ISSN 1195-8898

CMOS BULLETIN SCMO

Canadian Meteorological and Oceanographic Society

La Société canadienne de météorologie et d'océanographie

October / octobre 2006 Vol.34 No.5

CANDAC

Canadian Network for the Detection of Atmospheric Change

Polar Environment Atmospheric Research Laboratory

PEARL

ØPAL

Zero Altitude PEARL Auxiliary Laboratory

Our thanks to the following for their support of CANDAC and PEARL

Environment Canada | Environnement Canada

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

NSERC
CRSNG

Ontario Innovation Trust

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Ontario MINISTRY OF RESEARCH & INNOVATION

Nova Scotia Research and Innovation Trust

CSA ASC

Polar Continental Shelf Project (PCSP)

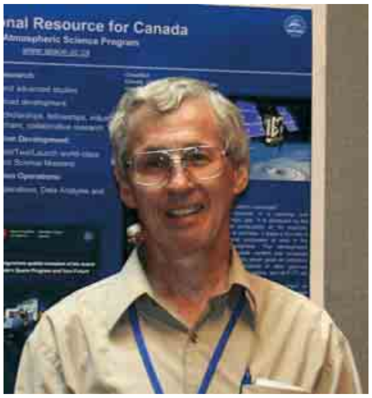
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

International Arctic Systems for Observing the Atmosphere
IASOA

INTERNATIONAL POLAR YEAR 2007-2008

....from the President's Desk

Friends and colleagues:



Geoff Strong, President CMOS
Président SCMO

Summer has pretty much passed as I write this brief article, and it seems like the new year really begins in September when summer holidays are over and students head back to school or university, and some of us start teaching again. In agricultural areas, September is also a time to assess the results of harvest, often on the heels of drought in some regions, heavy rains over other areas, damaging hailstorms, tornadoes, etc. This summer has been no exception on the prairies, with deadly tornadoes in Manitoba, damaging hail in central Alberta during early August at the most critical time prior to harvest, and continuing drought in central Alberta despite the hailstorms. Other regions have comparable weather problems; for example, the Atlantic region is still under threat from hurricanes right through October, while all Canadians need to be concerned about climate change. Our Canadian weather and climate truly exert major controls on how we live.

Meanwhile, CMOS has received increased visibility as a result of its statement and press conference on climate change at the Toronto Congress, with various follow-up interviews and articles on this issue. This statement was published in the August *CMOS Bulletin SCMO* (Vol.34, No.4, pp.108-109). Our official stand has been to support the IPCC statement on climate change, which has the consensus of the majority of scientific experts nationally and internationally. This viewpoint was also reflected in a CMOS open letter to the Prime Minister in April also published in the June *CMOS Bulletin SCMO* (Vol.34, No.3, pp.71-72).

Further to this, the new CMOS *ad hoc* Strategic Planning Committee, at its first meeting in September, among other issues such as membership and publicity, will decide how best to address the motion passed at the Congress Annual General Meeting that committed us *to take a more visible and effective, national and political role in support of issues relevant to CMOS and its members*. The above actions show that we are already moving in that direction.

(Continued on page 143 / Suite à la page 143)

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

Le but de la SCMO est de stimuler l'intérêt pour la météorologie et l'océanographie au Canada.

Volume 34 No.5
October 2006 — Octobre 2006

Inside / En Bref

Printed in Kanata, Ontario, by Gilmore Printing Services Inc.
Imprimé sous les presses de Gilmore Printing Services Inc., Kanata, Ontario.

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

Editor / Rédacteur: Paul-André Bolduc
Canadian Meteorological and Oceanographic Society
Société canadienne de météorologie et d'océanographie
P.O. Box 3211, Station D
Ottawa, ON, Canada K1P 6H7
E-Mail: bulletin@cmos.ca; Courriel: bulletin@scmo.ca

Cover page : The composite picture on the front cover shows scenes from Eureka, Nunavut, where CANDAC has recently established the PEARL (upper left) and ØPAL (upper right) laboratories to provide comprehensive measurements of the atmosphere from the ground to 100 km. Also shown are members of the 2006 ACE Arctic validation team (lower left) and members of the summer 2006 instrument installation team (lower right). This special issue includes a series of articles describing past, current and planned research activities at Eureka. Photos shown are courtesy of Pierre Fogal, Paul Loewen and Keith MacQuarrie.

Page couverture: L'image composite de la page couverture avant montre des scènes de Eurek, Nunavut, où CANDAC a récemment établi les laboratoires PEARL (haut gauche) et ØPAL (haut droit) pour fournir des mesures compréhensives de l'atmosphère, du sol jusqu'à 100 km. On voit aussi les membres de l'quipe de validation de ACE Arctique 2006 (bas gauche) ainsi que les membres de l'équipe d'installation des instruments de l'été 2006 (bas droit). Ce numéro spécial comprend une série d'articles décrivant les activités de recherche passées, courantes et planifiées à Eureka. Les photos sont de Pierre Fogal, Paul Loewen et Keith MacQuarrie.

Finally, we will continue to vigourously publicize the upcoming Congress in St. John's next May. This will be somewhat of a watershed congress, since for the first time we will be co-hosting the congress with the Canadian Geophysical Union (CGU), of which roughly half their members are hydrologists. The Eastern Snow Conference will also meet at this time, as well as three prominent committees of the American Meteorological Society (Polar Meteorology and Oceanography, Climate Variability, and Air-Sea Interactions). This level of interdisciplinary and international collaboration bodes very well for CMOS. Plan to attend this busy Congress while visiting one of the oldest and most interesting cities in North America!

Together with on-going issues, the coming year promises to be a very demanding one.

Sincerely,

Geoff Strong
President / Président

Highlights of Recent CMOS Meetings

There were no official CMOS meetings held during July or August. See the August issue of the *CMOS Bulletin SCMO* (Vol.34, No.4, p.140) for a summary of Congress and June meetings. The next scheduled meetings are:

- CMOS Student Committee, September 2006 (day to be announced;
- *ad hoc* Strategic Planning Committee, 13 September 2006 (postponed from July);
- CMOS Executive, 20 September 2006;
- CMOS Council, 27 September 2006.

Next Issue *CMOS Bulletin SCMO*

Next issue of the *CMOS Bulletin SCMO* will be published in **December 2006.** Please send your articles, notes, workshop reports or news items before **November 3, 2006** to the address given on page 142. We have an URGENT need for your written contributions.

Prochain numéro du *CMOS Bulletin SCMO*

Le prochain numéro du *CMOS Bulletin SCMO* paraîtra en **décembre 2006.** Prière de nous faire parvenir avant le **3 novembre 2006** vos articles, notes, rapports d'atelier ou nouvelles à l'adresse indiquée à la page 142. Nous avons un besoin URGENT de vos contributions écrites.

CMOS Office Moved

During the summer, CMOS office moved within the Centennial Towers Building where most of DFO offices are located. CMOS Office moved from the 8th to the 10th floor, on the East wing of the cruciform building.

CMOS Office has actually three "workstation" addresses:

- 10E235 for Lise Harvey, Office Manager.
- 10E236 for Ian Rutherford, Executive Director, and for Dorothy Neale, Executive Secretary.
- 10E238 for Richard Asselin, Director of Publications, for Uri Schwarz, Executive Director Emeritus, and for Paul-André Bolduc, *CMOS Bulletin SCMO* Editor.

Please note that the CMOS postal address, telephone numbers and fax number remain unchanged.

For security reasons, please contact us before visiting our office.

Les bureaux de la SCMO ont déménagé

Durant l'été, les bureaux de la SCMO ont déménagé à l'intérieur des Tours Centennial où sont situés la plupart des bureaux du MPO. Les bureaux de la SCMO sont déménagés du 8^{e} au 10^{e} plancher dans l'aile est de l'édifice en forme de croix.

Les bureaux de la SCMO occupent présentement trois espaces de travail:

- 10E235 pour Lise Harvey, Chef de bureau.
- 10E236 pour Ian Rutherford, Directeur exécutif, et pour Dorothy Neale, Secrétaire exécutive.
- 10E238 pour Richard Asselin, Directeur des publications, pour Uri Schwarz, Directeur exécutif émérite, et pour Paul-André Bolduc, Rédacteur du *CMOS Bulletin SCMO*.

Prière de prendre note que l'adresse postale, les numéros de téléphone ainsi que le numéro de télécopie sont restés inchangés.

Pour des raisons de sécurité, contactez-nous avant de venir nous visiter.

EUREKA - A Short History of the Weather Station

by Shelley Rouire, Editor[1]

Early History

Eureka is the "garden spot of the Arctic." Only 1100 kilometres from the North Pole, it is located on the Fosheim Peninsula, on the northern shore of Slidre Fiord. A few kilometres to the northeast is 825-metre-high Blacktop Ridge, while the Sawtooth Mountains, with peaks to 1200 metres, are 65 kilometres east of the station.

Eureka, the first High Arctic Weather Station (HAWS), was established on April 7, 1947 when the United States Army Air Force flew in materials which had been assembled at Thule, Greenland the previous year. Although much of the land was rough, rising to 1,000 or 2,000 metres, the most satisfactory location appeared to be in Slidre Fiord on Ellesmere Island, centrally located at latitude 80º00'N longitude 85º56'W. Within the fiord, the ice was quite smooth. Protected by hills from the prevailing north-westerly winds, it is surrounded by low rolling country and is in the vicinity of two rivers, which promised fresh water in summer. A six-man joint staff erected Jamesway huts as temporary buildings to house themselves and their equipment, while starting and maintaining a program of weather observations. The station personnel landed at Slidre Fiord at 11:00 AM with one of these buildings on board. By 7:00 PM, the building was up and heated, radio equipment and facilities for weather observations were in operation and hot meals were available for personnel. The white wolves gambolled with the packing paper flying about from open crates and were as curious in 1947 as they are today.

A land airstrip was considered very desirable in the event of medical emergency and to provide against the possibility that ice would not freeze smooth in the fiord near the station every year. Accordingly, two small airborne tractors, an airborne roller, harrow grader and hydraulic pan were airlifted to the station in May. The six men at the station constructed an airstrip during July, at the same time maintaining full weather observations and radio schedules at the station. The original airstrip is orientated north/south about 5 km NE of the camp. The present airstrip became operational around 1950-52.

An icebreaker reached the Eureka Weather Station on August 9, 1947. This ship brought permanent buildings, additional equipment, a year's supply of consumable stores, and two additional men for station staff. Work was immediately begun on erection of the permanent buildings and all were completed prior to the dark period and cold weather in winter. Additional buildings were added in subsequent years to provide more space and additional facilities. An icebreaker has successfully reached the Eureka Weather Station every year at the end of August since 1947.

Figure 1: Eureka 2006 - the new operations complex.

Current Operations

Eureka facilities have been upgraded over the years and provide transient room and board for the many expeditions in the Spring to the North Pole but primarily is for support to accredited scientists, generally screened through the Polar Continental Shelf Project (PCSP) of NRCan. Construction of a new 16,000 square foot operations complex in Eureka was completed in September 2005 (Figure 1). The complex houses six Environment Canada staff, two researchers from the University of Toronto and two employees contracted to operate heavy machinery and provide mechanical services. The structure includes a kitchen and dining room, recreation space, Weather Station offices and other workspaces.

Given its unique location, Eureka will also play a pivotal role in the 2007-2008 International Polar Year (IPY). The IPY offers a chance to build on existing programs and develop a range of education and outreach activities that will attract the next generation of polar scientists and engage the Canadian public.

The opening of the National Parks Reserve on Northern Ellesmere in September 1989 has also increased the visitor

[1] Surface Operational Programs, Atmospheric Monitoring Section
Meteorological Service of Canada, Prairie and Northern Region, Winnipeg

and transient population during the summer months. The Russian tour ship Kapitan Kalibnekov has visited Northern Ellesmere Island on a number of occasions during the last decade with stops in Slidre Fiord and visits to Eureka as well.

A Research Support Opportunity at Eureka and Mould Bay for graduate students in environmental research was established in 1987 by the Minister of Environment to help encourage field research in the High Arctic Islands. This opportunity still continues at Eureka and almost every year candidates are recommended by the Association of Canadian Universities for Northern Studies.

One significant action plan announced from the 1990 federal government Green Plan was a high Arctic stratospheric ozone detection observatory. A site was selected on May 1, 1991, located approximately 15 km west of the Weather Station. Road construction and power lines were completed in September 1991 and the observatory (called Project AStrO) was constructed by Christmas 1992. The AStrO observatory was operational in March 1993, with two Japanese/Canadian laser radars (LIDAR) and one infrared interferometer. The University of Saskatchewan also installed a variety of sophisticated optical instruments for studies of auroral phenomena in the mesosphere.

Clean-up efforts of solid waste material at the HAWS commenced in the early 1980s with about 7000 returnable empty fuel drums at Eureka steam cleaned and shipped to Montréal. The remaining 15,000 empty drums were crushed for landfill and used to widen the airfield shoulders. This is an ongoing and co-operative activity with Environment Canada's partners in the High Arctic: the Department of National Defence (DND), PCSP, and Parks Canada. Discussions have taken place to determine the feasibility of eliminating fuel drums by switching to bulk aviation fuel and installing a suitable dispensary at the airstrip. A similar drum-crushing exercise occurred at Mould Bay in 1991.

Eureka, Nunavut is the last remaining High Arctic Weather Station that is totally operated and managed by Environment Canada (EC). The Department holds the land lease for the immediate area surrounding the station. The Department of National Defence controls the land usage and maintains the 4800 ft gravel airstrip. The DND and PCSP have established seasonal bases at Eureka, usually between May and August to support their operations during the summer months. DND completed a new facility (1998-99) at the airstrip to accommodate up to 40 military personnel who maintain the High Arctic Data Communications System (HADCS) between Eureka and Alert.

Normally there is a re-supply charter from Resolute Bay every three weeks during the winter season, which increases to every two weeks in the summer due to the influx of people staying at the station. Additional charters come in between scheduled produce flights in support of other agencies on an 'as & when required' basis to bring in (or out) supplies. DND will often use a C-130 Hercules to bring in their fuel and supplies via Trenton-Thule-Alert. A major sea-lift occurs once a year during the latter part of summer (anywhere from the last week of August to the first week of September) to bring in our annual re-supply of dry goods, equipment, supplies and fuel by Canadian Coast Guard icebreakers.

At present there is a minimum staff of six EC personnel – Station Program Manager (SPM), Senior Aerological Observer (SAO), Meteorological Technicians (two), Cook, and Handyperson – who cycle through Eureka on a 3-4-month rotation. Environment Canada staff conduct ice and snow measurements and provide upper air observations required for weather predictions, services and science both nationally and internationally as part of EC's global commitments. In addition, observations from Eureka provide stratospheric ozone and UV data required to support health-related warnings, the UV index and trends in stratospheric ozone used in determining the effectiveness of the Montréal Protocol and the Vienna Convention. Additionally there is a contract mechanic and heavy equipment operator that cycle through on a 4-month rotation.

Other Research at Eureka

Two groups currently partnered with Environment Canada, the Canadian Network for Detection of Atmospheric Change (CANDAC) and the Study of Arctic Environmental Change (SEARCH), have established a number of experiments at Eureka.

CANDAC, led by the University of Toronto, opened the Polar Environmental Atmospheric Research Laboratory (PEARL). SEARCH, led by the National Oceanic and Atmospheric Administration (NOAA) in the United States, conducts research to understand the full scope of changes occurring in the Arctic.

Environment Canada has entered into an agreement to allow these groups to use the physical structure that was home to the Arctic Stratospheric Ozone Laboratory. CANDAC received funding for the refurbishment and re-equipping of the laboratory and collaborates with Canadian government departments, universities and industrial research organizations to further their mutual goals.

PEARL will measure atmospheric parameters from the ground to 100 km on a continuous basis, and will be associated with the Environment Canada Weather Station. The PEARL location has significant advantages as an atmospheric observing site: the large number of clear "nights"; opportunities for measurements inside and outside the polar vortex; and the high overpass rate by polar orbiting satellites (important for satellite validation activities). Parameters measured will include: temperature, wind, composition, aerosols, clouds and precipitation.

Through SEARCH, government agencies in the United States cooperate to understand the full scope of the changes occurring in the Arctic. Scientists research exactly how the observed changes relate to the Arctic's natural variability and if the changes indicate the start of a major climate shift in the North.

The SEARCH science strategy contains four major activities:

- Long-term observations to detect and monitor the environmental changes;
- Modeling to synthesize observations, test ideas about the coupling between components of change and to predict its future course;
- Process studies to understand potentially important feedbacks; and
- Application of what we learn to understanding and responding to the impact of physical changes on ecosystems and societies.

History of the Eureka Arctic Ozone Observatory

by Hans Fast[2], Tom Duck[3] and Kimberly Strong[4]

Introduction

The establishment of the Eureka Arctic Ozone Observatory originates from the discovery of the Antarctic Ozone Hole, the realization that similar ozone destruction could happen in the Arctic, and the initiation, primarily by NASA, of the Network for Detection of Stratospheric Change (NDSC) during the mid-1980s. By 1989, it was evident that Canada could be vulnerable to Arctic ozone loss and that, while several countries had proposed or indeed commissioned NDSC observatory sites in mid-latitudes and the Antarctic, Canada should build an Arctic Observatory. Environment Canada then initiated planning for an observatory, developed or contracted development of observing equipment such as the Optech ozone DIAL system, the double Brewer Spectrometer and a BOMEM Interferometer. Also, partnerships were developed with Japanese agencies, such as the Japan Meteorological Agency and the Communications Research Laboratory (CRL), which had expressed interest in making Arctic stratosphere measurements in Canada. The University of Saskatchewan Institute of Space and Atmospheric Studies which, as part of the Canadian Network for Space Research, was to undertake a program of Arctic aurora studies. This was another initial partner, as were York University and CRESTech, then known as ISTS.

The NDSC held what might be considered its first truly international meeting in November 1989, on the occasion of its joining with the World Meteorological Organization. At that meeting, the plans for the Canadian Arctic Observatory were described. The location was then to be either Resolute or Alert. Soon after, the choice of Eureka was made following a review of the atmospheric viewing conditions, the Arctic stratosphere vortex statistics, the optimum latitude for Fourier spectrometer solar occultation measurements of stratospheric chemistry, and a tour of the various potential sites. The Arctic Stratospheric Ozone (AStrO) observatory, as it came to be known, was a designated "component" (Ny Alesund, Thule, Summit and Sondre Stromfjord are the other components) of the "primary" "Arctic Station" in the NDSC, which was recently renamed NDACC (Network for the Detection of Atmospheric Composition Change).

Shortly after the November 1989 meeting, the Observatory was incorporated into the federal government's "Green Plan", which was a comprehensive plan to enhance Canada's environmental stewardship and which was subsequently funded and announced publicly in 1992. The building was erected during the summer and fall of 1992 (see Figures 1, 2, 3, and 4), and the first measurements were taken in January 1993. These included lidar measurements of the vertical distribution of aerosol and stratospheric ozone. Figures 5 and 6 show the installation of the lidar system. Brewer measurements of column ozone using moonlight and airglow spectral measurements were also carried out. These were followed, after sunrise on February 22, by the first Fourier Transform Infrared (FTIR) measurements at Eureka.

---

[2] Environment Canada, Downsview, ON

[3] Department of Physics and Atmospheric Science, Dalhousie University, Halifax, NS

[4] Department of Physics, University of Toronto, Toronto, ON

Figure 1: Construction of the AStrO Observatory in July, 1992.

Figure 2: Insulating the Observatory.

Figure 3: Constructing roof hatches for a variety of remote sensing instruments.

Figure 4: Completed Observatory as seen in July, 1993.

Figure 5: Installing support frames for the lidar systems.

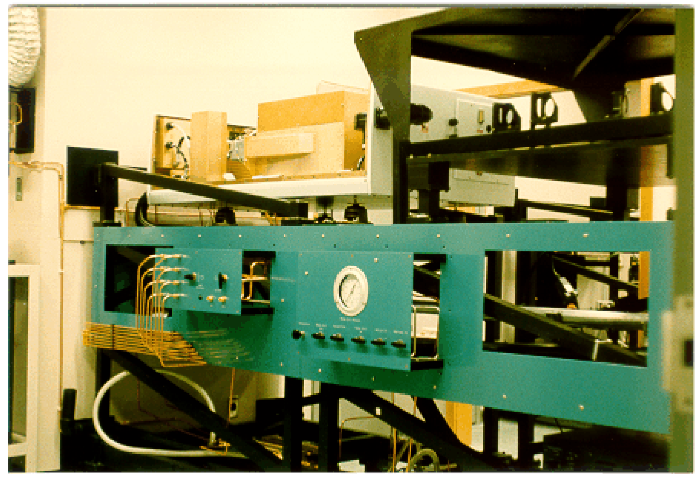


Figure 6: Completed Optech ozone DIAL installation in January, 1993.

.

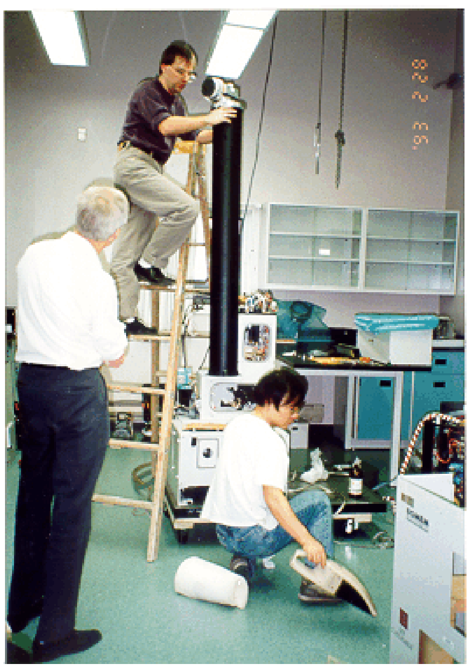


Figure 7: Installation of the BOMEM DA8 FTIR spectrometer in March, 1993.

Figure 8: Mounting the Japanese solar tracker to the roof hatch for FTIR measurements.

Spectroscopic Measurements

In a collaborative program between the Meteorological Service of Canada (MSC) and the Meteorological Research Institute (MRI) of Japan, a BOMEM DA8 FTIR spectrometer was installed at AStrO, and in March of 1993 the first solar atmospheric absorption spectra were recorded with this instrument (Figures 7 and 8). Vertical column amounts of a number of atmospheric gases that control stratospheric ozone concentrations were derived from these spectra and archived on the NDSC Data Host Facility (Donovan et al., 1997; Fast et al., 2000, 2001). So far, column measurements for N_2O, CH_4, CO, CO_2, HF, COF_2, HCl, ClO, $ClONO_2$, HNO_3, NO, NO_2 and O_3 have been made, but altitude profiles for these and other gases associated with climate change issues will also be retrieved from the archived spectral data base. An NDSC FTIR Instrument Intercomparison Campaign was conducted at AStrO from April to May of 1999 by carrying out side-by-side measurements with the Eureka DA8 and the travelling Bruker 120 M FTIR spectrometer from the National Physics Laboratory, UK. This exercise established the validity of the Eureka DA8 spectral data base and contributed to the overall precision estimates for FTIR spectrometers operated at NDSC stations (Murphy et al., 2001).

In the winter of 2001-02, the first lunar observations were made with the FTIR, providing information on the chemical composition of the stratosphere during polar night. The resulting measurements of nitric acid (HNO_3), an important constituent of polar stratospheric clouds, were compared with FTIR measurements at two other Arctic sites: Thule, Greenland (76.5°N, 68.8°W) and Kiruna, Sweden (67.8°N, 20.4°E) (Farahani et al., 2006). The Eureka lunar measurements were in good agreement with solar measurements made with the same instrument. Eureka and Thule HNO_3 columns were consistent within measurement error, while differences between HNO_3 columns at Kiruna and those at Eureka and Thule could be explained on the basis of available sunlight hours and location of the polar vortex. The measurements were also compared with results from a chemistry-climate model, the Canadian Middle Atmosphere Model (CMAM), and with results from a three-dimensional chemical transport model, SLIMCAT. More recently, spectra from the FTIR contributed to the first reported detection of NO in the mesosphere and lower thermosphere using ground-based FTIR spectroscopy (Wiacek et al., 2006).

Since 1999, the University of Toronto has deployed a UV-visible grating spectrometer at Eureka each spring in campaign mode. Eight such campaigns have been undertaken to date, with seven at AStrO and one at Resolute Bay (in 2002). This instrument records UV-visible absorption spectra of sunlight scattered from the zenith sky, from which vertical columns of ozone, NO_2, BrO, and OClO have been derived (Bassford et al., 2000, 2001, 2005). It has also been demonstrated that vertical profiles of NO_2 can be retrieved from these Arctic spectra (Melo et al., 2004). These measurements have been combined with data from the AStrO FTIR and with the Canadian Middle Atmosphere Model and SLIMCAT models to characterize and understand polar stratospheric processes (Farahani, 2006).

Lidar Measurements

From 1993-1998, sustained measurement efforts at Eureka were conducted by the York University/CRESTech and Japanese CRL/MRI lidar groups during wintertime, and continued thereafter by MSC. The Canadian group used an Optech ozone-DIAL lidar to measure profiles of temperature, ozone, and aerosols, including polar stratospheric clouds (PSCs). The Japanese group used a PSC-Haze lidar for dual-frequency aerosol measurements. The measurements were used to study ozone depletion, stratospheric dynamics, and aerosol optical properties.

Dynamics

Temperature profiles provided detailed information on the dynamics above Eureka. Large-scale middle-atmospheric temperature variations for each winter are presented by Duck et al. (2001), following the study by Whiteway and Carswell (1994) for the 1993 season. The stratospheric temperatures were found to be strongly correlated with motions of the wintertime stratospheric vortex. When the vortex core was over Eureka the lower stratosphere was cold and the upper stratosphere was warm. Conversely, when Eureka was outside the vortex altogether the lower stratosphere was warm and upper stratosphere was cold so that isothermal temperature profiles sometimes resulted. The profiles were apparently more affected by vortex motions (and therefore advection) than "sudden stratospheric warming" events that had been described in earlier studies of zonal-mean dynamics. Analysis of the dynamics, ozone, and aerosol measurements in the context of the location of the vortex and its movements was an important theme in the Canadian lidar work.

Gravity waves were observed by the small-scale perturbations that they induce in measured temperature profiles. The Eureka measurements showed that gravity wave activity is generally highest in the jet of the polar vortex, and low both inside and outside of the vortex altogether. The speed of the stratospheric wind and critical level filtering were demonstrated to determine the amount of gravity wave activity (Whiteway and Duck, 1996; Whiteway et al., 1997; Duck et al., 2001).

The average evolution of temperatures in the vortex core was investigated, and revealed a surprising result: In late December, temperatures near the stratopause rise by 30 K and propagate downward into the lower stratosphere within a few weeks. The vortex core warming is accompanied by increased gravity wave activity in the vortex jet (Duck et al., 1998, 2001). It was proposed that frictional drag induced by the gravity waves during the wave-breaking process drives flow into the core of the vortex which causes the stratospheric warming. The warming was observed to extend into the lower stratosphere, and so the process has implications for ozone depletion.

The lidar measurements were also used for studies of mesospheric inversion layers (Duck and Greene, 2003). It was found that mesospheric inversion layers occur very infrequently over Eureka, about only 5% of the time during winter. The reasons for the lack of mesospheric inversion layers when compared to the high rates at mid-latitudes are not yet understood.

Ozone

The ozone-DIAL lidar was capable of measuring ozone from the tropopause to 60 km altitude (Carswell et al., 1993), and used both the Rayleigh and Raman techniques. Yearly measurements of ozone variability are described by Donovan et al. (1995, 1996, 1997). The measurements showed that ozone variability was dominated by movements of the polar stratospheric vortex, similar to the thermal structure results. In particular, ozone was correlated with vorticity in the lower stratosphere, but was anti-correlated with vorticity in the upper stratosphere. The measurements showed evidence for strong descent in the vortex core during winter, which brings higher ozone-mixing-ratio air from the upper stratosphere and mesosphere into the lower stratosphere.

The measurements showed significant ozone depletions each year. The depletions were compared with concurrent measurements of PSCs, measurements of ClO by the FTIR system, and radiosonde temperatures (Donovan et al., 1997). Ozone depletions were shown to be associated with the formation of PSCs in cold temperatures, with elevated levels of ClO providing a key indicator of the chemistry. These results supported the proposed heterogeneous chemistry pathway involving chlorine compounds for ozone depletion.

Small-scale variability in the ozone profiles showed evidence for "laminations" due to dynamical filamentation of the vortex edge (Bird et al., 1997). The strongest laminations were found at 16 km altitude, and had a peak thickness of 1 km. Lamination occurrence was highest when the vortex was moving quickly from its quiescent position over Eureka.

<u>*Aerosols*</u>

Tropospheric haze and stratospheric aerosols were studied by both the Canadian and Japanese groups (e.g., Donovan et al., 1995, 1997, 1998; Nagai et al., 1997; Ishii et al., 1999). The stratospheric aerosol content was found to be generally anti-correlated with the potential vorticity, which indicates that air inside the vortex is very clean. Arctic haze was generally observed up to 3 km altitude, but sometimes reached as high as 5 km. A climatology for the optical properties of tropospheric haze was constructed.

Techniques were developed to measure the microphysical characteristics of stratospheric aerosols (Donovan et al., 1998). These multiple-wavelength measurements used a combination of signals from the Canadian and Japanese lidars, and produced profiles of aerosol volume mixing ratio, surface area mixing ratio, effective radius, and sulphate mixing ratio. The observations indicated that sulphate amounts decreased and the aerosol distribution changed in the lowermost stratosphere below the vortex during 1995.

Upper Atmosphere Observations

Early upper atmosphere observations at Eureka, taken in the 1990s, with optical instrumentation supported by D.J. McEwen (University of Saskatchewan) and G.G. Sivjee (Embry-Riddle Aeronautical University), provided some indications of the complexity of polar mesospheric dynamics. Although the main focus of these instruments was auroral observations, tidal and low frequency oscillations were observed in airglow and temperature (Oznovich et al., 1997; Sivjee and Walterscheid, 2002) and the signature of a stratospheric warming was analysed (Walterscheid et al., 2000). PEARL, with its emphasis on observations throughout the atmosphere (0-100 km), will be able to explore the causes of these phenomena in more detail.

The End of the AStrO Years

After ten successful years of operation, the AStrO Observatory was mothballed by Environment Canada in summer 2002, due to internal budget pressures. This decision was greeted with dismay in both the national and international atmospheric research communities (Strong, 2002). However, with support from the Canadian Foundation for Climate and Atmospheric Sciences in 2003, and from the Canadian Space Agency in 2004, 2005, and 2006, it proved possible to undertake a series of limited springtime campaigns, thereby maintaining some continuity in the data record at Eureka. In the meantime, largely spurred on by the situation at Eureka, the Canadian Network for the Detection of Atmospheric Change (CANDAC) was formed, consisting of a consortium of university and government partners. The first priority of CANDAC has been to reinvigorate the measurement program at Eureka, and the success and current status of that effort is described in the accompanying article on CANDAC and PEARL.

References

Bassford, M.R., K. Strong, and J. Rebello, An Automated Spectrometer for Monitoring Arctic Ozone Depletion, *Spectroscopy*, **15 (10)**, 42-46, 2000.

Bassford, M.R., C.A. McLinden, and K. Strong, Zenith-Sky Observations of Stratospheric Gases: The Sensitivity of Air Mass Factors to Geophysical Parameters and the Influence of Tropospheric Clouds, *J. Quant. Spectrosc. Radiat. Transfer,* **68**, 657-677, 2001.

Bassford, M.R., K. Strong, C.A. McLinden, and C.T. McElroy. Ground-Based Measurements of Ozone and NO_2 during MANTRA 1998 Using a New Zenith-Sky Spectrometer, *Atmos.-Ocean*, **43 (4)**, 325-338, 2005.

Bird, J. C., S. R. Pal, A. I. Carswell, D. P. Donovan, G. L. Manney, J. M. Harris, and O. Uchino, Observations of Ozone Structures in the Arctic Polar Vortex, *J. Geophys. Res.,* **102**, 10,785-10,800, 1997.

Carswell, A.I., A. Ulitsky, and D. Wardle, Lidar Measurements of the Arctic Stratosphere, *SPIE*, **2049**, 2031-2048, 1993.

Donovan, D.P., J.C. Bird, J.A. Whiteway, T. J. Duck, S. R. Pal, and A. I. Carswell, Lidar Observations of Stratospheric Ozone and Aerosol Above the Canadian High Arctic during the 1994/95 Winter, *Geophys. Res. Lett.*, **22**, 3489-3492, 1995.

Donovan, D.P., J.C. Bird, J.A. Whiteway, T.J. Duck, S.R. Pal, A.I. Carswell, J.W. Sandilands, and J.W. Kaminski, Ozone and Aerosol Observed by Lidar in the Canadian Arctic during the Winter of 1995/96, *Geophys. Res. Lett.*, **23**, 3317-3320, 1996.

Donovan, D.P., H. Fast, Y. Makino, J.C. Bird, A.I. Carswell, J. Davies, T.J. Duck, J.W. Kaminski, C.T. McElroy, R.L. Mittelmeier, S.R. Pal, V. Savastiouk, D. Velkov, and J.A. Whiteway., Ozone, Column ClO and PSC Measurements

Made at the NDSC Eureka Observatory (80N, 86W) during the Spring of 1997, *Geophys. Res. Lett.,* **24**, 2709-2712, 1997.

Donovan, D.P., A.I. Carswell, T. Shibata, J.C. Bird, T.J. Duck, T. Itabe, T. Nagai, S.R. Pal, O. Uchino, and J.A. Whiteway, Multiwavelength Lidar Aerosol Measurements Made at Eureka (80 N, 86 W) during early 1995, *Geophys. Res. Lett.,* **25**, 3139-3142, 1998.

Duck, T.J., and M.D. Greene, High Arctic Observations of Mesospheric Inversion Layers with Overlying Nearly Adiabatic Lapse Rates, *Geophys. Res. Lett*., **31**, L02105, doi: 10.1029/2003GL018481, 2003.

Duck, T.J., J.A. Whiteway, and A.I. Carswell, Lidar Observations of Gravity Wave Activity and Arctic Stratospheric Vortex Core Warming, *Geophys. Res. Lett.,* **25**, 2813-2816, 1998.

Duck, T.J., J.A. Whiteway, and A.I. Carswell, The Gravity Wave - Arctic Stratospheric Vortex Interaction, *J. Atmos. Sci.*, **58**, 3581-3596, 2001.

Farahani, E., Stratospheric Composition Measurements in the Arctic and at Mid-latitudes and Comparison with Chemical Fields from Atmospheric Models, *Ph.D. Thesis*, Department of Physics, University of Toronto, April 2006.

Farahani, E.E., H. Fast, R.L. Mittermeier, Y. Makino, K. Strong, C. McLandress, T.G. Shepherd, M.P. Chipperfield, J.W. Hannigan, M.T. Coffey, S. Mikuteit, F. Hase, T. Blumenstock, and U. Raffalski, Nitric Acid Measurements at Eureka Obtained in Winter 2001-2002 Using Solar and Lunar Fourier transform Infrared Absorption Spectroscopy: Comparisons with Observations at Thule and Kiruna and with Results from Three-Dimensional Models. *J. Geophys. Res*., in press, 2006.

Fast, H., R.L. Mittermeier and Y. Makino, Arctic Trace Gas Measurements in the Winter of 1996/1997 with the Solar Interferometer at Eureka, Canada, *Atmospheric Ozone, Proc. Quad. Ozone Symp.,* R.D. Bojkov and K. Shibasaki eds., 367-368, 2000.

Fast, H., R.L. Mittermeier and Y. Makino, Fourier Transform Infrared Absorption Measurements of Ozone-related Gases in the Canadian Arctic: Winters 1996/1997 and 1997/1998, *NDSC 2001 Symposium,* Arcachon, France, 24-27 September, 2001.

Ishii, S., T. Shibata, T. Nagai, K. Mizutani, T. Itabe, M. Hirota, T. Fujimoto, and O. Uchino, Arctic Haze and Clouds Observed by Lidar during Four Winter Seasons of 1993-1997, at Eureka, Canada, *Atmos. Env*.**, 33 (16)**: 2459-2470, 1999.

Makino, Y., H. Fast, R.L. Mittermeier, T. Sasaki, Y. Sawa, M. Hirota and K. Kondo Miyagawa, IR-Spectroscopic Measurements of Stratospheric Minor Constituents over Tsukuba, Japan and Eureka, Canadian Arctic, *Atmospheric Ozone, Proc. Quad. Ozone Symp.,* R.D. Bojkov and K. Shibasaki eds., 531-532, 2000.

Melo, S.M.L., E. Farahani, K. Strong, M.R. Bassford, and K.E. Preston, NO_2 Vertical Profiles Retrieved from Ground-Based Measurements During Spring 1999 in the Canadian Arctic. *Advances in Space Research,* **34 (4)**, 786-792, 2004.

Murphy, C., W. Bell, P. Woods, Ph. Demoulin, B. Galle, J. Mellqvist, W. Arlander, J. Notholt, A. Goldman, G.C. Toon, J-F. Blavier, B. Sen, M.T. Coffey, J.W. Hannigan, W.G. Mankin, N. Jones, D. Griffith, A. Meier, T. Blumenstock, H. Fast, R. Mittermeier, Y. Makino, Validation of NDSC Measurements of Ozone, Reservoir Compounds and Dynamical Tracers: Results of a Series of Side-by-Side Instrument Intercomparisons, *NDSC 2001 Symposium,* Arcachon, France, 24-27 September, 2001.

Nagai, T., O. Uchino, T. Itabe, T. Shibata, K. Mizutani, and T. Fujimoto, Polar Stratospheric Clouds Observed at Eureka (80^0N, 86^0W) in the Canadian Arctic during the 1994/1995 Winter, *Geophys. Res. Lett.,* **24**, 2243-2246, 1997.

Oznovich, I., D.J. McEwen, G.G. Sivjee, and R.L. Walterscheid, Tidal Oscillations of the Arctic Upper Mesosphere and Lower Thermosphere in Winter, *J. Geophys. Res.,* **102,** 4511-4520, 1997.

Sivjee, G.G., and R.L. Walterscheid, Low-frequency Intraseasonal Variations of the Wintertime Very High Latitude Mesopause Regions, *J. Geophys. Res.,* **107**, doi: 10.1029/2001JA000164, 2002.

Strong, K,. Canada Closing Arctic Ozone Observatory, *Meridian*, the Newsletter of the Canadian Polar Commission, pp. 6-9, Fall/Winter 2002 edition.

Walterscheid, R.L., G.G. Sivjee, R.G. Roble, Mesospheric and Lower Thermospheric Manifestations of a Stratospheric Warming Event over Eureka, Canada (80°N), *Geophys. Res. Lett.,* **27**, 2897-2900, 2000.

Whiteway, J.A., and A.I. Carswell, Rayleigh Lidar Observations of Thermal Structure and Gravity-Wave Activity in the High Arctic during a Stratospheric Warming, *J. Atmos. Sci.,* **51 (21),** 3122-3136, 1994.

Whiteway, J.A., and T.J. Duck, Evidence for Critical Level Filtering of Atmospheric Gravity Waves, *Geophys. Res. Lett.,* **23**, 145-148, 1996.

Whiteway, J.A., T.J. Duck, D.P. Donovan, J.C. Bird, S.R. Pal, and A.I. Carswell, Measurements of Gravity Wave Activity Within and Around the Arctic Stratospheric Vortex, *Geophys. Res. Lett*., **24**, 1387-1390, 1997.

Wiacek, A., N.B. Jones, K. Strong, J.R. Taylor, R.L. Mittermeier, and H. Fast, First Detection of Meso-Thermospheric Nitric Oxide (NO) by Ground-Based FTIR Solar Absorption Spectroscopy. *Geophys. Res. Lett.*, **33 (3)**, L03811, doi:10.1029/2005GL024897, 2006.

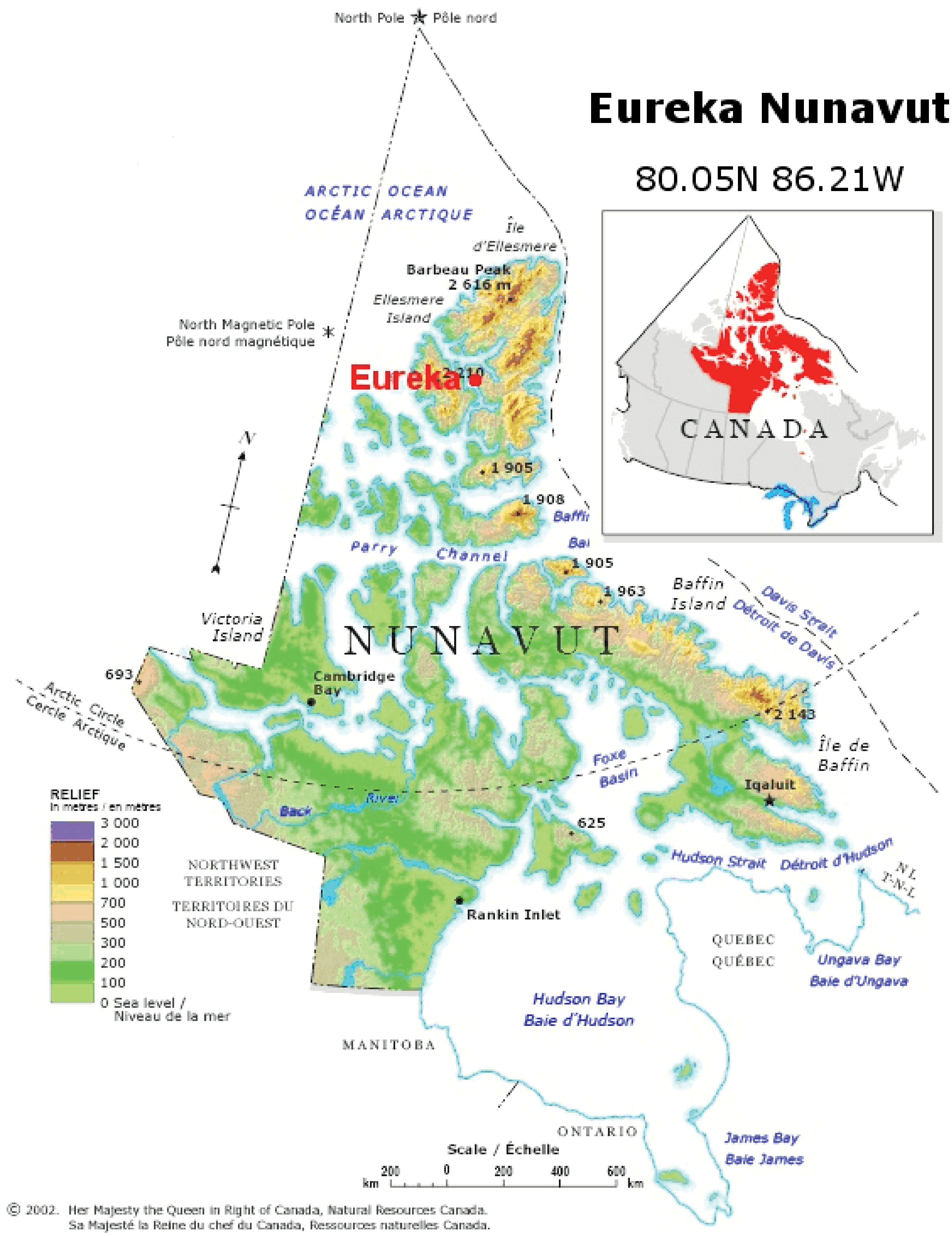


Figure 1: Eureka and Nunavut. Adapted from Natural Resources Canada relief map (http://atlas.nrcan.gc.ca/site/english/maps/reference/provincesterritoriesrelief/nunavut_relief).

CANDAC and PEARL

by Kimberly Strong[1] and the CANDAC/PEARL Science Team

Introduction

In the summer of 2005, four seatainers full of scientific equipment arrived at Eureka, two by sealift and two on a chartered Hercules aircraft. Their arrival signalled the start of an exciting new phase of atmospheric research at Eureka, involving the establishment of the Polar Environment Atmospheric Research Facility (PEARL). PEARL is located on the northern part of Ellesmere Island near 80°N, 86°W, and 1100 km from the North Pole, as indicated in Figure 1. It is composed of a number of linked observation sites, with the primary building (shown in Figure 2), which is leased from Environment Canada, being the former home of the Arctic Stratospheric Ozone Observatory. While this facility is situated on a mountain ridge 610 metres above sea level, it has a new companion named ØPAL – the Zero Altitude PEARL Auxiliary Laboratory – which is 15 km away, close to Environment Canada's Weather Station on the shore of Slidre Fjord. A third site, the Surface and Atmospheric Flux, Irradiance, Radiation Extension (SAFIRE) is also planned. A suite of state-of-the-art instrumentation is being installed at these three facilities to provide comprehensive measurements of the atmosphere from the ground to 100 km.

PEARL is being established by the Canadian Network for the Detection of Atmospheric Change (CANDAC), which is a new initiative bringing together researchers and resources dedicated to addressing the issues of air quality, climate change, and ozone depletion over Canada, with particular emphasis on the Arctic. The initial focus of CANDAC is the revitalization of measurements at Eureka, but CANDAC also has a wider set of objectives aimed at understanding atmospheric change. We envision the establishment of additional research stations, or "anchor sites" across Canada, as well as additional laboratory facilities and data management capabilities. CANDAC will use a variety of observation methods and platforms (space, aircraft, balloons, and the ground) to make long-term quality-controlled research measurements of tropospheric and stratospheric ozone, particulate matter, greenhouse gases and other constituents, temperature, vertical and horizontal structure, winds, turbulence and clouds. The network will undertake extensive analyses to interpret the resulting data. Training of skilled personnel and public education are also part of CANDAC's mandate. Linkages are very important for CANDAC, and we anticipate working in a collaborative mode with many Canadian and international organizations.

The Arctic is recognized in many reports and studies as being under stress. This comment from the Arctic Climate Impact Assessment (ACIA) report is typical of the conclusions of these studies: *"The increasingly rapid rate of recent climate change poses new challenges to the resilience of Arctic life. In addition to the impacts of climate change, many other stresses brought about by human activities are simultaneously affecting life in the Arctic, including air and water contamination, overfishing, increasing levels of ultraviolet radiation due to ozone depletion, habitat alteration and pollution due to resource extraction, and increasing pressure on land and resources related to the growing human population in the region, The sum of these factors threatens to overwhelm the adaptive capacity of some Arctic populations and ecosystems."* (ACIA, 2004). Furthermore, the polar regions are an essential element of the study of the entire Earth system: *"The polar regions are integral components of the Earth system. As the heat sinks of the climate system they both respond to and drive changes elsewhere on the planet. Within them lie frontiers of knowledge as well as unique vantage points for science."* (International Council for Science, 2004).

Figure 2: The PEARL observatory, with the new CANDAC upper satellite dish to the left. (Photo courtesy of Hermann Berg, 2005)

However, the Arctic is also (perhaps along with the deep ocean) one of the hardest parts of the Earth system to study because measurements are very scarce and, without measurements, understanding is hard to come by. Recognising the lack of measurements in the Arctic, and the very real challenges involved in working in this region, the first task of CANDAC has been to ensure the future continuity of atmospheric research measurements at Eureka. This has led to a large and concerted effort to establish PEARL. This activity has recently been accelerated by a desire to be ready for International Polar Year in 2007-2008 in order to participate in the world-wide effort to intensively study the Arctic region. PEARL is ideally situated for atmospheric measurements, as its high-latitude, high-altitude location

[1] Department of Physics, University of Toronto, Toronto, ON

offers unusually clear skies during winter. In addition, the Arctic vortex, a cold isolated mass of air that acts as a container for the chemical reactions that lead to ozone destruction, regularly passes overhead, allowing observations both inside and outside this chemically perturbed region.

Research Themes

CANDAC/PEARL research is being conducted within four major themes. The first of these is *Arctic Tropospheric Transport and Air Quality*, which is designed to help us learn about the amounts and kinds of materials that are transported into the Arctic. The transport pathways shown in Figure 3 illustrate the wide variety of source regions for these materials. The measurements at PEARL will focus on pollutants that are in the form of very small particles produced by urban pollution, industrial processes, and forest fires. In addition to the particles, there is a constant flow of volatile organic materials into the Arctic due to an evaporation-condensation mechanism called the "grasshopper effect" that cycles the organic compounds from the surface to the atmosphere during warm periods, then back to the surface when the temperature decreases. While in the atmosphere, they are spread in all directions by winds and thus migrate northwards, where they become trapped by the consistently low temperatures and accumulate to levels that are dangerous to the human and animal populations. Studies to be carried out at PEARL will quantify the amounts of material transported by these mechanisms and help identify the sources from which they originate.

The second research theme deals with *The Arctic Radiative Environment: Impacts of Clouds, Aerosols, and "Diamond Dust"*. The climate of the Arctic has changed significantly in recent decades. Over the past 30 years, temperatures have risen by as much as 4ºC, which is comparable to the amount of warming after an ice age. As seen in Figure 4, summertime Arctic sea ice coverage has steadily declined in response to the warming, which has implications for wildlife, indigenous peoples, and sovereignty. The Arctic is quickly entering a new climate regime that is unprecedented in the past few million years, and this is causing substantial stress on natural ecosystems, which cannot adapt so rapidly. Continued warming of the atmosphere and melting of sea ice may result in the following sequence of events: (1) The surface albedo will be reduced, and more solar radiation will be absorbed by the ground and ocean; (2) The relatively warm Arctic Ocean will be exposed and will heat the atmosphere; (3) Water vapour will be released, and the 20-µm "dirty window" will become opaque. This sequence provides a strong positive feedback on climate, potentially resulting in very rapid warming. Thus, this research theme seeks to fully characterize the Arctic atmosphere's composition and structure using instruments to measure infrared radiation and profiles of atmospheric temperatures, aerosols, clouds, and water vapour, documenting any changes in the radiative regime.

The third theme is that of *Arctic Middle Atmospheric Chemistry*, and is concerned with improving our understanding of the processes controlling the Arctic stratospheric ozone budget and its future evolution, using measurements of stratospheric constituents and other observations made at PEARL. Stratospheric ozone concentrations have declined significantly since about 1980 in response to enhanced levels of chlorine resulting from anthropogenic emissions of chlorofluorocarbons. This is particularly true in the Arctic, where, since 1979, the accumulated annually averaged ozone loss has been about 7% and the average springtime losses have been 10-15%, as indicated in Figure 5 (WMO 2003, ACIA 2004). Long-term trends in Arctic ozone can be difficult to distinguish from meteorological variability, with polar ozone loss critically dependent on low stratospheric temperatures. With the signing of the Montreal Protocol and its subsequent amendments to regulate the production of chlorofluorocarbons, a gradual recovery of global stratospheric ozone is anticipated. However, predictions of the future evolution of Arctic ozone vary, given the interannual variability in the area, strength, and timing of the polar vortex, uncertainties related to the coupling to climate change, and vulnerability to new perturbations, such as aerosols from volcanic eruptions. The recent IGOS Atmospheric Chemistry Theme Report (IGOS 2004) notes that "*… the frequency of measurements deep in the Arctic vortex remains low. The situation is unsatisfactory given the highly non-linear sensitivity of Arctic stratospheric ozone to cold winters. … Chemical and dynamical perturbations caused by strong volcanic eruptions make it impossible to derive a linear trend [in total ozone], which highlights the importance of continuous measurements throughout the expected recovery of the ozone layer during the coming decades."* This theme, and the datasets resulting from it, will directly address this lack of observations and will help answer the question of "What is the composition of the Arctic atmosphere above the site, and how and why is it changing with time?"

The last of the four CANDAC research themes is that of *Waves and Coupling Processes*, which seeks to determine how the various regions of the atmosphere interact. The polar regions are special locations for the atmosphere. Throughout most of the year, the atmosphere ascends over the summer pole from about 40 km to about 85 km, then crosses the globe to the winter pole and descends again. At the same time in the middle levels of the atmosphere, the stratosphere, a strong circulation forms each winter around the pole – the polar vortex – and significantly influences the chemistry of this region. While these large-scale events are reasonably well understood, the coupling between them and other regions of the atmosphere is a topic of vigorous scientific research. Much of the atmospheric structure that we see is a result of waves, such as those seen in the temperature measurements of Figure 6, which also couple different parts of the atmosphere. Identifying the sources of waves, where they travel, and their impact when they dissipate is important to understanding the atmosphere's basic form. At PEARL, a variety of instruments will be used to study the nature of the wave field in the Arctic atmosphere and how it varies. Details of the coupling will develop through looking at data from several instruments, collaborations with other observatories, and the use of satellite data and models.

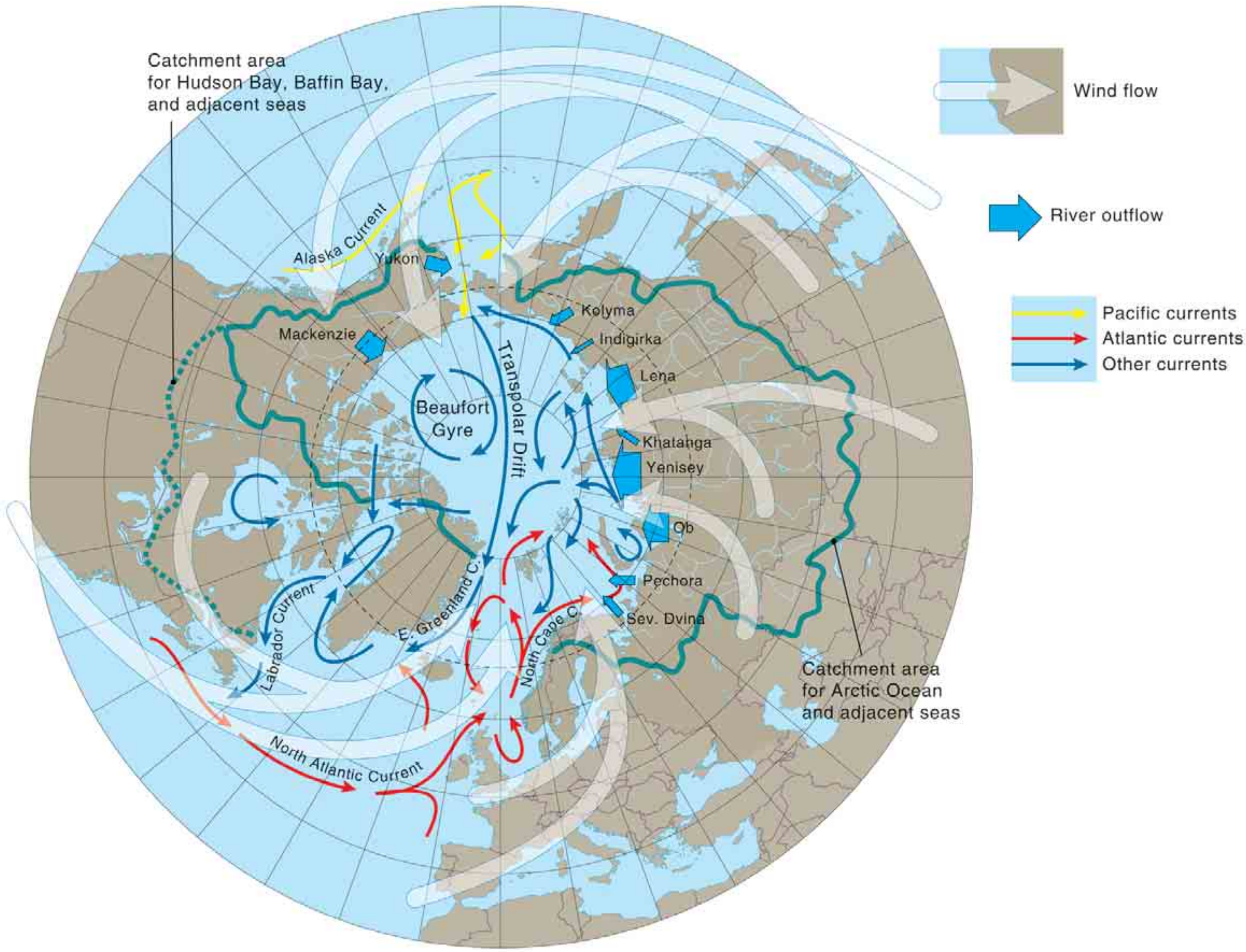


Figure 3: The major atmospheric transport pathways (wide white arrows) in the northern hemisphere. Ocean transport is indicated by the smaller solid arrows. (Adapted from Macdonald et al., *AMAP Assessment 2002*, 2003.)

Measurements at PEARL and ØPAL are also contributing to the validation of satellite instruments. This activity – the reconciliation of satellite measurements of a geophysical quantity with measurements made by a different technique – is an important issue for all satellite missions. In order for satellite validation to be effective, the validation methods themselves need validating and this requires long-term activities to ensure that the measurements are fully understood. Thus validation within the context of the ongoing CANDAC/PEARL program will be particularly effective. The PEARL site is in a unique position for Arctic validation of polar-orbiting satellites. The most Northern latitude of these satellites is about 80°N and the shortness of the latitude circle means that many of the overpasses are close to Eureka. In addition, the tangential nature of the pass makes the duration of the coincidence maximal. This is illustrated in Figure 7, which shows the enhanced overpass rate at the site. Thus with both the overpass rate and duration enhanced, one of the major problems with satellite validation, the frequency of overpasses, is reduced. Initial validation activities at PEARL have been focussed on the SCISAT-1 Atmospheric Chemistry Experiment (see accompanying article by Walker) and Cloudsat, and it is anticipated that such activities will continue with a number of upcoming missions.

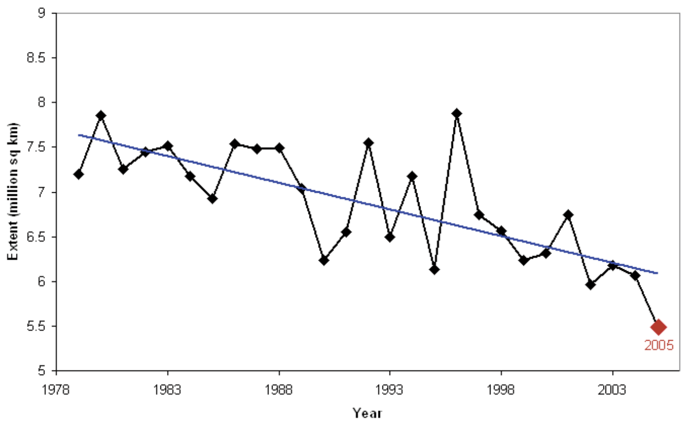


Figure 4: Total Arctic sea ice coverage in September determined from the satellite record, published in a joint press release by the US-based National Snow and Ice Data Center (NSIDC), NASA, and the University of Washington (see http://nsidc.org/news/press/20050928_trendscontinue.html).

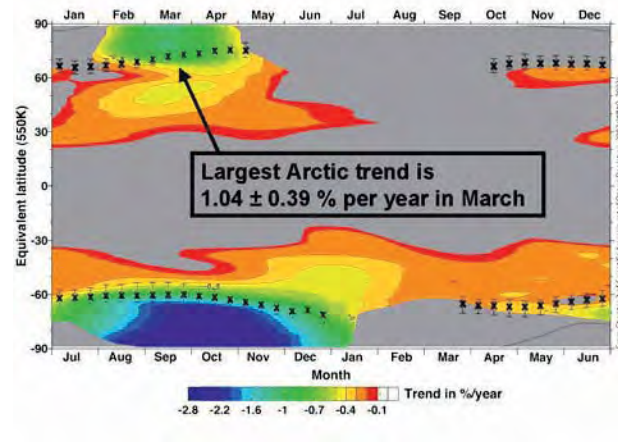


Figure 5: Total ozone column trends as a function of equivalent latitude and season using TOMS (Total Ozone Monitoring System) and Global Ozone Monitoring Experiment (GOME) data for 1978-2000. x indicates the mean position of the vortex edge (Adapted from WMO 2003).

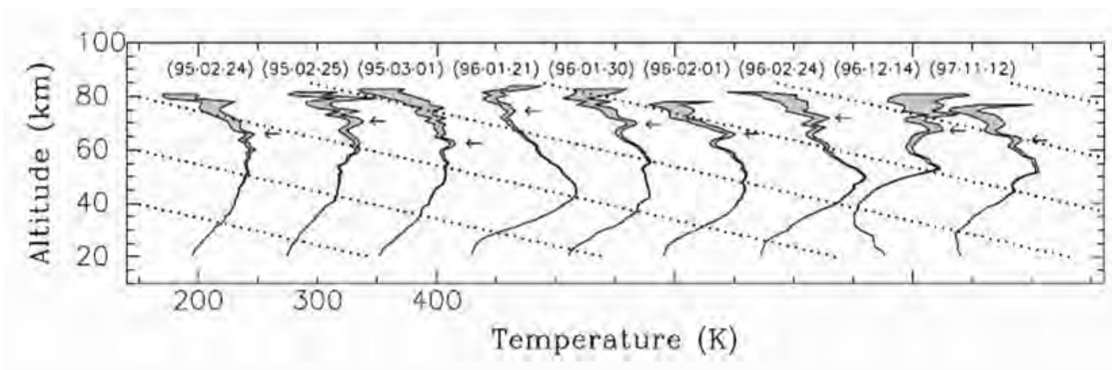


Figure 6: Lidar observations of the temperature structure over Eureka as a function of height showing wave-like structures (courtesy of T. Duck).

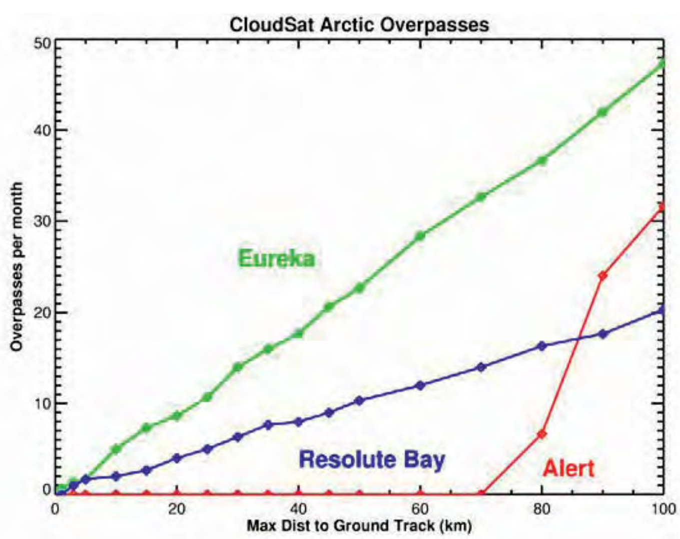


Figure 7: The overpass frequency for Cloudsat at Eureka (80°) compared with Resolute Bay, a site to the South (~75°N), and Alert, a site to the North (~82.5°N).

Instruments	Date of Installation	Planned Measurements
Instruments at PEARL:		
Stratospheric Ozone Lidar	Existing AStrO instrument	Stratospheric ozone and temperature profiles
Bomem Fourier Transform Infrared Spectrometer	Existing AStrO instrument	Trace gas columns and profiles
Brewer Spectrophotometer (Environment Canada)	Existing AStrO instrument	Ozone columns
Aerosol Mass Spectrometer	July 2006	Composition, number and size distribution of ground level particulate matter
Bruker Fourier Transform Infrared Spectrometer	July 2006	Trace gas columns and profiles
UV-Visible Grating Spectrometer	August 2006	Trace gas columns; profiles of NO_2
Cimel Sun Photometer	Fall 2006	Radiances and aerosol properties
Spectral Airglow Temperature Imager	Fall 2006	Upper mesospheric temperatures and gravity waves
All Sky Imager	Winter 2007	Oxygen, gravity waves, tides and planetary waves from airglow, auroral emissions and cloud/clear sky morphology
E-Region Wind Interferometer	Fall 2007	Mesospheric winds and wave activity from airglow emission
Instruments at ØPAL:		
Millimetre Wave Cloud Radar	August 2005 (SEARCH) Spring 2007 (CANDAC)	Cloud properties, reflectivity, wind velocities, precipitation rate and type, polarimetric products
High Spectral Resolution Lidar (SEARCH)	August 2005	Absolutely calibrated lidar profiles for aerosols and cloud composition
Polar Atmospheric Emitted Radiance Interferometer	March 2006 (SEARCH) Spring 2007 (CANDAC)	Absolute infrared spectral radiances, lower tropospheric profiles of temperature and water vapour, trace gas columns
SkiYMET VHF Meteor Wind and Temperature Radar	February 2006	Horizontal wind vectors ,temperatures and atmospheric waves from 80-100 km
Sun and Star Photometers	Winter 2007	Radiances and aerosol properties
Tropospheric Ozone Lidar	Winter 2007	Tropospheric and lower stratospheric ozone profiles
Rayleigh / Mie / Raman Lidar	Spring 2007	Profiles of tropospheric aerosols, clouds, diamond dust, temperatures, and water vapour
Instruments at SAFIRE:		
Wind Ttracker (Wind and Turbulence tracker VHF Radar	Summer 2007	Wind vectors and turbulence from 0.5-16 km
Baseline Surface Radiation Network Instrumentation	Summer 2007	Up-welling and down-welling, long-wave and short-wave broadband radiation, and albedo
Flux Tower	Summer 2007	Atmospheric and surface coupling, moisture and energy balances, plant productivity, latent and sensible heat fluxes, CO_2 fluxes

Table 1: Instrumentation being installed at PEARL and ØPAL.

Facilities and Instruments

The research planned for PEARL will be based on measurements to be made by a comprehensive suite of instruments deployed at three locations. The main PEARL observatory includes four large laboratories and a roof-top observing platform. It is in all respects a self-contained scientific laboratory. Its primary power source is the Eureka power generation plant to which PEARL is connected via an approximately 15-km long cable laid on the ground along the road. However, it also has an independent power source (diesel generator), self-contained water and sewage systems, kitchen, limited living quarters, a garage, a small machine shop, and a "safe hut" away from the main building that can function independently should a disaster befall the main building during extreme weather. The local generator only runs in case of a power failure at Eureka, resulting in a relatively pristine local environment that is above some of the boundary layer phenomena that would serve as an impediment to stratospheric measurements. Of its four laboratories, two are currently housing lidar systems, one is dedicated to infrared spectral measurements, and one is primarily for ultraviolet and visible spectral measurements, as well as a new Aerosol Mass Spectrometer. Figures 8, 9, and 10 show the three new CANDAC instruments that were installed at PEARL in the summer of 2006.

Figure 8: The infrared spectroscopy lab at PEARL, with the newly installed Bruker IFS 125HR Fourier Transform Spectrometer in the foreground and the existing Bomem DA8 FTS in the background. From left to right, members of the 125HR installation team: Tony Eng, Gregor Surawicz, Kimberly Strong, Pierre Fogal, Rodica Lindenmaier, and Keith MacQuarrie. (Photo courtesy of Kimberly Strong, 2006)

Figure 9: The new Aerodyne Aerosol Mass Spectrometer installed at PEARL by post-doctoral fellow Thomas Kuhn in July 2006. (Photo courtesy of Thomas Kuhn, 2006)

The Zero Altitude PEARL Auxiliary Laboratory was built to allow measurements in the lowermost atmosphere, as it is located essentially at sea level at the Northwest corner of the Eureka Weather Station complex. It is constructed of seatainers – shipping containers normally used to transport goods on ocean-going ships. The first phase of ØPAL was constructed by placing two seatainers, customized to serve as laboratory space, 8 feet apart and enclosing the intervening area with a breezeway. A third seatainer, immediately adjacent, serves as a storage unit. In the space of a few months in the first half of 2005, the ØPAL observatory was designed, constructed, transported from Toronto to Eureka, being situated and made operational in August of that year. Figure 11 shows members of the ØPAL construction crew, while Figure 12 shows the SEARCH Millimetre Wave Cloud Radar, which was one of the first instruments installed at ØPAL. Phase II of ØPAL is now under construction, following the delivery of the next pair of seatainers on the 2006 sealift; these will house a Rayleigh-Mie-Raman lidar and a tropospheric ozone lidar.

Communications are a significant issue for such a remote facility as PEARL. To ensure adequate and safe communications both for instrument and health and welfare reasons, CANDAC installed a dedicated vertical diversity C-band satellite link in summer 2005. This has the distinction of being the most northernly geostationary ground station in the world. The 3.4-m upper dish can be seen just outside PEARL in Figure 2, while the lower dish is located several hundred metres down the road. The current bandwidth is 128 kbit/sec and this can be increased as required. This link is extended to ØPAL via a microwave link.

Figure 10: The new UV-Visible Grating Spectrometer installed at PEARL by PhD student Annemarie Fraser in August 2006. (Photo courtesy of Annemarie Fraser, 2006)

The equipment being installed at PEARL comprises a complete atmospheric monitoring system, including lidars, radars, spectrometers, and radiometers that will probe the atmosphere above Eureka from the surface to about 100 km. Installation began in July 2005 and will be complete in time for International Polar Year 2007-2008. Plans are also underway to establish the SAFIRE facility near the Eureka airstrip, which will be the site of a flux tower, a Baseline Surface Radiation Network station, and a VHF radar. In addition, we expect to run a ”guest instrument” program for other experimenters who wish to place instrumentation temporarily or permanently at PEARL. CANDAC already has an active collaboration underway with the Study of Environmental Arctic Change (SEARCH) group in the USA for co-operative use of resources. Three SEARCH instruments have already been installed at ØPAL: a Millimetre Wave Cloud Radar, a High Spectral Resolution Lidar, and a Polar Atmospheric Emitted Radiance Interferometer.

Figure 11: The ØPAL construction crew preparing to build the breezeway between the first two seatainers. From left to right: Oleg Mikhailov, Paul Loewen, Pierre Fogal, and Jim Drummond. (Photo courtesy of Pierre Fogal, 2006)

Figure 12: The SEARCH Millimeter Wave Cloud Radar installed at ØPAL in August 2005. (Photo courtesy of Pierre Fogal, 2006)

In combination with the measurements taken at Environment Canada's Weather Station, the suite of instruments installed at PEARL will provide an important new dataset for studies of the Arctic. It is intended that these measurements will be combined with atmospheric models to facilitate both improved modelling of the atmosphere and the interpretation of the measurements, with the ultimate goal of obtaining a better understanding of chemical, dynamical, radiative, and microphysical processes occurring in the Arctic atmosphere.

References

ACIA, *Arctic Climate Impact Assessment*, Cambridge University Press, 2004.

IGOS, *The Changing Atmosphere: An Integrated Global Atmospheric Chemistry Observation Theme for the IGOS Partnership.* Report of the Integrated Global Atmospheric Chemistry Observation Theme Team. ESA SP-1282. Report GAW No. 159 (WMO TD No. 1235), 2004.

International Council for Science, *A Framework for the International Polar Year 2007-2008*, ICSU IPY 2007-2008 Planning Group, 2004.

Macdonald, R.W., T. Harner, J. Fyfe, H. Loeng and T. Weingartner. *AMAP Assessment 2002: The Influence of Global Change on Contaminant Pathways to, within, and from the Arctic*. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. 2003.

WMO (World Meteorological Organization), *Scientific Assessment of Ozone Depletion: 2002*, Global Ozone Research and Monitoring Project - Report No. 47, Geneva, 2003.

Acknowledgements

Funding for the PEARL facility is provided by the following: the Canada Foundation for Innovation (CFI), the Ontario Innovation Trust (OIT), the Ontario Ministry of Research and Innovation (MRI), the Nova Scotia Research and Innovation Trust (NSRIT), Environment Canada (EC), the Natural Sciences and Engineering Research Council (NSERC), the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS), the Polar Continental Shelf Project (PCSP), and the Canadian Space Agency (CSA). In addition to these grants, the PEARL facility is reimbursed for activities on behalf of other agencies, such as the operation of the SEARCH equipment at ØPAL.

Finally, the support of the Eureka Weather Station staff and the Meteorological Service of Canada (Prairie and Northern Region) staff for assistance with many aspects of logistics and other matters related to living and working in the Arctic is gratefully acknowledged. Without their active collaboration in this endeavour, it would not be possible to continue.

The CANDAC/PEARL Science Team

Principal Investigator
Prof. James R. Drummond University of Toronto/Dalhousie University
CANDAC Manager of Operations
Dr. Pierre Fogal, University of Toronto
Theme Leaders
Prof. Tom Duck, Dalhousie University, *The Arctic Radiative Environment: Impacts of Clouds, Aerosols, and "Diamond Dust"*
Prof. Jim Sloan, University of Waterloo, *Arctic Tropospheric Transport and Air Quality*
Prof. Kimberly Strong, University of Toronto, *Arctic Middle Atmospheric Chemistry*
Prof. William Ward, University of New Brunswick, *Waves and Coupling Processes*
Co-Investigators
Dr. Stephen Argall, University of Western Ontario
Dr. Hans Fast, Environment Canada
Dr. David Hudak, Environment Canada
Prof. Alan Manson, University of Saskatchewan
Dr. Bruce McArthur, Environment Canada
Dr. Tom McElroy, Environment Canada
Prof. Norman O'Neill, Université de Sherbrooke
Prof. Marianna Shepherd, York University
Prof. Gordon Shepherd, York University
Prof. Robert Sica, University of Western Ontario
Dr. Kevin Strawbridge, Environment Canada
Prof. Kaley Walker, University of Toronto
Prof. Jim Whiteway, York University

Collaborators
Prof. Theodore Shepherd, University of Toronto
Prof. John McConnell, York University
Prof. Jean-Pierre Blanchet, University du Québec à Montréal
Prof. Peter Bernath, University of Waterloo/University of York
Dr. Taneil Uttal, National Oceanic and Atmospheric Administration, USA

Technical Support	
Dr. Hermann Berg	Dr. Suzanne Bingham
Paul Chen	Adam Diamant
Dr. Denis Dufour	Ashleigh Harrett
Paul Loewen	Keith MacQuarrie
Clive Midwinter	Oleg Mikhailov
Lana Tobiash	

CANDAC Board of Directors
Dr. Leonard Barrie, World Meteorological Organization (Chair)
Earle Baddaloo, Government of Nunavut
Dr. Michael Coffey, National Center for Atmospheric Research, USA
Dr. Martin Jarvis, British Antarctic Survey, UK
CANDAC representatives: Jim Drummond, Jim Sloan, Kimberly Strong and William Ward
CFCAS representative: Dr. Keith Puckett, Environment Canada
Representatives of NSERC, EC and CSA

NSERC: Natural Sciences and Engineering Research Council of Canada

EC: Environment Canada

CSA: Canadian Space Agency

The Grand Opening of the Polar Environment Atmospheric Research Laboratory (PEARL)

by Pierre Fogal[1], Kimberly Strong[1] and James R. Drummond[2]

July 24, 2006 marked the official opening of the Polar Environment Atmospheric Research Laboratory (PEARL), the first Canadian Network for Detection of Atmospheric Change (CANDAC) site. The creation of a pearl by an oyster is an apt metaphor for this "gem" of an atmospheric research facility. In the same manner that the oyster builds up its pearl through the application of myriad layers, CANDAC, with support from its many funding agencies, has revitalized this Ellesmere Island site. PEARL is located at approximately 80°N, 86°W, near Environment Canada's (EC) Eureka Weather Station. The Weather Station has its own reasons for celebrating with the opening of a new accommodation block built to house Weather Station personnel. Construction began in 2003, and continued over the next three summers, with the station taking up residence in the fall of 2005. This is a much welcomed upgrade to the station facilities, providing station personnel with improved working conditions and quite comfortable accommodations, and demonstrating EC's continuing commitment to its operations at Eureka.

The construction of the new accommodation block and the transformation of the former EC Arctic Stratospheric Ozone Observatory (AStrO) into PEARL, have been the most visible recent changes. Less visible have been the changes in the research which has expanded beyond studies of ozone, still an important issue, to include air quality and climate change. Along with that has been an expansion of the research team to include scientists from eight universities plus a significant collaboration with the US Study of Environmental Arctic Change (SEARCH) group. EC participation continues through collaboration with members of the Science and Technology Branch (STB), in Downsview, ON. CANDAC activities at Eureka have also extended beyond the former AStrO laboratory and now include the Zero Altitude PEARL Auxiliary Laboratory (ØPAL), a facility at the Weather Station for studying the lowermost portions of the atmosphere. In 2007, PEARL and ØPAL will be joined by SAFIRE, the Surface and Atmospheric Flux, Irradiance, Radiation Extension site, to be situated near the Eureka runway. This site will provide a location for a flux tower supplied by our collaborators at the National Oceanic and Atmospheric Administration (NOAA), a Baseline Surface Radiation Network (BSRN) station contributed by EC, and a VHF radar from CANDAC.

With changes like this, a celebration is mandated, and so it was that on July 24, 2006, PEARL and Eureka welcomed an influx of visitors from Canada and the US. Since access to Eureka is only by chartered plane, this had to be carefully orchestrated. A First Air Boeing 737 aircraft was chartered to be filled partly with scientific equipment for PEARL (see Figure 1), and partly with guests for the opening ceremonies. Given that this type of travel in the High Arctic is rather rare (this was only the second 737 ever to land at Eureka), many issues not usually associated with travel on commercial aircraft, such as the gravel runway conditions, had to be taken into account. So, very early in the morning, 43 people checked in at Edmonton International Airport for the flight to Eureka, including representatives of the Federal and Territorial governments, funding agencies and international organizations, as well as researchers and the media (see Figure 2). The path to Eureka is roughly straight North from Edmonton, and with only a refuelling stop at Resolute Bay, the aircraft reached Eureka in 5.5 hours flying time. Since this is pretty comparable with the flying time from Toronto to Vancouver it gave everyone a new appreciation of the size of Canada!

The charter arrived in the early afternoon, and the day at Eureka began with a lunch provided by the Weather Station staff. Lunch was followed by the presentation of gifts and accolades to Weather Station personnel in celebration of the opening of their new building, with remarks from Tim Goos (Director, MSC Operations for EC's Prairie and Northern Region) and Rai LeCotey (Station Program Manager, Eureka) (see Figure 3). Opening activities for NOAA involvement with PEARL and ØPAL then took place, with remarks by Brian Gray (Assistant Deputy Minister for EC's Science and Technology Branch), Alexander (Sandy) McDonald (Director for the Earth System Research Laboratory, Office of Oceanic and Atmospheric Research, NOAA), Russ Schnell (Director, Observatory and Global Network Operations, NOAA) and Taneil Uttal (Research Scientist, NOAA) (Figure 4). This was notable for the presentation of several beautiful and fragrant bouquets of Hawaiian flowers, a gift to the staff at the Eureka Weather Station from staff at NOAA's Mauna Loa Observatory.

Upon completion of these events, the PEARL opening part of the day began. PEARL is located approximately 15 km by gravel road from the Weather Station, and several trips with the trucks and vans on-site were required to move the guests from Eureka to PEARL, with the reverse operation being carried out on completion. During the transportation phases, our guests were able to tour the PEARL facility and see the laboratory spaces and instrumentation. All agreed that PEARL (AStrO) is a tremendous facility and that the agreement between CANDAC and EC, which has returned it to operational status, **should** be celebrated!

[1] Department of Physics, University of Toronto, Toronto, ON

[2] Department of Physics and Atmospheric Science, Dalhousie University, Halifax, NS

Figure 1: Loading the chartered First Air Boeing 737 in Edmonton with scientific equipment for PEARL. (Photo courtesy of Thomas Kuhn, July 2006)

Figure 2: En route to Eureka - passengers inside the chartered First Air Boeing 737. (Photo courtesy of Jim Drummond, July 2006)

Figure 3: Attentive members of the audience at the opening ceremonies for the new Weather Station building at Eureka. (Photo courtesy of Jim Drummond, July 2006)

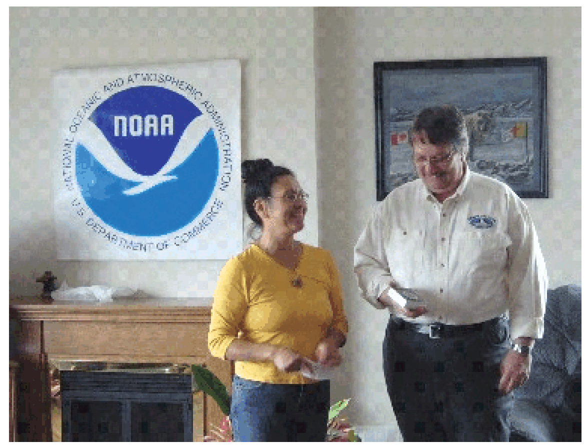


Figure 4: NOAA's Taneil Uttal and Eureka's Station Program Manager Rai LeCotey enjoy the opening activities for NOAA involvement with PEARL and ØPAL. (Photo courtesy of John Calder, July 2006)

Figure 5: PEARL opening ceremonies underway in the garage-auditorium. John Calder presents a commemorative plaque to CANDAC's Jim Drummond on behalf of NOAA/SEARCH, while master of ceremonies Pierre Fogal looks on. (Photo courtesy of David Bogart, July 2006)

Figure 6: The launch of an ozone sonde by Weather Station personnel. (Photo courtesy of Pierre Fogal, July 2006)

Figure 7: The departure of the First Air Boeing 737 from Eureka, marking the end of the PEARL grand opening. (Photo courtesy of Kimberly Strong, July 2006)

Figure 8: The Bruker IFS 125HR FTS and Aerodyne AMS being delivered to PEARL the day after the opening ceremonies. (Photo courtesy of Kimberly Strong, July 2006)

Once everyone was on site, all were gathered into the PEARL garage, pressed into duty as an auditorium, and Pierre Fogal (PEARL Manager, CANDAC Manager of Network Operations) acted as our master of ceremonies. Remarks were offered by Brian Gray (Assistant Deputy Minister for EC's Science and Technology Branch), Simon Awa (Deputy Minister of the Environment for Nunavut), Eliot Phillipson (CEO of the Canadian Foundation for Innovation), David Bogart (Executive Vice President and Chief Operating Officer - Ontario Innovation Trust), Alison Barr (Director, Research Branch, Ontario Ministry of Research and Innovation), Dawn Conway (Executive Director, Canadian Foundation for Climate and Atmospheric Science), Nigel Lloyd (Executive Vice-President, NSERC),and John Calder (Head of Arctic Research Program, NOAA) on behalf of NOAA/SEARCH, and finally James Drummond (CANDAC/PEARL Principal Investigator), shown in Figure 5. Of particular note were the comments from Simon Awa of the Nunavut government. He impressed upon those present the very real impact of climate change on the lives of the Inuit and on the face of the North. It is both fitting and proper that atmospheric and climate scientists be reminded of the very real human dimension of the impacts of climate change.

Upon completion of the festivities at PEARL, everyone returned to Eureka for dinner, again prepared by the station staff. Dinner was followed by an opportunity for all participants to interact and discuss various topics relating to the station, laboratories, and science in general. This included a briefing on plans for International Polar Year given by Barry Goodison (EC, Manager, IPY). The final major event of the day was the launch of a Raven balloon carrying an ozone sonde by station personnel Heather Baier (Meteorological Technician) and Luc Sarrazin (Senior Aerological Observer), with assistance from Jonathon Davies of STB. The balloon launch is always an interesting spectacle, as is clear from Figure 6, and the data provided by the ozone and radio sondes are of great utility in the analyses of PEARL data.

The grand opening festivities concluded with the re-loading of the 737 and its subsequent departure in a cloud of dust, seen in Figure 7, leaving the station with its more usual solitude and quiet. However, for six of those who had travelled north, the work was just beginning. The aircraft had been chosen in part because it could carry a significant amount of cargo in addition to passengers. On this flight, CANDAC delivered a Bruker IFS 125HR Fourier Transform Spectrometer (FTS) and an Aerodyne Aerosol Mass Spectrometer (AMS) to PEARL. Both of these instruments represent the state of the art in their respective fields of infrared atmospheric spectroscopic measurements, and the analyses of aerosols for their constituents. Both were installed in the main PEARL laboratory and were quickly made operational (Figure 8). After the initial commissioning phase, these instruments will provide automated sampling of their data products as and when conditions permit. In particular, the AMS will provide a measurement capability not hitherto available at Eureka. The FTS is replacing an older non-automated instrument of similar capability. The installation of these instruments raises the total operational instrument count to eight.

The sonde launch demonstrates some of the synergy brought about by the collocation of research and monitoring facilities. Clearly, many of the requirements related to establishing an observational program as comprehensive as that of CANDAC/PEARL are only sustainable given the infrastructure provided by the Weather Station. Even so, difficulties, obstacles, and shortcomings remain. Understanding the Arctic atmosphere is of great importance in atmospheric and climate research, yet it continues to be undersampled, in part because it is a difficult location in which to operate. In light of this, CANDAC operations such as the design, fabrication and establishment of ØPAL, the installation of one of the world's most northerly geostationary satellite ground stations and the delivery and implementation of new state-of-the-art research grade instrumentation are significant and worthy of celebration. In the months leading up to the start of International Polar Year (IPY), CANDAC will continue to add new instruments, with the goal of reaching full operational status by the end of summer 2007.

The continuing effort to establish PEARL represents a significant new atmospheric and climate research activity aimed at learning more about the Earth's atmosphere from ground level to 100 km, and combining those mostly complementary but sometimes disparate measurements and results, into a more cohesive picture. CANDAC/PEARL looks forward to helping to fulfill some of the IPY objectives such as the establishment of infrastructure in the polar regions, and to making a significant contribution to the research and learning that will undoubtedly result from IPY activities. As we celebrate this milestone on our journey, we thank all those who have made it possible, and we welcome all those interested in joining us in this endeavour.

Arctic Validation Campaigns for Canada's Atmospheric Chemistry Experiment Satellite Mission

by Kaley A. Walker[1]

Figure 1: The 2005 ACE Campaign Team during the Twin Otter flight to Eureka: First row (left - right): Annemarie Fraser, Richard Mittermeier; Second row: Paul Loewen (hidden), Jennifer Walker, Michael Harwood; Third row: Clive Midwinter, Keeyoon Sung, Kaley Walker; Fourth row: Richard Berman (partially hidden). (Photo courtesy of Michael Harwood, February 2005)

February 18, 2005, Eureka, Nunavut: The campaign team steps off the plane into the dim afternoon twilight. They are happy to stretch their legs after the flight from Resolute Bay on the Twin Otter packed with people and equipment (Figure 1). Over the next three weeks, they will use a suite of seven remote sounding instruments to monitor the changes that occur in Arctic atmosphere following polar sunrise. They unload the plane and pack the instruments and support equipment into the pick up truck for the 15 km drive up the ridge to the Polar Environment Arctic Research Laboratory (PEARL).

For the past three winters, PEARL (80.05°N, 86.42°W, 610 m) has been the site of three campaigns for the validation of Arctic measurements being made by the Atmospheric Chemistry Experiment (ACE) satellite mission, also known as SCISAT-1 (Figure 2). The satellite was launched by the Canadian Space Agency on 12 August 2003 [Bernath et al., 2005]. The primary goal of the ACE mission is to investigate the chemical and dynamical processes that control the distribution of ozone in the stratosphere and upper troposphere, with particular emphasis on Canada and the Arctic. Two solar occultation instruments make up the ACE payload. One is a high-resolution (0.02 cm^{-1}) infrared Fourier transform spectrometer (ACE-FTS) operating from 750-4400 cm^{-1}, which includes a two-channel imager operating at 0.525 and 1.02 µm. The other is a dual UV-visible-near infrared spectrometer, named MAESTRO (Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation), measuring from 285-1030 nm at a resolution of 1-2 nm. During each sunrise or sunset, as seen from the satellite, the ACE-FTS and MAESTRO measure a series of absorption spectra at different altitudes above the Earth's surface. These are used to retrieve vertical profiles of 14 "baseline" species (O_3, CH_4, H_2O, NO, NO_2, $ClONO_2$, HNO_3, N_2O, N_2O_5, HCl, CFC-11, CFC-12, HF, CO), atmospheric extinction, temperature and pressure from cloud tops up to about 150 km. Since routine operations started in February 2004, about 11,600 occultations have been measured by the ACE satellite.

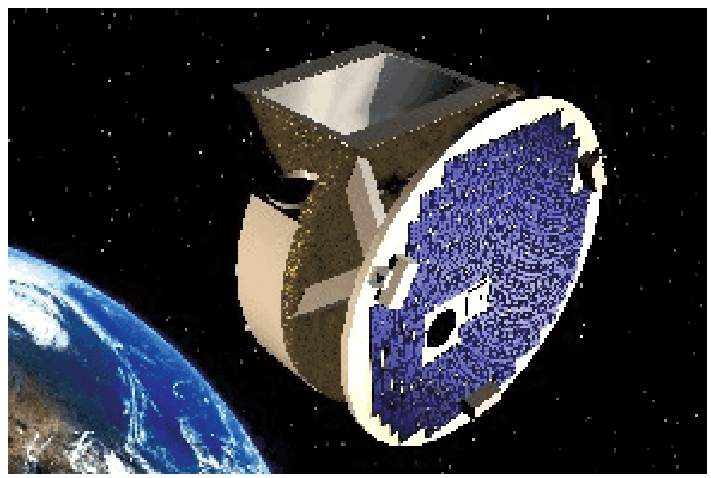


Figure 2: Illustration showing the ACE satellite in orbit. (Courtesy of Thomas Doherty and Canadian Space Agency)

It is important to establish the accuracy and reliability of satellite remote sensing results through comparisons with measurements obtained by instruments using a range of techniques. These comparisons are particularly difficult for Arctic observations because few atmospheric observatories exist at these high latitudes. The first ACE Arctic Validation campaign in 2004 was developed by researchers at the University of Toronto, University of Waterloo and Environment Canada (EC) to address a gap in the data available for validating the SCISAT-1 results. Because the satellite was launched prior to the opening of PEARL, the only Arctic measurement data available for validation studies over the Canadian Arctic were the routine ozone measurements made

[1] Department of Physics, University of Toronto, Toronto, ON, and Department of Chemistry, University of Waterloo, Waterloo, ON

by the Meteorological Service of Canada using ozonesondes and Brewer spectrometers at the Eureka Weather Station, Resolute (75°N) and Alert (82.5°N). There was no Arctic measurement capability in Canada for the 13 other ACE-FTS and MAESTRO baseline trace gases. The 2004 Canadian Arctic Validation of ACE campaign was funded by the Canadian Space Agency to provide the measurements needed to validate the ACE-FTS and MAESTRO Arctic observations. Eureka was chosen for the campaign location because there were many opportunities to make coincident measurements with the ACE satellite (Figure 3) and because the former Arctic Stratospheric Ozone Observatory provided the infrastructure necessary to support the campaign. Additionally, Eureka lies directly below the point of maximum stratospheric variability [Harvey and Hitchman, 1996] which makes it an ideal site for stratospheric measurements. The winter polar vortex regularly passes over Eureka and thus measurements both inside and outside the vortex region can be made from this single location. As understanding of the chemical and physical processes associated with the Arctic polar vortex is a key scientific goal of ACE, validation of ACE measurements under the unusual conditions found in the Arctic springtime is vital to establishing their credibility. Funding of these campaigns was continued in 2005 and 2006 to expand the ACE Arctic validation dataset.

The primary scientific objective of the ACE Arctic validation campaigns is to measure total columns and (where possible) vertical profiles of the 14 ACE baseline species, atmospheric extinction, temperature, and pressure in the Canadian Arctic for use in validation of ACE satellite data. There are also three secondary objectives for the campaigns. First, to attempt to make spectral, as well as trace gas, measurements from ground-based versions of ACE-FTS and MAESTRO to use for validating both the Level 1 and Level 2 ACE data under the chemically perturbed conditions found in the springtime Arctic stratosphere. Second, to make campaign measurements at high temporal resolution from a single location to help give context to the sparse (in time and space) ACE occultation measurements over the Canadian Arctic. Third, to continue the time series of springtime observations made by the Network for the Detection of Stratospheric Change (now Network for Detection of Atmospheric Composition Change) validated Fourier transform spectrometer located at Eureka. These measurements were started by Environment Canada in 1993.

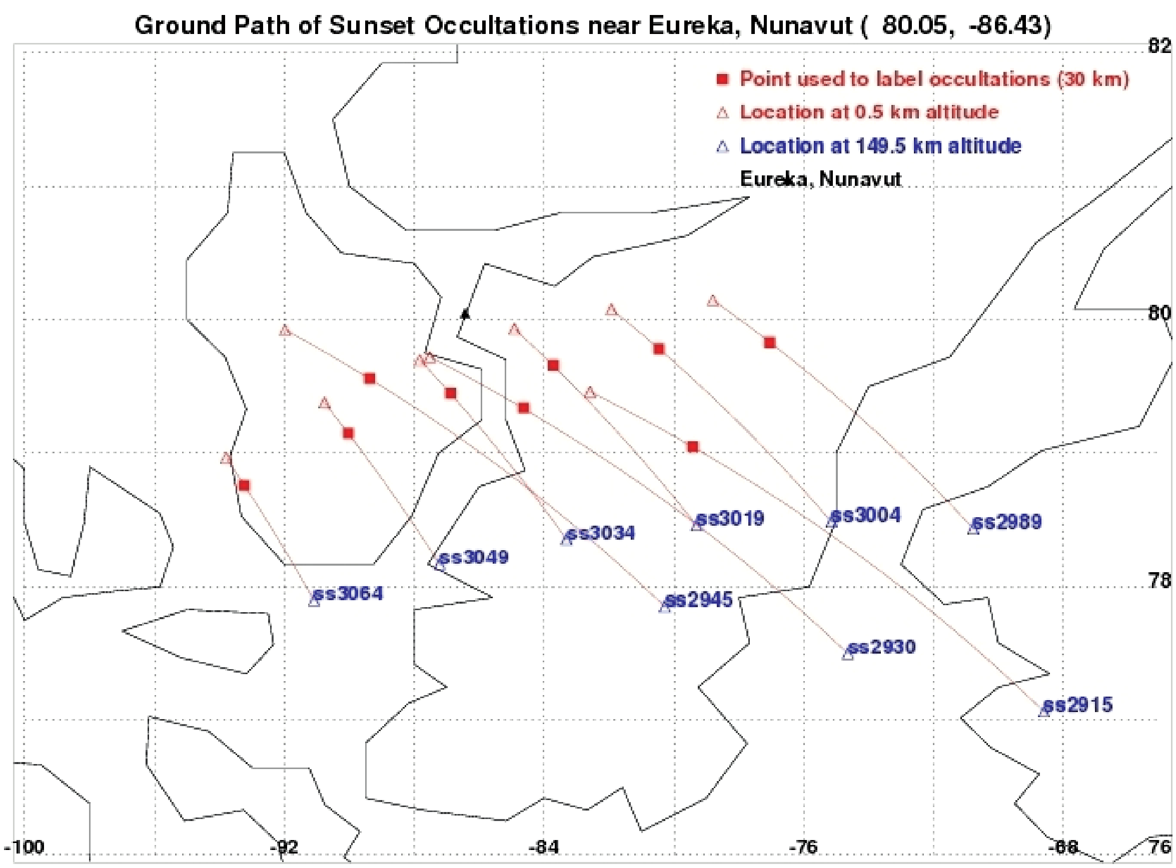


Figure 3a

Figure 3: The ground paths of the ACE occultations within 200 km of PEARL during the 2004 (Figure 3a), 2005 (Figure 3b) and 2006 (Figure 3c) validation campaigns in the late February to mid-March period. Typically, there were 20-25 more occultations within 200-500 km of PEARL during this same period. The black triangle in each plot shows the location of PEARL.

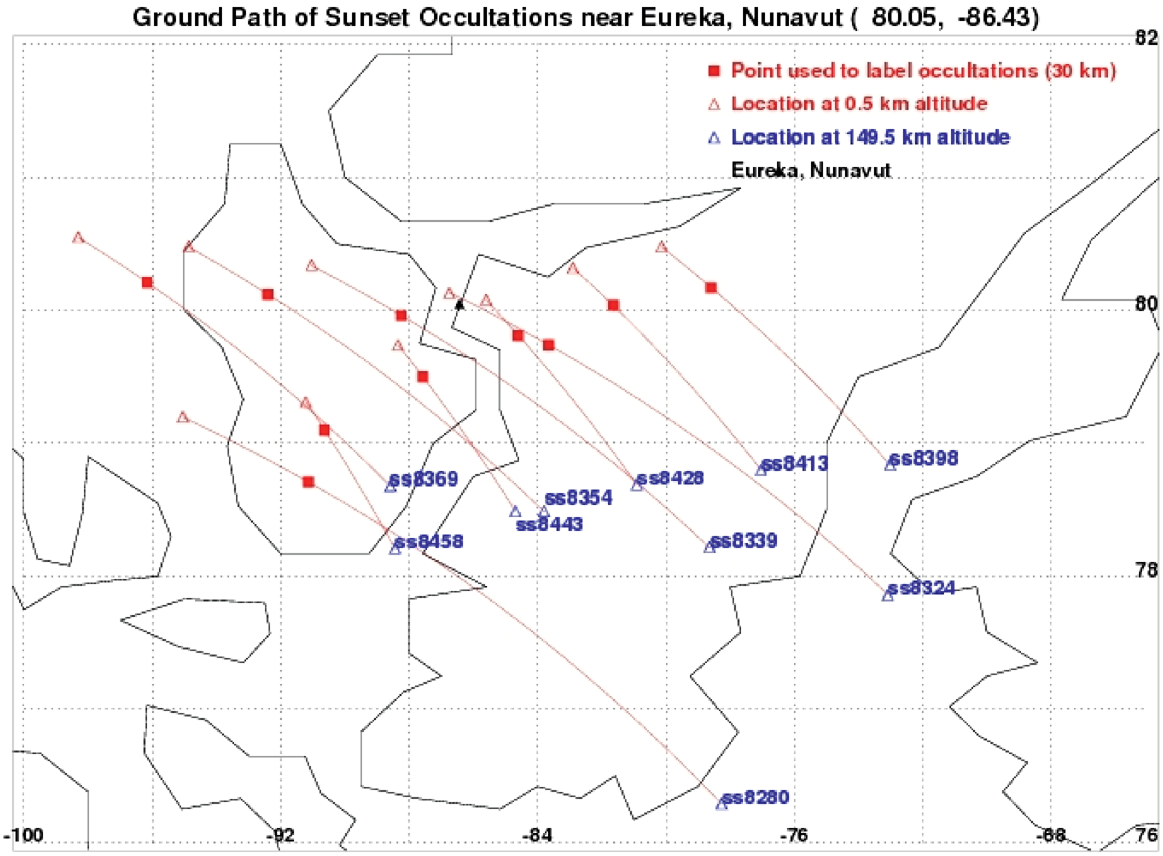


Figure 3b

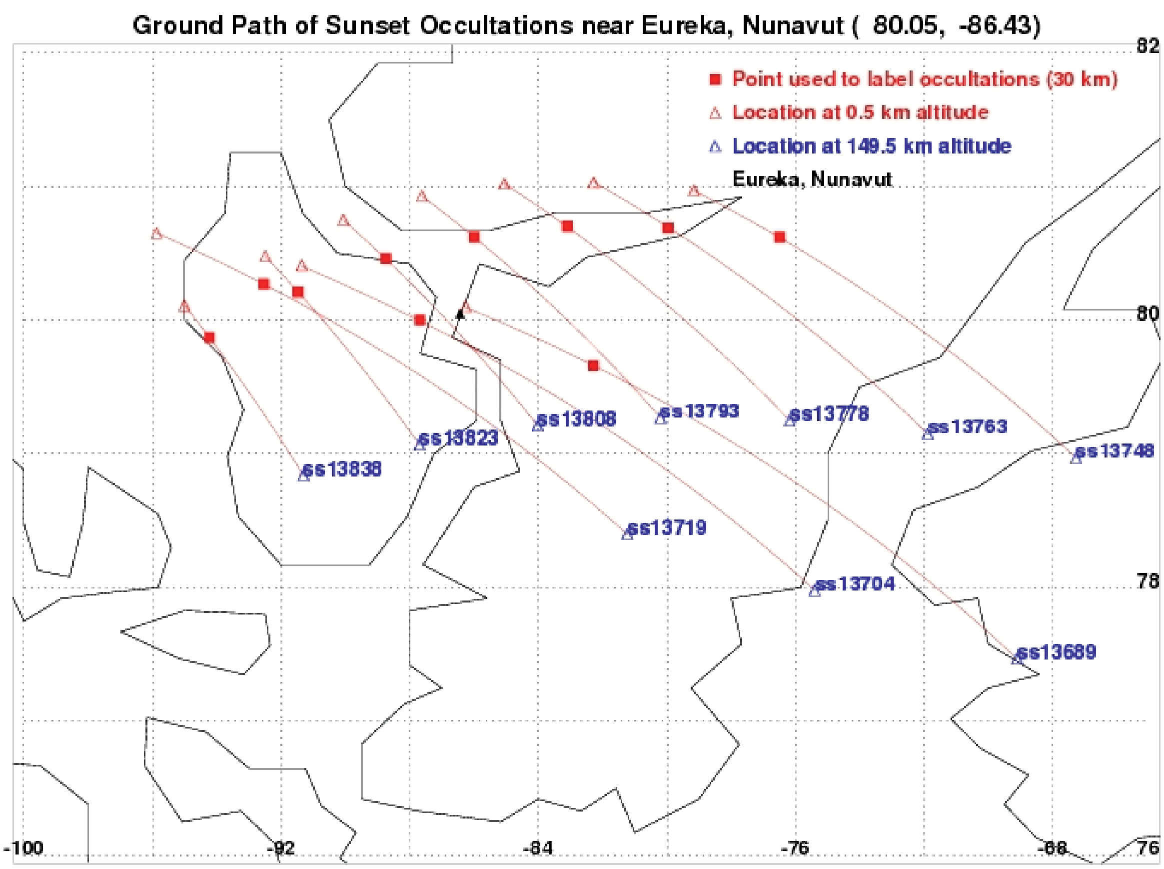


Figure 3c

ON-SITE INSTRUMENTS (LOCATION)	CAMPAIGN INSTRUMENTS (PEARL)
• EC DA8 FTS (PEARL) • EC DIAL (PEARL) • EC ozonesondes (Weather Station) • EC Brewer spectrophotometer (Weather Station)	• U of Waterloo PARIS-IR FTS • MAESTRO-G • EC SPS-G • U of Toronto grating spectrometer (UT-GBS) • Service d'Aéronomie SAOZ* • EC Brewer spectrophotometer (PEARL)*
* SAOZ and Brewer spectrophotometer at PEARL were added for the 2005 and 2006 campaigns.	

Table 1: Instruments used during the 2004, 2005 and 2006 ACE Arctic validation campaign.

The 2004, 2005 and 2006 ACE Arctic validation measurements were performed using a combination of on-site instrumentation and instruments deployed at PEARL on a campaign basis. For the first campaign in 2004, seven ground-based instruments were operated and ozonesondes [Davies et al., 2000] were flown daily from the Eureka Weather Station (Figure 4). Four of the instruments were deployed at PEARL on a campaign basis. Two of these, PARIS-IR [Fu et al., 2005] and MAESTRO-G, are ground-based adaptations of the ACE satellite instruments. The other two are UV-visible spectrometers, a zenith-viewing grating spectrometer [Bassford et al., 2001, 2005], and a SunPhotoSpectrometer (SPS), the forerunner of the MAESTRO instrument [McElroy, 1995] (Figure 5). The remaining three are permanently based at Eureka. A Bomem DA8 Fourier transform spectrometer (DA8 FTS) [Donovan et al., 1997] and a differential absorption lidar (DIAL) [Bird et al., 1996] are installed at PEARL and were operated by Environment Canada for the campaign. A Brewer spectrophotometer located at the Eureka Weather Station was also included in the measurement suite [Savastiouk and McElroy, 2005]. For the 2005 and 2006 campaigns, a Système d'Analyse par Observation Zénithale (SAOZ) [Pommereau and Goutail, 1988] and a second Brewer spectrophotometer were added to the set of instruments. The list of instruments and locations is given in Table 1.

Figure 4: An ozonesonde is launched from the Eureka Weather Station. (Photo by Paul Loewen, March 2006).

Each of the three campaigns had two phases: an intensive phase and an extended phase. The intensive phase of the campaign took place from polar sunrise (21 February) to approximately 9 March each year. During this period, all of the instruments were operated as frequently as weather permitted and additional ozonesondes were flown to provide daily measurements. Typically, it was possible to make measurements on most days in 2005 but the conditions were slightly less favourable in 2004 and 2006. At the end of the intensive phase of the campaign, the DIAL and PARIS-IR measurements were stopped (since these instruments are not automated) and the ozonesonde flights resumed their regular weekly schedule. The UV-visible grating spectrometer, SAOZ, and DA8 FTS measurements continued during the extended phase of the campaign. The automation of the MAESTRO-G and SPS-G measurements was enabled in time for the extended phase of the 2006 campaign. In 2005 and 2006, the extended phase lasted for three weeks and it was six weeks in length in 2004.The ACE Arctic validation campaign project has provided a very useful data set for correlative comparisons with the ACE satellite data and also for scientific investigations of the Arctic stratosphere. To date, the data sets from the three campaigns have been processed and analyses are in progress. Part of these analyses has focussed on understanding the discrepancies between the Fourier transform spectrometers and the zenith-sky viewing UV-

Figure 5: UV-visible instruments (SPS, MAESTRO-G and Brewer spectrophotometer) measuring atmospheric spectra from the rooftop at PEARL. (Photo by Tobias Kerzenmacher, March 2006)

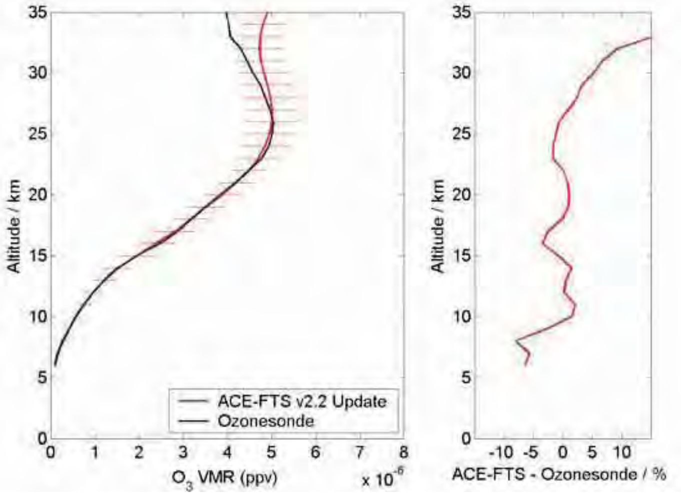


Figure 6: Comparison of ozonesonde data with ACE-FTS ozone (version 2.2 update) results. Left panel: the average profiles of ozone VMR from ACE-FTS and ozonesonde measurements between 25 February and 22 September 2004 (primarily in February and March with only 3 pairs from September). 35 profiles are included in each average. The error bars show 1-σ standard deviation of the distribution of the ACE-FTS measurements at each altitude. The average latitude of the measurements was 79.2 °N. Right panel: The average percent difference profile for the ACE-FTS and ozonesonde comparisons is shown.

visible instruments. Initial comparisons have been made between the satellite and campaign data sets [Kerzenmacher et al., 2005]. The ozone and temperature profile comparisons show results that are consistent with those obtained with other satellite comparisons. For example, the ACE-FTS ozone results have been compared with ozonesonde profiles obtained during the 2004 campaign (Figure 6). Between 10 and 30 km, the ACE-FTS ozone measurements are within ~3-5% of the ozonesonde observations. This is similar to comparisons with profiles from the SAGE III and POAM III satellite instruments. The divergence in these comparisons seen at higher altitudes (greater than 27 km) is most likely because the ozonesonde data gets much sparser at these altitudes. Ozone total column comparisons have been made for 2004, 2005 and 2006 using the FTS, UV-visible, and ACE-FTS results. There is general agreement between the different instruments and there is evidence of the quite different atmospheric conditions above Eureka in the three campaigns. Papers describing the results of the 2004, 2005 and 2006 ACE Arctic Validation campaigns are in preparation.

Outreach work in local schools is an important component of the ACE Arctic validation campaigns. This part of the program began in 2004 when the team was delayed in Resolute because of bad weather. The additional day was spent visiting the students and staff at Qarmartalik School (75 students from K to grade 12) and a presentation on the ACE mission and the validation campaign was made to the entire school. In 2005, the team returned to Qarmartalik School to lead classroom workshops on ozone science, Canadian space science and weather for the five classes (Grades 1-3, Grade 4, Grades 5-7, Grades 8-9 and Grades 10-12). In 2006, the program was extended to include a visit to Grise Fiord as well as Resolute. Umimmak School in Grise Fiord (76.4°N) is the most northern school in Canada and is the closest to Eureka (located 500 km south of PEARL). New classroom presentations were prepared for 2006 that included topics on climate change science, satellites and light analysis (spectroscopy). Workshops were presented to three class groups at Umimmak School (Grades 1-4, 5-8, 9-12) and a general presentation was given to the whole school. The team has enjoyed these opportunities to talk about atmospheric and space science with the students of northern Nunavut (Figure 7).The ACE Arctic validation campaigns at PEARL have contributed to the ACE Validation Program. The datasets are being used to better understand the accuracy and reliability of the ACE-FTS and MAESTRO results. The campaign has also provided important opportunities for outreach activities with students in Grise Fiord and Resolute. It is hoped that these campaigns can continue with the CANDAC activities at PEARL for the lifetime of the ACE satellite mission.

Figure 7: The Grade 1-2 class at Qarmartalik School in Resolute, Nunavut show off their new weather mobiles. Also, pictured (left-right): Jeffrey Amarualik (Student Support Assistant), Jeff Taylor (ACE team), Kaley Walker (ACE team), and Dejian Fu (ACE team). (Photo by Tobias Kerzenmacher, March 2006)

Acknowledgements

The Canadian Arctic ACE validation campaigns were supported by the Canadian Space Agency (CSA), the Meteorological Service of Canada (MSC) of Environment Canada, the Natural Sciences and Engineering Research Council (NSERC) of Canada, and the Northern Scientific Training Program. We would like to thank Jonathan Davies and the staff at the Eureka Weather Station for the ozonesonde launches and profile analysis, and CANDAC/PEARL for its logistical support. Funding for ACE is provided by CSA and NSERC. Support at Waterloo was also provided by the NSERC-Bomem-CSA-MSC Industrial Research Chair in Fourier Transform Spectroscopy.

References

Bassford, M. R., C. A. McLinden, and K. Strong (2001), Zenith-sky observations of stratospheric gases: The sensitivity of air mass factors to geophysical parameters and the influence of tropospheric clouds, J. Quant. Spectrosc. Radiat. Transfer, 68, 657– 677.

Bassford, M. R., K. Strong, C. A. McLinden, and C. T.

McElroy (2005), Ground-based measurements of ozone and NO_2 during MANTRA 1998 using a new zenith-sky spectrometer, Atmos. Ocean, 43, 325-338.

Bernath, P. F., et al. (2005), Atmospheric Chemistry Experiment (ACE): Mission overview, Geophys. Res. Lett., 32, L15S01, doi:10.1029/2005GL022386.

Bird, J. C., et al. (1996), Stratospheric Studies at the Eureka NDSC Station Using a Rayleigh/Raman Differential Absorption Lidar, XVIII Quadrennial Ozone Symposium- 96, Sept. 12-21, 1996, University of L'Aquila, Italy.

Davies, J, D., et al. (2000), Evaluation of ECC Ozonesonde Preparation Methods from Laboratory Tests and Field Comparisons during MANTRA, Proceedings of the Quadrennial Ozone Symposium, Hokkaido University, Sapporo, Japan, July 3-8, 2000. R. D. Bojkov and S. Kazuo, eds., pp. 137-138.

Donovan, D. P., et al. (1997), Ozone, column ClO, and PSC measurements made at the NDSC Eureka Observatory (80N, 86W) during the spring of 1997, Geophys. Res. Lett., 24, 2709–2712.

Fu, D., et al. (2006), The portable atmospheric research interferometric spectrometer for the infrared, PARIS-IR, J. Quant. Spectrosc. Rad. Transfer, in press.

Harvey, V. L., and M. H. Hitchman (1996), A climatology of the Aleutian high, J. Atmos. Sci., 53, 2088– 2101.

Kerzenmacher, T. E., et al. (2005), Measurements of O_3, NO_2 and Temperature during the 2004 Canadian Arctic ACE Validation Campaign, Geophys. Res. Lett., 32, L16S07, doi:10.1029/2005GL023032.

McElroy, C. T. (1995), A Spectroradiometer for the Measurement of Direct and Scattered Solar Spectral Irradiance from On-Board the NASA ER-2 High-Altitude Research Aircraft, Geophys. Res. Lett., 22, 1361.

Pommereau, J.P. and F. Goutail (1988), O3 and NO_2 ground-based measurements by visible spectrometry during Arctic winter and spring 1988, Geophys. Res. Lett., 15, 891-894.

Savastiouk V. and C.T. McElroy (2005), Brewer Spectrophotometer Total Ozone Measurements Made During the 1998 Middle Atmosphere Nitrogen Trend Assessment (MANTRA) Campaign, Atmos. Ocean, 43, 315-324.

The Canadian Arctic Validation of ACE Team

ACE Validation Team Co-Leaders
Kimberly Strong, University of Toronto
Kaley Walker, University of Toronto/University of Waterloo
ACE Mission Scientist
Peter Bernath, University of Waterloo
Co-Investigators
James R. Drummond, University of Toronto
Hans Fast, Environment Canada
C. Thomas McElroy, Environment Canada
Richard Mittermeier, Environment Canada
Kevin Strawbridge, Environment Canada
Campaign Team Members
Richard Berman, Spectral Applied Research
Suzanne Bingham, University of Toronto
Pierre Fogal, University of Toronto
Annemarie Fraser, University of Toronto
Dejian Fu, University Of Waterloo
Florence Goutail, Service d'Aéronomie, CNRS
Michael Harwood, Environment Canada
Tobias Kerzenmacher, University of Toronto
Paul Loewen, University of Toronto
Keith MacQuarrie, University of Calgary
Clive Midwinter, University of Toronto
Oleg Mikhailov, University of Toronto
Keeyoon Sung, University of Waterloo
Jeffrey Taylor, University of Toronto
Jennifer Walker, University of Toronto
Hongjiang Wu, University of Toronto

International Polar Year (IPY) and International Arctic Systems for Observing the Atmosphere (IASOA)

by James R. Drummond[1]

Figure 1 Composite image of the Arctic observatories participating in the IASOA project: Barrow, Eureka, Alert, Summit Station, Ny-Alesund and Tiksi (courtesy of IASOA).

International Polar Year (IPY) will be a period of intense research activity from 1 March 2007 to 1 March 2009 when all nations are encouraged to intensify scientific research in the polar regions. The time period has been chosen to permit a full observing cycle – summer and winter – in both the Arctic and Antarctic. IPY continues a series of polar years: the first was in 1882-83, the second in 1932-33 and the third was International Geophysical Year (IGY) in 1957-58. IPY activities in 2007-2009 will cover the full range of polar research in both the Arctic and the Antarctic and, since Canada has a strong vested interest in Arctic issues, is an opportunity for this country to gain valuable understanding of these regions.

The main themes of IPY are to:

- Utilise the vantage point of the polar regions to carry out an intensive and internationally coordinated burst of high quality, important research activities and observations that would not otherwise occur;

- Lay the foundation for major scientific advances in knowledge and understanding of the nature and behaviour of the polar regions and their role in the functioning of the planet;

- Leave a legacy of observing sites, facilities and systems to support ongoing polar research and monitoring;

- Strengthen and enhance international collaboration and co-operation in polar regions research and monitoring;

- Address both polar regions and their global interactions;

- Link researchers across different fields to address questions and issues lying beyond the scope of individual disciplines;

- Collect a broad-ranging set of samples, data and information regarding the state and behaviour of the polar regions to provide a reference for comparison with the future and the past;

- Ensure data collected under the IPY are made available in an open and timely manner;

- Intensify the recovery of relevant historical data and ensure that these also are made openly available;

- Attract, engage and develop a new generation of polar researchers, engineers and logistics experts;

- Optimise exploitation of available polar observing systems, logistical assets and infrastructure;

- Develop and embrace new technological and logistical capabilities;

- Build on existing and potential new funding flows;

- Engage the awareness, interest and understanding of schoolchildren, the general public and decision-makers worldwide in the purpose and value of polar research and monitoring.

IPY is co-sponsored by the International Council of Science (ICSU) and the World Meteorological Organisation (WMO). It is managed by an international Joint Committee chaired by Dr. Ian Allison (Australia) and Dr. Michel Béland (Canada). The main web-site is: www.ipy.org. In Canada, the Canadian Steering Committee (CSC), chaired by Mr. Ian Church, (Government of Yukon), works with the Canadian Polar Commission and the IPY Federal Working Group to coordinate Canada's IPY initiatives. The CSC web-site is: www.ipy-api.ca and the Federal Government web-site is: www.ipy-api.gc.ca. All of these web-sites have a wealth of information on IPY activities and this short article cannot hope to offer any comprehensive view of the entire enterprise. Thus we focus on one particular activity which heavily involves the PEARL facility at Eureka: IPY #196, International Arctic Systems for Observing the Atmosphere (IASOA) [PI: Dr. Taneil Uttal, NOAA].

---

[1] Department of Physics and Atmospheric Science, Dalhousie University, Halifax, NS

Figure 2: The locations of the initial sites in the IASOA network (courtesy of IASOA).

IASOA is an activity designed primarily to develop a legacy of continuous measurements of the Arctic atmosphere from a number of fixed observatories that will be combined with additional measurements from episodic, focussed, campaigns. The goal is to develop sufficient understanding to determine relative contributions of natural versus anthropogenic forces in shaping the nature of the Arctic atmosphere.

A particular emphasis is to promote and integrate the activities of a number of major, intensive, and permanent observatories: Barrow (Alaska), Eureka and Alert (Canada), Summit Station (Greenland), Ny-Alesund (Svalbard, Norway) and Tiksi (Russia) (see Figure 1). These observatories will provide circumpolar coverage, as illustrated in Figure 2. This element is responsive to a number of international assessments and research programs that have recommended that multi-disciplinary “super-sites” be developed to collect the information needed to determine the processes and drivers of environmental Arctic change across disciplines. A further hope is that these sites will be developed in IPY but will then leave a legacy of capabilities in the Arctic to be further developed in the future. One has only to think of the stimulus that IGY gave to many fields of research to realise how significant this could be for long-term studies of the polar environment.

An initial meeting of IASOA was held in Toronto on 19-20 June, 2006 and was attended by over 75 researchers from many countries. At this meeting, committees were set up to oversee the work of IASOA and many contacts between groups and laboratories were initiated. As the program for IPY is developed and the funding situation becomes clearer, many of these collaborations will begin to produce meaningful results. The IASOA web-site is: www.iasoa.org.

The Canadian Network for the Detection of Atmospheric Change (CANDAC) is a founding sponsor of IASOA and will support the activity with a full range of activities at the PEARL laboratory complex at Eureka. The first major task for CANDAC is to complete the installation of the new equipment at PEARL and the schedule has been accelerated to put installation of the equipment on the fastest possible track. This will make much of the equipment available by the summer of 2007. In addition, an application has been made to the Government of Canada for additional funding to support an intensive program of research at PEARL in addition to the normal research program and for an extensive outreach program associated with the research activity.

One of the most exciting things about an activity like IPY is the opportunity to bring together people and equipment in a highly co-operative manner to produce results which would be impossible to obtain in other ways. Several of the projects proposed for IPY build on the significant equipment base that exists at PEARL, supplemented by equipment brought in especially for the IPY activity. Thus a project on the validation of space-based measurements of cloud properties and precipitation characteristics led by David Hudak of Environment Canada (EC) will take advantage of the multiple radars and lidars already existing at PEARL and add a Precipitation Occurrence Sensor System (POSS); a 10 GHz CW Doppler bi-static radar that provides precipitation type, precipitation rate, and particle size distribution; a HotPlate Advanced Precipitation-Measuring System for snowfall rate; and a sonic snow depth sensor. With this array of equipment, Dr. Hudak and colleagues will develop an understanding of how measurements of clouds and the like from satellites such as CloudSat can be related to Arctic conditions of temperature and land cover. These are radically different from the conditions at mid-latitudes where most of the satellite validation is done.

Figure 3: Prof. Kaley Walker leading a science workshop for students in grades 5-8 at Umimmak School in Grise Fiord, Nunavut in March 2006. (Photo courtesy of Dejian Fu)

Similarly by combining the resources of EC, PEARL and the Study of Environmental Arctic Change (SEARCH) groups, Bruce McArthur and colleagues will be performing studies of radiation and energy budget closure at the surface. They will observe changes in the moisture and energy balances, along with plant productivity over two growing seasons to look at the relationships between atmospheric and surface coupling. To do this, in addition to the normal PEARL equipment, a flux tower with associated equipment and a Baseline Surface Radiation Network (BSRN) site will be installed at the Surface and Atmospheric Flux, Irradiance, Radiation Extension (SAFIRE) PEARL site located away from the main building complex at Eureka.

Other projects will make more intensive and novel use of the multiple lidars and other instrumentation at PEARL. Several projects make use of the multiple lidar systems for temperature and composition, relating them to measurements at other observatories. IASOA provides an ideal basis for such collaborative projects. There are also extensive opportunities for making co-ordinated measurements of the upper atmosphere using, for example, the meteor radar already operating at the facility.

One of the major foci of IPY and of CANDAC is the communication of research to the broader community and CANDAC is proposing several activities in this area. One will bring students from Northern Canada into the research program for a significant period of time to familiarize them with the techniques and objectives of the activity. Another activity will bring students from Southern Canada to the North and a third will continue the highly successful program of outreach to high schools in Northern Canada (see Figure 3).

IPY and IASOA are an extremely good fit with the activities of CANDAC and the PEARL laboratory. The timing of the refurbishment of the laboratory is almost perfect for participation in this enterprise. (The CANDAC team would like to take credit for this, but it is in fact purely serendipitous.) The development of linkages with other laboratories, networks and projects in the Arctic whose interests overlap with those of CANDAC will be greatly accelerated by IPY and this will lead to an acceleration of the atmospheric studies in Canada near the pole. The CANDAC team is looking forward to the next few years as a time of intense and rewarding activity.

The Wolves of Eureka

by L. David Mech[1]

Seventeen shaggy, adult muskoxen and 6 young calves grazed placidly along a barren, windblown meadow oblivious to 7 taut, white forms sneaking cautiously toward them. Suddenly, one of the bulls caught a familiar, threatening waft of air and rushed toward the calves; instantly the scattered herd coalesced to a dark brown mass around their young. Almost as quickly, 7 Arctic wolves shot toward the herd. But as usual, it was too late. The hungry but tireless patrollers of the high-Arctic plains would have to travel on to find a less-wary herd or better circumstances so they could finally eat.

Figure 1: Arctic wolves inhabit the Eureka area year-around.

Dramas like this play out daily on the broad Fosheim Peninsula of Ellesmere Island where the Eureka Weather Station lies snow-bound for all but 2 or 3 months of the year. And each summer for the past 20 years I have been there trying to watch those dramas (Mech 1987, 2005). Such scenes would be interesting to anyone, but to me they provide important insight into the behavior of the wolf, a creature I have spent my half-century-long career getting to know.

Although wolves originally inhabited Earth's entire northern hemisphere, they were exterminated from large areas, especially from most of the U.S. outside of Alaska and Minnesota. Almost everywhere else in the world they were so persecuted that they survived only in wilderness and highly inaccessible areas, and where they did survive they grew extremely wary (Boitani 2003). In the contiguous 48 states, wolves became so scarce they were declared endangered and fully protected by law in 1973. Thus it was very difficult to learn anything about wolves in most areas, and special techniques had to be used such as studying captive wolves, aerially observing wild wolves during winter or live-trapping and radio-collaring wolves and monitoring their movements remotely by aircraft or satellites (Mech 1974, Ballard et al. 1995). And as the U.S. Department of the Interior's first full-time wolf biologist, I employed all those techniques and any others I could find to learn whatever I could about wolves.

Figure 2: Muskoxen constitute one of the main prey items of the wolves in the area, but wolves must chase many herds before finding an animal they can capture.

Imagine my elation, then, when in April 1986, I happened upon a pack of wolves near Eureka that, rather than instantly fleeing like any other wolves in the world, merely stood and watched me as I stared back. I was on a personal assignment from *National Geographic* magazine to gather material for an article about Ellesmere Island, and Eureka was my first stop (Mech 1987, 1988). Bleak, barren, and beautiful, and bright with spring's perpetual sun, the Eureka area occupies a thermal oasis where from June through August its hills, ridges, and plains usually lie snow- and ice-free, contrary to most of Ellesmere. A special configuration of elevation, topography, and reflecting ice focusses the sun's constant rays to heat certain areas like Eureka.

This phenomenon promotes growth of various low plants in scattered areas that allows herbivores such as lemmings, Arctic hares, Peary caribou, and muskoxen to eke out a meagre living. And carnivores such as weasels, foxes, and wolves cash in on the available prey they can catch. Because the growing season is short and the region only marginally fertile, the density of all these creatures is low and their existence precarious. The Eureka wolf pack must traverse an area of at least 2,600 square kilometres to make a living. When conditions tip unfavourably, animal numbers drop and recovery can take years. Arctic hares that were relatively common there in the 1980s and 1990s suffered from adverse weather in 1997 and 2000 and still have not recovered to anywhere near their former numbers (Mech 2000, 2004). As food for weasels, foxes, wolves, hawks,

[1] Biological Resources Discipline, U. S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

owls, and jaegers, the hare population must struggle especially hard to increase. The same adverse weather—permanent snow cover starting in mid-August during each of those 2 years—also slammed muskoxen, but their numbers rebounded more quickly, having only wolves to contend with (Mech 2005). Currently muskoxen appear to be the main prey of the wolves, but when hares fully recover, these large white lagomorphs will nicely supplement the wolf's diet.

Although the interactions between wolves and their prey in the Eureka area are intriguing, the primary benefit of studying the Eureka wolves is the ability to closely examine their behaviour. I and others have done studies of wolf relations with prey in several other parts of the world. However, nowhere but in the Eureka area can anyone observe such intimate details of wolf behavior as how far a wolf can spot a hare; on what schedule a female wolf nurses her pups; which wolf babysits the pups when the mother is gone; what pack member delivers the most food to the pups; specifically where, when, and what food wolves bury in caches and when they retrieve it to eat..

The reason one can gather this kind of information from the Eureka area wolves is because they are so tolerant of an observer. (After they got to know me, one bold wolf strolled up and tried to pull my glove off as I sat on an all-terrain vehicle!) Thus I returned to the area in July 1986, and spent a week trying to follow a wolf that was obviously nursing pups and located her den. Wolves use dens only to raise pups for about eight weeks, June and July near Eureka. After that, they continue tending their fast-growing pups in a homesite above ground called a rendezvous site, for another 2-3 months. Finally by late fall the whole pack becomes nomadic over a large territory until they den again the next June,

Figure 3: During summer most muskoxen the wolves kill are calves.

usually in the same den. Thus, during each summer, for me it is simply a matter of visiting the den and sitting there watching the wolves. Eventually, by observing subtle color patterns, urination postures, shedding patterns, and even degree of tooth wear when a nearby wolf yawns, I can identify each pack member.

Figure 4: Arctic wolves use a den each year for about 8 weeks in which to raise their litter of 1-6 pups.

Many wolves in the high Arctic are similarly tolerant, and the Eureka wolves have been that way at least since 1955 when ornithologist David Parmalee visited the area. He hand-captured a wolf pup, and the mother wolf followed at his heels while he carried the pup to his tent (Parmalee 1964). Contrary to everywhere else in the world, wolves in much of the high Arctic have never been hunted, trapped, snared, or poisoned. Thus they never learned to avoid humans.

This unique proclivity of the Ellesmere wolves to tolerate observers has all been a boon to science. Every summer since 1986 (except 1999 when a back injury cut short my journey at Resolute Bay) I have visited the Eureka area and studied the wolves (Mech 1997, 2005). Other scientists from Texas, Alaska, Montana, Northwest Territories, Nova Scotia, and even Italy, have joined me, and a long list of candidates awaits their turn. Each biologist, having studied wolves indirectly or from afar, has been eager to gain the close-up experience that working with the Eureka wolves allows.

Not only can one gather much new data that it was previously impossible to obtain, but two other less-tangible scientific benefits also accrue. First, being able to observe the Eureka pack up close provides new insights into wolf behaviour and ecology that allow one to form hypotheses that can be tested elsewhere. For example, by learning the age and sex of pack members that tend to baby-sit pups most often in the Eureka pack, a researcher may then plan projects using radio-collars on several packs in other study areas that allow him or her to test hypotheses about this subject.

Second, and less tangible, is the ability to gain the kind of insight one gets from living closely with a pet. Most people who have raised a dog understand how daily interaction and observation of their pets teach them subtle information about that animal. Much of such information could not be quantifiable enough to publish in a scientific journal, yet it certainly adds to the store of knowledge one has about a pet. Similarly, by living daily close-up with a wild wolf pack, one gains valuable knowledge about the species that greatly rounds out knowledge of the animal.

So, given all these advantages of studying the Eureka area wolves, what have we actually learned? First, the basics. Like most wolf packs, the Eureka pack is a family comprised of an adult pair of wolves that most likely are unrelated, and their offspring of the previous 1 or 2 years. The current Eureka pair had formed in 2003 after the last remnants of the pack I studied from 1986 through 2000 had died off or dispersed after the hares and muskoxen declined (Mech 2000, 2004, 2005). The new pair did not produce pups until 2004 when they had a litter of 4. In summer 2005, the pack contained 6 adults and 3 pups, and in 2006, 7 adults and 5 pups.

Contrary to traditional scientific understanding about wolf social behavior, the breeding male and female do not fight with other wolves to obtain or hold their breeding status. Rather they originally find each other as maturing adults, mate, and then produce their offspring. As their offspring grow and develop, the parents – like those of most other species of mammals – automatically maintain dominance over their offspring until they disperse, usually at 1 or 2 years of age. The long-presumed contention that pack members constantly compete for dominance, however, with the winner being the “alpha wolf” has no basis in the real world of the Eureka wolf family (Mech 1999). What bits and pieces of information are known about this subject from other studies supports this important insight gained from the Eureka pack.

Figure 5: Wolf pups grow quickly and regularly beg food from the adults, who regurgitate it to them.

Pups in the Eureka area are usually born in early June in a rock cave that wolves have used for decades and probably for hundreds of years (Grace 1976, Mech and Packard 1999). The mother wolf nurses the pups for about 9 weeks, but at 3 weeks of age the pups start consuming food that their mother, father and older siblings carry to them or regurgitate to them (Packard et al. 1992). Food regurgitation is extremely important to the pups, and the study of this interesting food-provisioning technique provides significant insight into the social organization of the wolf pack. However, for the reasons discussed above, the only place food regurgitation can be studied in free-ranging wolves is around Eureka (Mech et al. 1999).

The father wolf is the only pack member that does not get fed by any other wolf. Rather he regurgitates to his pups, to their mother, and to his older offspring. The mother regurgitates to her pups and sometimes to her older offspring, and the older offspring regurgitate primarily to the pups. In keeping with evolutionary theory, the father regurgitates more often to his mate while she feeds their pups mostly via nursing, but later he regurgitates more to the pups. Theory explains that the only way the male can invest in his genes (offspring) early in the summer is through the female, whereas after the pups depend less on milk and more on meat, the male can forgo feeding the female (who shares none of his genes) and invest directly in his offspring.

Similar to the above intimate details about regurgitation around the den, details about the behaviour of individual pack members during various activities has lent significant insight into the question of pack leadership. Other studies had obtained anecdotal evidence allowing tentative conclusions to be reached about which wolf is the pack leader. However, with the Eureka wolves, I could quantify leadership behaviour during hunting, travelling, den defence, territorial fighting, and pup care. This evidence led me to conclude that although the breeding male dominates the female socially, both animals assume leadership roles in a division-of-labour relationship (Mech 2000). The male tends more to direct pack travel and hunting, while the female tends the pups more and guards the den from intruders such as stray muskoxen that blunder to it.

Other types of unique behavioral information that I have been able to collect from the Eureka wolves have provided insight and understanding on many other aspects of wolf life including rate of travel (Mech 1994), scent-marking (Mech in review), caching, hunting strategy (Mech in preparation), sensory abilities, pup-care recognition behaviour, daily activity patterns (Mech and Merrill 1998), sleep patterns, the functions of howling, and many more.

When I first started studying wolves, the use of high technology such as aircraft (Mech 1966) and radio-tracking (Mech and Frenzel 1971) became the new research technique that revolutionized data collecting and produced much greater understanding of wolf natural history, behaviour, and ecology. Similarly, when I first found Eureka’s cooperative wolves, the persistent observation and low-tech approach I have been able to use with them has allowed me to supplement much of the broader-scale movement and population information obtained earlier with a new finer-scale understanding of the wolf’s basic nature.

But I’m not done yet. As in any new data-collection system, as soon as one answers a long-existing question, the very answer suggests a new puzzle. Every summer, then, Eureka’s unique wolves lure me back to that thermal oasis in the frozen desert that is Ellesmere Island. And every year I learn more and more about those big, white, wild dogs that haunt the barren plains totally unaware of just how valuable are the secrets they so freely yield.

Acknowledgements
The studies summarized here were supported by the U. S. Geological Survey, the U. S. Fish and Wildlife Service, the U. S. National Biological Survey, and the National Geographic Society. Logistical support was provided by the Atmospheric Environment Service of Environment Canada, the Eureka Weather Station, and the Polar Continental Shelf Project (PCSP). Research permits were granted by the Nunavut Department of the Environment. This is PCSP paper.025-06.

References

Ballard, W. B., D. J. Reed, S. G. Fancy, and P. R. Krausman et al. 1995. Accuracy, precision and performance of satellite telemetry for monitoring wolf movements. Pages 461-467 *in* L. N. Carbyn, S. H . Fritts, and D. R. Seip (Eds.). Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Occasional Publication 35. Edmonton, Alberta. 620 pp.

Boitani, L. 2003. Wolf conservation and recovery. Pages 317-340 *in* L. D. Mech and L. Boitani, (Eds.) Wolves: Behavior, Ecology, and Conservation. University of Chicago Press. 405 pp.

Grace, E. S. 1976. Interactions between men and wolves at an Arctic outpost on Ellesmere Island, Canadian Field Naturalist 90:149-156.

Mech, L. D. 1966. The Wolves of Isle Royale. National Parks Fauna Series No. 7. U.S. Government Printing Office. 210 pp. (Reprinted 2002. University of the Pacific, Honolulu Hawaii).

Mech, L. D. 1974. Current techniques in the study of elusive wilderness carnivores. Proceedings of the 11th International Congress of Game Biologists. pp. 315-322.

Mech, L. D. 1987. At home with the arctic wolf. National Geographic 171(5):562-593.

Mech, L. D. 1988. Ellesmere Island: Life in the high arctic. National Geographic 173(6):750-767.

Mech, L. D. 1994. Regular and homeward travel speeds of arctic wolves. Journal of Mammalogy 75:741-742.

Mech, L. D. 1997. The Arctic Wolf: Ten Years with the Pack. Voyageur Press, Stillwater, MN. 144 pp.

Mech, L. D. 1999. Alpha status, dominance, and division of labor in wolf packs. Canadian Journal of Zoology 77:1196-1203.

Mech, L. D. 2000. Lack of reproduction in muskoxen and arctic hares caused by early winter? Arctic 53(1):69-71.

Mech, L. D. 2000. Leadership in wolf, *Canis lupus*, packs. Canadian Field Naturalist 114(2):259-263.

Mech, L. D. 2004. Is climate change affecting wolves in the High Arctic? Climatic Change 67: 87-93.

Mech, L. D. 2005. Decline and recovery of a High Arctic wolf-prey system. Arctic 58:305-307.

Mech, L. D. Accepted. Scent-marking by free-ranging arctic wolves in summer. Canadian Field Naturalist.

Mech, L. D. In preparation. Possible use of foresight, understanding, and planning by wolves hunting muskoxen.

Mech, L. D., and L. D. Frenzel, Jr. 1971. Ecological studies of the timber wolf in northeastern Minnesota. USDA Forest Service Research Paper NC-52. North Central Forest Experimental Station, St. Paul, Minnesota 62 pp.

Mech, L. D. and S. B. Merrill. 1998. Daily departure and return patterns of wolves, Canis lupus, from a den at 80° N latitude. Canadian Field Naturalist 112(3):515-517.

Mech, L. D., P. C. Wolf, and J. M. Packard. 1999. Regurgitative food transfer among wild wolves. Canadian Journal of Zoology 77:1192-1195.

Packard, J. M., L. D. Mech, and R. R. Ream. 1992. Weaning in an arctic wolf pack: behavioural mechanisms. Canadian Journal of Zoology 70:1269-1275.

Parmelee, D. F. 1964. Myth of the wolf. The Beaver 295:4-9.

Acknowledgements

The *CMOS Bulletin SCMO* wishes to thank the University of Toronto and the Eureka Science Team for their financial assistance in printing this special issue. The use of colour will make this Bulletin much more appealing. We also wish to thank Dr. Kimberly Strong for her continuous effort in collecting and submitting the articles published in this special issue of the Bulletin. Without her initiative and assistance, it would not have come true.

CMOS Bulletin SCMO Editorial Team

Remerciements

Le *CMOS Bulletin SCMO* désire remercier l’Université de Toronto et l’équipe scientifique du projet Eureka pour leur assistance financière dans l’impression de ce numéro spécial. L’utilisation de la couleur rehausse grandement l’apparence de ce Bulletin. Nous désirons également remercier la Dr. Kimberly Strong pour ses efforts soutenus pour rassembler et soumettre les articles qui apparaissent dans ce numéro spécial du Bulletin. Sans son initiative et son assistance, ce numéro n’aurait pas vu le jour.

L’équipe éditoriale du CMOS Bulletin SCMO

Avoiding Dangerous Climate Change

Editors H-J. Schellnhuber, W. Cramer, N. Nakicenovic, T. Wigley and G. Yohe

Cambridge University Press, 2006, 392 pages
ISBN 0-521-86471-2, Hardback, US$130.

Book reviewed by John Stone[1]

It is now almost 15 years since the umbrella United Nations Framework Convention on Climate Change was completed at the Earth Summit in Rio de Janeiro, and almost ten years since the Kyoto Protocol that provided specific greenhouse gas emission reductions for developed countries was negotiated. Over that period Canadian governments have produced several "plans" and promised billions of dollars in order to meet our target. The results have been disappointing as our emissions continue to grow to the point where they are now close to 30% above the target. Canada is not alone; other countries are experiencing difficulties in meeting their commitments although Canada is almost in a league of its own. This first step is proving to be a considerable political challenge even though the collective target for developed countries is a modest five percent reduction below 1990 levels. Many scientists are convinced that perhaps ten Kyotos are necessary to stabilize atmospheric concentrations at levels that will avoid, in the words of Article 2 of the Convention, dangerous interference with the climate system.

The United Kingdom is something of an exception. Intellectually, the UK government has understood the threat of climate change. One early indication was when Margaret Thatcher, some 20 years ago, called in some key climate scientists for a two-day discussion on the subject. Having been convinced of the seriousness of the problem, she established the Hadley Centre for Climate Prediction and Research. The present Prime Minister, Tony Blair, has put in place new policies to achieve emission reductions (reductions that are made somewhat easier by closing the coal mines and switching to North Sea natural gas). He also chose to make climate change one of his priorities for his presidency of the G-8 Summit in 2005. In preparation for this Summit, he asked his officials to organize a conference to explore "what levels of greenhouse gases in the atmosphere are self-evidently too much?" and "what options do we have to avoid such levels?" This book is a result of that seminal conference. The book's aim is not only to be a record of the conference but also a resource for those wishing to understand the science behind the threat of climate change and the urgent need for humanity to tackle it.

The book has arranged the presentations according to the sections of the conference programme. Each section is prefaced by a short readable summary. These summaries are based on synthesis papers that were prepared at the end of each section by one of the participants and discussed with the conference as a whole. They are a useful, quick read for those who might find the individual papers too demanding of specialist knowledge.

The book provides a valuable introduction to defining what is "dangerous". This term was introduced by the original negotiators of the Convention. However, it defies easy interpretation as was admitted in the Synthesis Report of the Intergovernmental Panel on Climate Change's Third Assessment. The term basically depends on what we value – be it an ecosystem such as a butterfly population, a culture such as that of the Inuit in the Arctic, or a community such as a coastal settlement – as well as on the result of a political process, informed by science, that balances the risks and the benefits of different investment decisions.

One of the major contributions of the conference was raising awareness of the urgency of addressing the climate change threat. The pace of government action and intergovernmental negotiations would seem to suggest that the threat is still regarded as being some way off in the future. And so it may be, but, as was illustrated in several of the presentations, the longer we delay in taking action the more costly and risky it is likely to be. The paper by Rik Leemans et al showed quite disconcertingly that we are now seeing ecological impacts attributable to climate change that are occurring at a much faster rate than had been anticipated. He suggested this may be because over the last decade extreme weather has changed more markedly than average weather. Several other papers showed that simply from an economic perspective, delaying action is likely to increase costs by a significant amount. Not only would we have to reduce concentrations from a much higher level, but the longer we delay the higher we allow atmospheric concentrations to increase and the greater the risk of an abrupt and potentially irreversible transition.

Several of the talks reported in the early sections of the book discuss the possibility of crossing thresholds in the climate system - what are often, though often incorrectly, referred to as "tipping points". These are usually a function of the climate system itself but can also be as a result of society's decision that further changes are no longer acceptable. As Chris Rapley discussed, our understanding

[1] Retired meteorologist and adjunct Research Professor in the Department of Geography and Environmental Studies at Carleton University

of glacier and ice-sheet dynamics is now such that disintegration at the edges can cause rapid advances – almost as when a cork is taken out of a bottle. Several papers in the book explore the chances of a shut-down of the North Atlantic Thermohaline Circulation. These papers, such as the one by Michael Schlesinger et al., suggest that the present consensus that a shutdown over the next century is unlikely, may be wrong.

A new concern is the acidification of the oceans. In the paper of Carol Turley et al. the authors note that the oceans have taken up around 50% of the total carbon dioxide released from the burning of fossil fuels and that ocean pH has already decreased. They suggest that this will continue and will have serious consequences for marine biogeochemistry and ecological processes on which we depend. Furthermore, some of these processes may be non-linear and complex and provide a further basis for concern over the increased concentrations of greenhouse gases in the atmosphere.

Based on such new research results and the inertia in the climate system, some scientists are now suggesting that we may not have more than 10 -15 years to get ourselves on the right track to eventually stabilize atmospheric concentrations at a level that will avoid dangerous impacts. In fact some are now becoming so concerned that such solid scientists as Jim Lovelock and others are again embracing nuclear power and Paul Crutzen is considering geo-engineering solutions such as seeding the atmosphere with sulphate aerosols.

The prospects need not be daunting. In one of the papers that made this a seminal conference, Robert Socolow discussed his now well-known “wedges diagram” in which he argues that we now have the technologies to be able to stabilize our emissions of greenhouse gases at today’s levels until 2050. He divides up the required reductions below business-as-usual emissions into one gigatonne wedges, with one technology for each of seven wedges. The technologies include energy efficiency, carbon capture and storage, renewable energy and nuclear power. Such a trajectory would get us on a path to stabilizing atmospheric concentrations at less than double pre-industrial levels by the end of the century. His clear messages are: now is the time to act; it is too soon to pick winners as all technological options will be needed; different countries will adopt different mixtures of technologies; and what is required is clear political will to institute carbon management strategies that reliably communicate the price of carbon. An encouraging sign is that Canada’s National Round Table on the Environment and the Economy has used this idea in its recent paper: *Advice on a Long-term Strategy on Energy and Climate Change.*

Those of us in Ottawa who try to decipher the new government sometimes question whether it understands that the threat of climate change is real and in need of urgent attention. This book should not only convince it that this is indeed the case but that, as Robert Socolow argues, we have the technological means to tackle the threat and in so doing a “planetary consciousness will have become much more widespread – not an unhappy prospect!”

Books in search of a Reviewer

Livres en quête d’un critique

The High-Latitude Ionosphere and its Effects on Radio Propagation, by Robert Hunsucker and John Hargreaves, Cambridge University Press, Hardback, 0-521-33083-1, US$140.00.

Flood Risk Simulation, by F.C.B. Mascarenhas, co-authored with K. Toda, M.G. Miguez and K. Inoue, WIT Press, January 2005, ISBN 1-85312-751-5, Hardback, US$258.00.

Extreme Events, A Physical Reconstruction and Risk Assessment, by Jonathan Nott, Cambridge University Press, May 2006, pp.297, ISBN 0-521-82412-5, Hardback, US$70.00.

Statistical Analysis of Environmental Space-Time Processes, by Nhu D. Le and James V. Zidek, Springer Science-Business Media Inc, 2006, ISBN 0-387-26209-1, Hardback, US$79.95.

Nonlinear Dynamics and Statistical Theories for Basic Geophysical Flows, by Andrew J. Majda and Xiaoming Wang, Cambridge University Press, 2006, pp.551, ISBN 0-521-83441-4, Hardback, US$90.00, 2 copies available.

Introduction to Coastal Dynamics and Shoreline Protection, by G. Benassai, Wessex Institute of Technology Press, July 2006, pp.331, ISBN 1-84564-054-3, Hardback, US$195.00.

If you are interested in reviewing one of these books for the *CMOS Bulletin SCMO*, please contact the Editor at the e-mail address provided below. Of course, when completed, the book is yours. Thank you in advance for your collaboration.

Si vous êtes intéressés à faire la critique d’un de ces livres pour le *CMOS Bulletin SCMO*, prière de contacter le rédacteur-en-chef à l’adresse électronique mentionnée ci-dessous. Bien entendu, le livre vous appartient lorsque vous avez terminé la critique. Merci d’avance pour votre collaboration.

Paul-André Bolduc, Editor / Rédacteur-en-chef
CMOS Bulletin SCMO
bulletin@cmos.ca or/ou bulletin@scmo.ca

"Project Atmosphere 2006"

by Natalie Jalette

On Monday, July 16th, I was introduced to the fascinating world of American meteorology. Dr. Ira W. Geer, Director of the American Meteorological Society (AMS) Education Program, welcomed seventeen secondary school teachers from across North America to the annual AMS workshop titled "Project Atmosphere". The workshop, sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF), was held at the National Weather Service Training Center (NWSTC) in Kansas City, Missouri. I, a grade nine geography teacher from Bishop Smith Catholic High School in Pembroke, Ontario, was selected by the Canadian Meteorological and Oceanographic Society (CMOS) and the Canadian Council for Geographic Education (CCGE) to represent Canada. I was accompanied by teachers from thirteen US states, namely Alabama, Georgia, Illinois, Indiana, Minnesota, Montana, Nebraska, New Jersey, New York, Ohio, Pennsylvania, Virginia, and Wisconsin.

Natalie Jalette in front of NOAA/NWS Training Centre Entrance

AMS staff developed and delivered an intense, interactive fourteen-day workshop covering a variety of topics. Topics of study included: the atmosphere, oceans, solar radiation, weather, climate, weather systems, clouds, the coriolis effect, El Niño, La Niña, hazardous weather conditions, storms, lightning, hurricanes, tornados, automated surface observation systems, aerosondes, radiosondes, radar, weather satellites, satellite imagery, general forecasting, and monitoring for aviation purposes.

The topics listed above were delivered by numerous professionals in the meteorology field. Key note speakers included: Dr. Louis Uccellini, Director of the National Center for Environmental Prediction (NCEP); Dr. Joseph Schaefer, Director of the Storm Prediction Center in Norman, Oklahoma; Mr. Max Mayfield, Director of the Tropical Predication Center in Miami, Florida; and, General David L. Johnson, Director of the National Weather Service (NWS) in Silver Spring, Maryland.

Some interesting facts:

- On average, ten hurricanes spawn in the western Atlantic Ocean each year, (NOAA, NWS, 2002).
- Hurricane track forecasting errors have been reduced by fifty percent over the past fifty years, (Mayfield, 2006).
- Doppler radar, which is widely used in both Canada and the United States today, was developed in Oklahoma in 1994.
- On average, one thousand tornadoes touch down in the United States annually, (NOAA, NWS, 2002).
- Tornado deaths have dropped significantly over the past fifty years, from an annual average of 350 in the year 1950 to 150 in the year 2000, (Schaefer, 2006).

Educational modules and a summary of classroom application procedures accompanied each lecture or presentation. Evening sessions allowed for collegial discussion and idea sharing. I had the opportunity to share Ontario's curricular expectations for weather and climate at a variety of grade levels. I also had the opportunity to promote weather and climate-related magazines and web sites produced in Canada.

Daily presentations and lessons were further complemented by a field trip to the National Weather Service (NWS) station in Topeka, Kansas, where we had the opportunity to witness real-time surface chart and satellite imagery analysis, as well as a radiosonde launch. A second field trip occurred at the National Aviation Weather Center in Kansas City, Missouri. There, we had the opportunity to observe surface and upper level weather conditions via radar and satellite imagery. Meteorologists work at this facility twenty-four hours a day, seven days a week. It was amazing to discover that approximately 7,000 aircrafts are flying over North America at any given time.

In the end, my original view of meteorology and weather forecasting as an acquired art was transformed into one of a dynamic science based upon complex chemical, physical, and mathematical modelling.

The information and materials gathered during this two-week experience will be shared with fellow teachers and students in the Renfrew County Catholic District School Board. My goal is to increase their understanding of the science behind meteorology, promote recent technological advances, and encourage them to further explore and/or possibly pursue this evolving and influential field.

I am truly grateful to CMOS and the CCGE for supporting my participation in the program. Hopefully, Canadian interest and participation will continue for years to come.

In Memory of Peter Zwack

The Autism Society of Canada has established the Dr. Peter Zwack Memorial Research Scholarship as the most fitting method of remembering the contributions of their beloved President, who died last year (*CMOS Bulletin SCMO*, Vol.33, No.6, p.192). Dr Zwack was also President of CMOS in 1996. Persons wishing to make a contribution to the Scholarship can do so through the web at:

www.autismsocietycanada.ca

http://www.autismsocietycanada.ca/

under the tab “Donate”, by specifying “In memory of Peter Zwack”.

À la mémoire de Peter Zwack

La Société canadienne de l'autisme a choisi de créer la Bourse de recherche commémorative du Dr Peter Zwack, comme la façon la plus appropriée de reconnaître les contributions de leur président bien aimé qui est décédé l'an dernier (*CMOS Bulletin SCMO*, Vol.33, No.6, p.192). Dr Zwack a également été président de la SCMO en 1996. Les personnes voulant contribuer peuvent le faire via l'internet à:

www.autismsocietycanada.ca

http://www.autismsocietycanada.ca/

sous l'onglet “Faire un don”, en spécifiant “En mémoire de Peter Zwack”.

Canadian Ocean Technology Directory

The recently established Ocean Science and Technology Partnership (OSTP) has compiled a Directory of Canadian organizations involved in ocean science and technology. The Directory is available on CD with a user interface capable of displaying records, multiple field search functions and help files. To obtain a free copy of the Directory or to register an organization, email Adam Dutton at adutton@ccmc.nf.ca. The Directory will also be posted on the OSTP website, currently under development.

C-CIARN Atlantic Workshop

The C-CIARN Atlantic Workshop on *"Adapting Water Management in First Nations Communities to Climate Change*" was held last October in Moncton, New Brunswick. Documents, including the presentations and a Workshop report, are available at http://c-ciarn.dal.ca/workshops/6/index.html.

50 Ways to Save the Ocean

The book entitled "*50 Ways to Save the Ocean*" focuses on practical, easily implemented actions to protect and conserve the oceans. It also addresses issues such as toxic pollutant runoff; protecting wetlands and sanctuaries; saving reef environments; and replenishing fish reserves. For details, including ordering information, access http://www.50waystosavetheocean.com.

Arctic Observing Network

"*Toward an Integrated Arctic Observing Network*", prepared by the Committee on Designing an Arctic Observing Network, US National Research Council is available at http://www.nap.edu/catalog/11607.html.

World Ocean Directory

The World Ocean Directory is an online service that describes more than 8300 ocean-related institutions around the world - http://www.thew2o.net/directory.html.

CMOS Accredited Consultants
Experts-Conseils accrédités de la SCMO

Gamal Eldin Omer Elhag Idris, C.Chem., MCIC

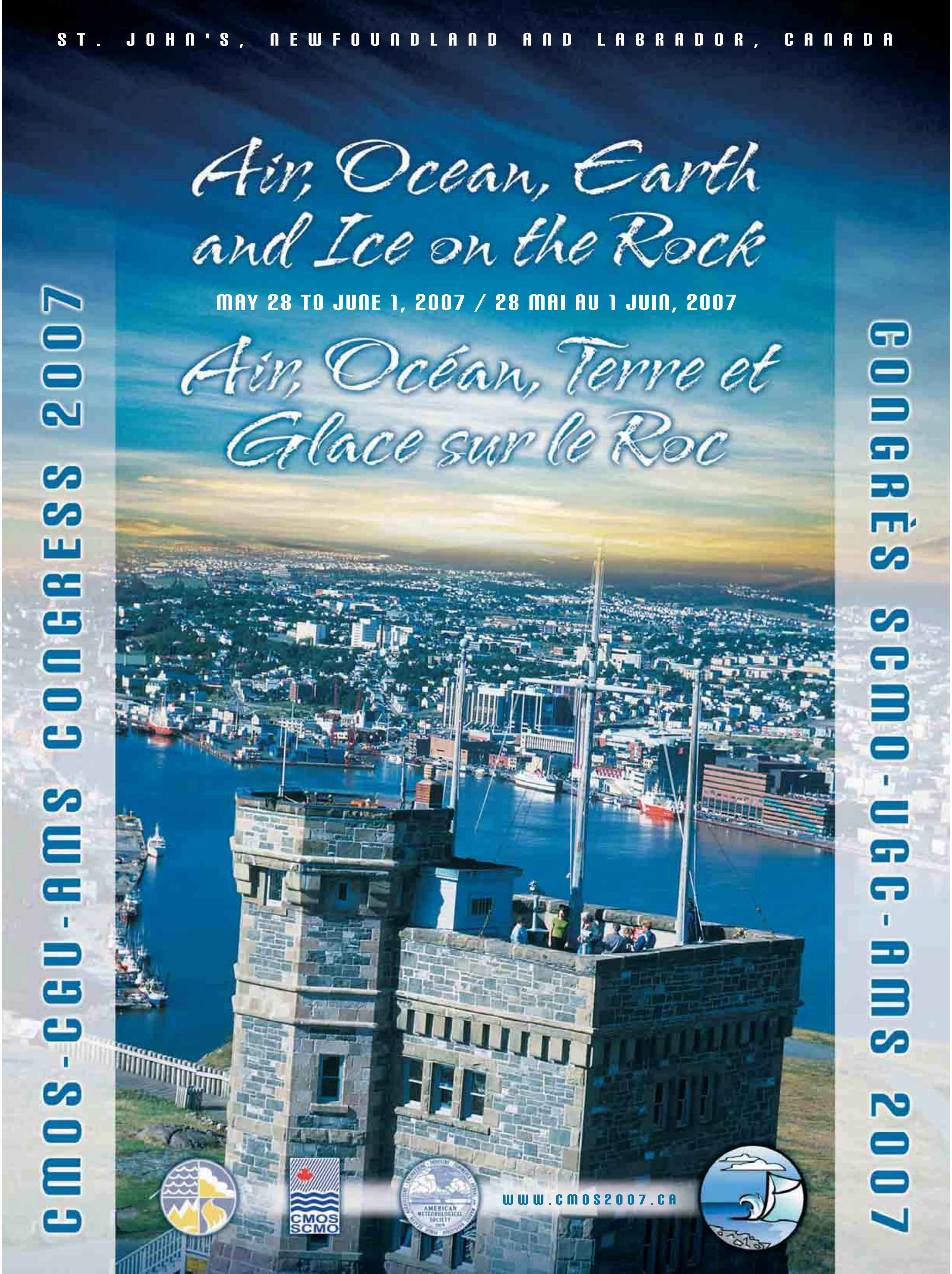
Chemical Oceanography,
Pollution Control and Water Technology

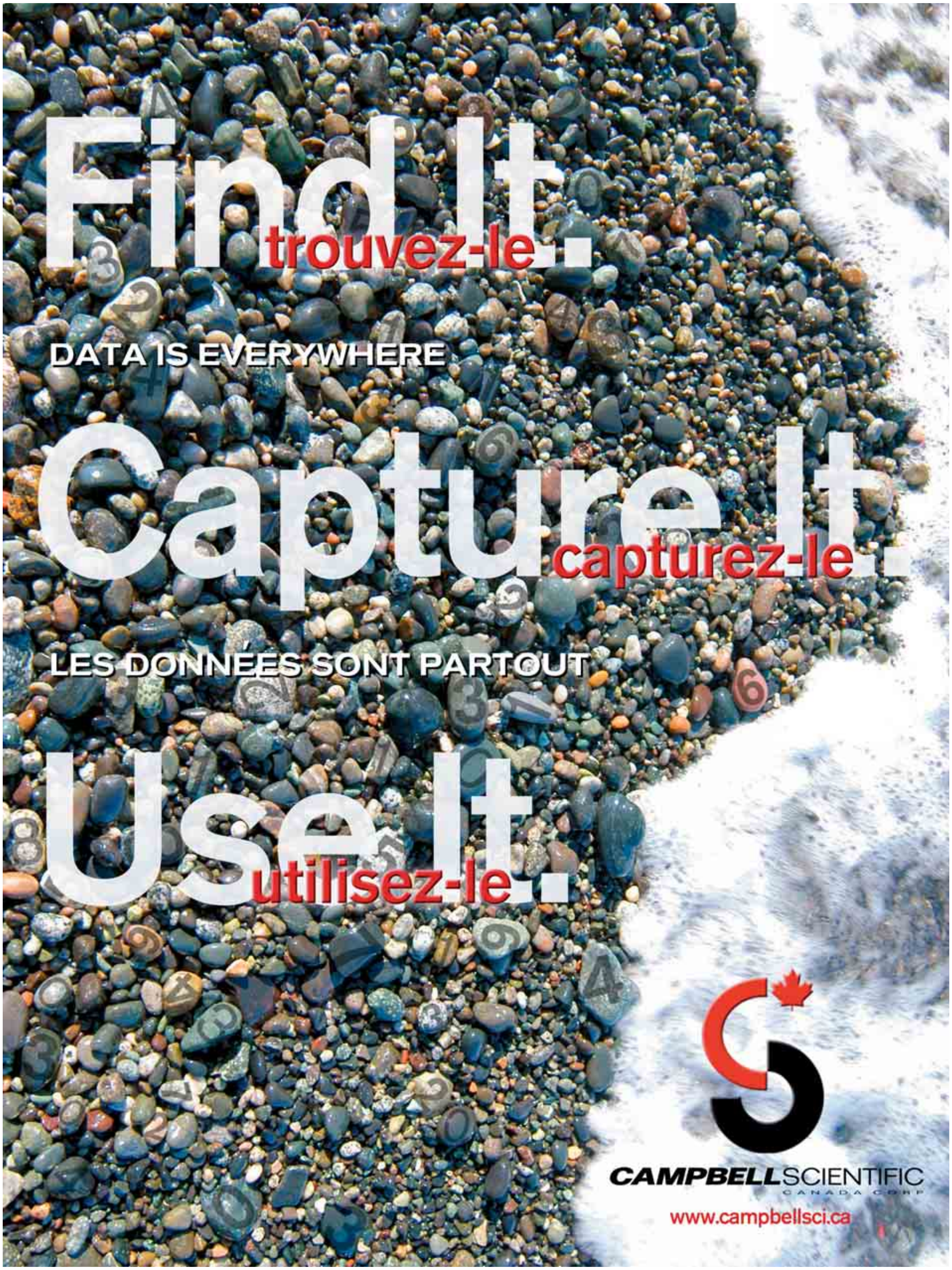
211-100 High Park Avenue
Toronto, Ontario M6P 2S2 Canada
Tel: 416-516-8941 (Home)
Email; omer86@can.rogers.com

Douw G. Steyn

Air Pollution Meteorology
Boundary Layer & Meso-Scale Meteorology

4064 West 19th Avenue
Vancouver, British Columbia,
V6S 1E3 Canada
Tel: 604-822-6407; Home: 604-222-1266


ST. JOHN'S, NEWFOUNDLAND AND LABRADOR, CANADA
Air, Ocean, Earth and Ice on the Rock
MAY 28 TO JUNE 1, 2007 / 28 MAI AU 1 JUIN, 2007
Air, Océan, Terre et Glace sur le Roc
CMOS-CGU-AMS CONGRESS 2007
CONGRÈS SCMO-UGC-AMS 2007
CMOS SCMO
AMERICAN METEOROLOGICAL SOCIETY
WWW.CMOS2007.CA


Find It.
trouvez-le
DATA IS EVERYWHERE
Capture It.
capturez-le
LES DONNÉES SONT PARTOUT
Use It.
utilisez-le
CAMPBELLSCIENTIFIC
CANADA CORP
www.campbellsci.ca