewen (Saskatchewan), responsable de la campagne, et Sophie Tran Ph.D. (Toronto).

Dan poursuit ses études de 3[e] cycle au département de physique de l'Université de Toronto, sous la direction de Kim Strong, au sein du groupe de physique atmosphérique expérimentale. Ses travaux portent principalement sur les mesures prises au PEARL et qui serviront aux études sur le climat, la diminution de la couche d'ozone, la dynamique de l'atmosphère et la qualité de l'air.

The team, hiking along a ridge north of PEARL.

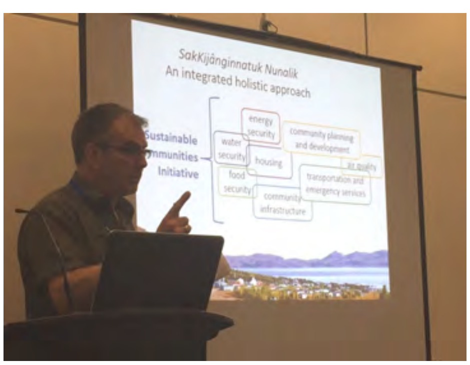
L'équipe en randonnée le long d'une crête au nord du PEARL.

The Brewer spectrophotometer dome. The instrument is deployed around the world to measure ozone.

Le dôme du spectrophotomètre Brewer. Ce type d'instrument mesure partout dans le monde les concentrations d'ozone.

Correction, October 2016 (Vol 44. No. 5) issue of the CMOS Bulletin:

Captions for photos were not included by the editor in the article by Ann McMillan "Arctic Leaders: Interview with Trevor Bell and Andrew Arreak" (p. 5 of the print edition, p. 7 of the web edition):



Trevor Bell presenting at the CMOS Congress in Fredericton. (Photo credit: Norah Foy)

Andrew Arreak being interviewed at the CMOS Congress in Fredericton. (Photo credit: Helen Joseph)

This photo, from "Meet the North", shows Andrew Arreak from Pond Inlet out on the ice with the SmartQAMUTIK, taking ice thickness measurements. (Photo credit: Eric Guth, www.meetthenorth.org)

From the Field

Ph.D. Fieldwork in the Canadian High Arctic

Dan Weaver, University of Toronto

Dan has been doing fieldwork at the Polar Environment Atmospheric Research Lab (PEARL) since 2012. Here, he offers some thoughts about projects he's been involved in.

The PEARL Ridge Lab, overlooking a blanket of fog. This fog likely resulted from a lead opening up in the area (i.e. a crack in the sea ice that exposes liquid water). The temperature inversion would help keep the fog in place for longer, as it impedes air from rising past its height.

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At 80°N, PEARL and the nearby Environment and Climate Change Canada weather station (Eureka, Nunavut) are located at one of the most northern places in the world. The location offers extraordinary opportunities to investigate the Arctic and global atmosphere. Despite the important role played by the Arctic in environmental issues such as climate change and ozone depletion, there are few measurements of the atmosphere taken at high northern latitudes. It's remote, and conditions are difficult. Because there are few places in the world like it, PEARL is the site of dozens of instruments, experiments, and international collaborations. PEARL's Principal Investigator, James Drummond, offered an overview of the wide-ranging research conducted at PEARL last year in the December 2015 issue of the CMOS Bulletin.

No single instrument can comprehensively map the atmosphere. Each instrument at PEARL has advantages and limitations. Collectively, they are offering a more complete picture of the Canadian high Arctic atmosphere than ever before. My efforts have primarily involved working with a high resolution Fourier transform Spectrometer (FTS) at PEARL, the Bruker 125HR. It's a sophisticated instrument that measures spectra from sunlight as frequently as every few minutes. Techniques for using FTS spectra to observe atmospheric gases have been under continuous development for decades. New analysis techniques can be applied to past spectra. One of the key advantages of FTS instruments is their ability to measure many gases simultaneously. This enables the capture of information about atmospheric processes that I'm interested in, such as the chlorine chemistry related to ozone depletion. The 125HR also measures gases related to global warming, pollution, biomass burning, and other topics.

Recently, I've compared techniques used by several PEARL instruments to measure atmospheric water vapour. I documented how well these techniques are performing, and quantified the agreement and biases between them. There is a lot of interest in understanding water vapour because of its substantial influence on weather, climate, and radiative balance. My work showed, for example, that a new 125HR dataset, produced using the recently-developed MUSICA[1] project retrieval technique, captures accurate measurements of high Arctic water vapour and its vertical distribution. This complements other datasets. Radiosondes, for example, have better vertical resolution but take infrequent measurements. Uniquely at PEARL, the 125HR can measure atmospheric HDO (semi-heavy water). Looking at the ratio of H_2O and HDO (i.e. δD) enables investigation of the water cycle, and tell us about the history of physical processes experienced by the air above the lab. Its ability to frequently measure water vapour and its isotopologue HDO with high accuracy makes PEARL's new 125HR MUSICA product a valuable addition to high Arctic datasets. The suite of instruments at PEARL offers a useful laboratory for experimenting with new measurement techniques, since the results can be compared to a variety of instruments and datasets.

FTS instruments like the 125HR can't take measurements at night because they use sunlight. Moreover, at 80° N, the sun sets mid-October and doesn't rise until mid-February (Figures 1 & 2). Polar Night lasts four months. Work towards using moonlight for 125HR measurements is ongoing and promising. But the moon is often not available, and it offers a significantly less intense signal than the sun, limiting what can be measured. (To start, I aim to get information about ozone and HNO_3). Other instruments can measure the atmosphere in the dark. For example, PEARL is equipped with an FTS instrument that measures infrared radiation emitted from the atmosphere (an Atmospheric Emitted Radiance Interferometer (AERI)) every few minutes. It can take measurements anytime. While it can't get information about gas profiles like a solar-viewing FTS, I've shown

[1] *Multi-platform remote sensing of Isotopologues for investigating the Cycle of Atmospheric water (MUSICA):* http://www.imk-asf.kit.edu/english/musica.php

that the AERI, too, can accurately measure atmospheric water vapour (total columns). We're making progress towards having continuous observation of the atmosphere, day and night, year-round.

When sunlight finally returns to Arctic latitudes, it initiates atmospheric chemistry processes that dramatically change the composition of the atmosphere. Intense ozone depletion happens. PEARL instruments make crucial measurements of this chemistry, but they are best able to understand what is happening across the Arctic in combination with satellite measurements.

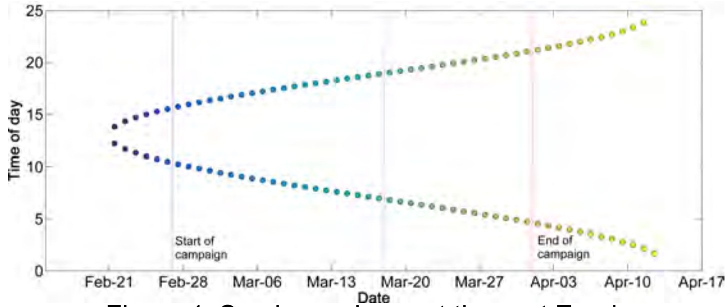

Figure 1: Sunrise and sunset times at Eureka.

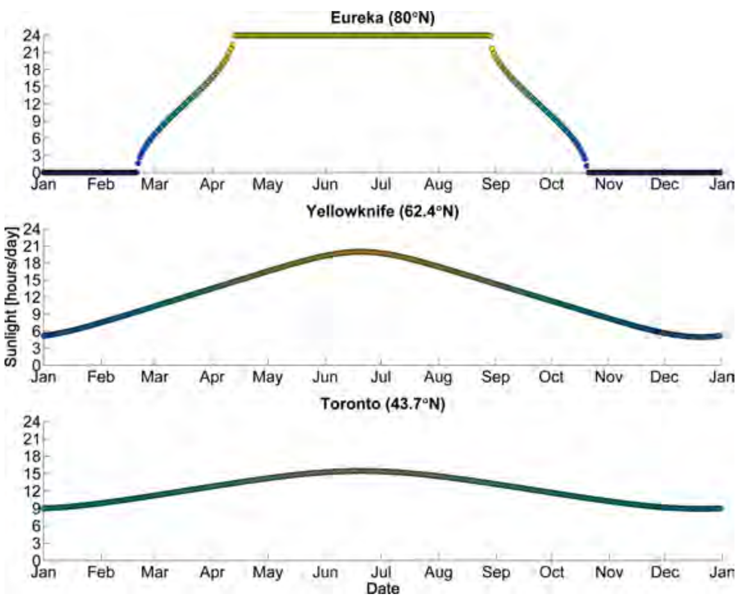

Figure 2: Sunlight hours per day (top to bottom): Eureka, Yellowknife, Toronto

A Canadian satellite, the Atmospheric Chemistry Experiment (ACE), has been monitoring ozone depletion chemistry for over a decade. Working with ACE data, and being a member of the validation campaigns has been a fantastic experience. The satellite validation campaigns at PEARL have taken place every winter/spring since 2004, supported by the Canadian Space Agency. They involve setting up, maintaining, upgrading, and troubleshooting instruments. And making measurements. I took the image on the cover of this issue of the CMOS Bulletin on one of the first days of the campaign in 2014, when the team was installing a ground-based version of an instrument on the ACE satellite (MAESTRO) on the roof of the PEARL Ridge Lab. It's quite the view from up there!

Operating state-of-the-art instruments in the Canadian high Arctic's extreme environment poses challenges. Not only for instruments (I've had to carefully free protective instrument covers that became frozen shut), but also for researchers. Whether you are a professor or grad student, you are likely to pick up a shovel at some point and dig the truck out of a snowdrift between Eureka and the PEARL Ridge Lab. There are some respites from the cold during strong temperature inversions. The PEARL Ridge Lab is sometimes 20°C warmer than Eureka.

If weather is favorable, it takes me a few days to travel from my home in Toronto to the PEARL Ridge Lab (located 4000 km North). Satellites in near-polar orbits, on the other hand, pass over the Arctic often. This type of orbit is often used by science missions because it enables instruments to have near-global coverage. Ground-based measurements taken at PEARL are used to complement, reinforce, and validate satellite data from a variety of missions. (Validation ensures the satellite data is accurate.) For example, using the ground-based 125HR and radiosondes, I've shown that ACE instruments are able to accurately measure high Arctic water vapour profiles in the upper troposphere, a part of the atmosphere significant for its influence on radiative balance. I've also supported teammates in taking measurements that support validation of NASA's Orbiting Carbon Observatory (OCO-2) and Japanese Greenhouse gases observing satellite (GOSAT) missions. Eureka is useful location for satellite validation, but it is also a challenge. The Arctic can be a difficult place for satellite measurements because of snow cover, clouds, and variable land cover types and terrain. PEARL-based validation measurements allow us to check if instruments in orbit are able to overcome those challenges.

To follow the annual field campaigns at PEARL, visit the campaign website between mid-February and late-March. I won't be there this time. I'll be writing my thesis. But I'll follow along. It's a great story of science and adventure in the Canadian North.

Campaign website: acebox.uwaterloo.ca/eureka/; Dan's website: www.danweaver.ca/photography/arcticphotos; CANDAC/PEARL website: www.candac.ca

Photo courtesy of Dan Weaver

Atmosphere-Ocean 54-5 Paper Order

Applied Research / Recherche appliquée

Occurrence, durée et intensité des précipitations simulées par deux modèles régionaux canadiens du climat sur la région du Maghreb
Mariem Jelassi, Philippe Gachon, and René Laprise

Fundamental Research/Recherche fondamentale

Statistical Evidence for Asymmetry in ENSO–IOD Interactions
R. Kartika Lestari and Tieh-Yong Koh

Long-Term Variability of the Wind Field over the Indian Ocean Based on ERA-Interim Reanalysis
R. Rashmi, V. Polnikov, F. Pogarskii, I. Gomorev, V. Samiksha, and P. Vethamony

A Review of Thunderstorm Trends across Southern Ontario, Canada
Steven M. Huryn, William A. Gough, and Ken Butler

Distributions of Downwelling Radiance at 10 and 20 µm in the High Arctic
Zen Mariani, K. Strong, and J. R. Drummond

Evaluation of Total Precipitable Water from CRCM4 using the NVAP-MEaSUREs Dataset and ERA-Interim Reanalysis Data
D. Paquin, A. Frigon, and K. E. Kunkel

Next Issue CMOS Bulletin SCMO

The next issue of the CMOS Bulletin SCMO will be published in February 2017. Please send your articles, notes, workshop reports or news items before January 6th, 2017, to bulletin@cmos.ca.

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Prochain numéro du CMOS Bulletin SCMO

Le prochain numéro du CMOS Bulletin SCMO paraîtra en février 2017. Prière de nous faire parvenir avant le 6 janvier 2017 vos articles, notes, rapports d'atelier ou nouvelles à bulletin@cmos.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.