Report on CANDAC Activities at Eureka, Nunavut during 2017

submitted to

The Nunavut Research Institute

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Executive Summary

The Canadian Network for the Detection of Atmospheric Change (CANDAC) continues to operate under the grant funded by the Natural Sciences and Engineering Research Council (NSERC) Canadian Climate and Atmospheric Research (CCAR) entitled "Research related to the Polar Environment Atmospheric Research Laboratory (PEARL): Probing the Atmosphere of the High Arctic (PAHA)". The PAHA grant permits CANDAC to continue a significant presence in Eureka with approximately 667 person-days in Eureka for 2017. We are pleased to report that we have received a commitment to extend our current PAHA funding to Fall of 2019, the details of which are to be established in early 2017. As has been the case for several years, not all of our Memoranda of Understanding (MoUs) with Environment and Climate Change Canada (ECCC) are in place but this has not proven to be a significant problem.

Our operation has stabilized at approximately 330 manned operator days per year, and we continue to remotely operate as many instruments as possible. Our days with personnel on-site are down slightly this year, due primarily to a delay in the replacement of a departing operator. We also continue our efforts directed at putting as much of our data as possible into national and international data catalogues. The Polar Sunrise campaign was once again run in combination with the Atmospheric Chemistry Experiment (ACE) satellite validation campaign in late winter – early spring.

In 2017, we had 19 visitors to the laboratory, 11 of them students (Appendix A). Additionally, we continue to publish research papers in peer-reviewed journals and to make numerous presentations at national and international conferences and workshops (Appendix C), and are members of multiple multi-nation Arctic research coordination efforts such as SAON, the Sustaining Arctic Observing Network, and IASOA, the International Arctic Systems of Observing the Atmosphere.

CANDAC continues to refine the resources for teachers available on our website (http://www.candac.ca) as well as continuing to participate in teacher training conferences and science outreach events for students. Based on the positive feedback we have received on our Student-Researchers Atmospheric Collaboration outreach project in past years we continue to look for opportunities to do so and are pleased to report that we again visited a Nunavut school in early February 2017.

In 2017 our funding allowed us to maintain the number of days of operator manned operation at over 300 as in the past 2 years. However, turn-over in operators meant that we could not reach that target. We hired a new operator, John Gallagher, and he made his first visit in the summer. Current funding remains insufficient for re-establishing full-time on-site operations. We also ran extended summer and fall campaigns to operate instruments, take new CANDAC members to Eureka, and carry out necessary repairs.

CANDAC instrumentation continues to operate as anticipated and have not experienced any new failures in 2017. We continue to make improvements to instruments as appropriate. This year, the Bruker IFS125HR was re-aligned to improve performance.

We continue to experience typical challenges including the normal turn-over in personnel from

operators, graduate students to instrument mentors. As a group we continue to work diligently to service our existing instrumentation while adding new instruments that will add to our relevance and scientific output. In 2018 we expect to put significant effort into continuing these efforts to renew and improve our PEARL operations and our scientific output. We are also always seeking funding to extend our outreach activities into Nunavut communities.

Introduction

2017 marked the fifth year of near full operation for the Canadian Network for the Detection of Atmospheric Change (CANDAC) at the Polar Environment Atmospheric Research Laboratory (PEARL) after having received further funding under the Natural Sciences and Engineering Research Council (NSERC) Canadian Climate and Atmospheric Research (CCAR) program. Our program of research entitled: Probing the Atmosphere of the High Arctic (PAHA) has seen us continue with the core observations and enables us to continue to maintain and improve our instruments.

In 2017 all but one of our instruments were in near-continuous operation whether autonomous, remotely operated, or operated on site. We have maintained where applicable, the joint operation capability of instruments so that science teams in southern Canada -particularly graduate students- can participate in the active collection of data with the assistance of the on-site operator. This year we experienced a typical rate of instrument problems and failures. The increasing age of many of them continues to be a concern and we monitor them very carefully. This year we have updated our aerosol measuring instruments, maintaining our expanded PEARL aerosol measurements. Unfortunately, the aerosol mass spectrometer (AMS) still requires further work. During the sunrise campaign, equipment was transported to Eureka to perform an alignment on the Bruker IFS125HR Fourier Transform Spectrometer (FTS). This is a technically advanced procedure which involves the inspection of laser fringes within the instrument using a telescope. We are happy to say that the procedure was carried out successfully and the instrument operation was improved. This year, as in previous years, we introduced 3 new graduate students to arctic operations.

Our research program continues to be highly relevant and our collaborators in various global efforts such as the Total Column Carbon Observing Network (TCCON), the Network for the Detection of Atmospheric Composition Change (NDACC) and the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) are increasingly interested in our data and science products. TCCON in particular seeks to be very interested in PEARL data as part of the Orbiting Carbon Observatory-2 (OCO-2) satellite validation program, and directed a DC-8 CO_2 profiling instrumentation to overfly PEARL in August of 2016. A 2017 DC-8 visit was scheduled for late October, but was cancelled when we informed them it was after the final sunset. PEARL continues to be an important site for satellite validation, and the Canadian Space Agency continues to support our operations by contributing to the infrastructure costs and have committed to continued support for 0PAL and SAFIRE power. We continue to invest in our infrastructure through the upgrading of the local network that links the various sites. We continue to host several guest instruments and remain open to discussions non CANDAC/PAHA scientists who are looking for Arctic research sites.

Data and metadata of results from PEARL continue to be included in the Polar Data Catalogue as well as various national and international databases.

Within the purview of our Outreach Program, we were delighted to be able to continue our Student-Researchers Atmospheric Collaboration with visits to Joamie Ilinniarvik School and Inuksuk High School in Iqaluit. Students measured atmospheric aerosols, temperature and wind speed. In addition to these larger projects, we continue to visit schools in southern Canada to educated students about the

research done at PEARL and participate in other public events such as Science Rendezvous .

Instrument Installations, Removals, and Modifications

Ridge Laboratory
In October/November 2017, the optical particle counter was replaced with a newer version and the the neutralizer tube of the scanning mobility particle sizer (SMPS) was also replaced. The Bruker IFS125HR FTS was aligned. The All Sky Imager (ASI) had filters installed that would permit day-time measurements, and the E-Region Wind Interferometer (ERWIN) and Spectral Airglow Temperature Imager (SATI) together with the ASI were removed, serviced, and re-installed.

The Zero-Altitude PEARL Auxiliary Laboratory (ØPAL)
There have not been any new instrument installations at 0PAL in 2017. In 2016, a Cimel Moonphotometer was installed in March. This instrument is also capable of taking solar measurements, and the expectation was that it would remain in operation throughout the year. As reported in 2016, its pointing and tracking device had been unable to cope with temperatures significantly below -20C and we were working with Cimel and ECCC to improve the installation. As of the end of 2017, the Cimel Sun/Moon photometer is successfully tracking the Moon and operating as expected.

The Surface and Atmospheric Flux, Irradiance and Radiation Extension (SAFIRE) Laboratory
There were no new instruments added at SAFIRE, but several repairs were made on the data collection side, mostly to do with damaged cables.

On-going Research

Once again for what was the 13th consecutive year, the Intensive Phase of the Canadian Arctic ACE Validation Campaign 2016 (aka the Polar Sunrise Campaign) took place from 26 February to 15 March at PEARL, with the Extended Phase immediately following between 16 March and 1 April. 2017 once again had some “pre-campaign” activity as team members went in late January to establish LIDAR operations. As per the previous campaigns, the team of researchers from the University of Toronto, Western University, York University and CANDAC collected atmospheric composition measurements using a suite of 11 instruments, some of which are permanently installed on-site and some of which were brought in for the campaign. These observations will be used to verify results obtained by two Canadian scientific satellite missions, the Atmospheric Chemistry Experiment (ACE) on SciSat and the Optical Spectrograph and InfraRed Imager System (OSIRIS) on the Swedish Odin satellite. The measurements are made at polar sunrise when sunlight returns to Eureka and which is the period when ozone depletion processes are occurring. These measurements continue to be of great importance in the validation of the satellite instruments, that have now exceed their planned life-time by a decade.

On-site operations for 2017 fall below those of 2015/2016, but were still a significant increase over the 2012-2014 time frame with on-site operator coverage from late January through to mid December. Michael Maurice left CANDAC with no notice at the end of 2016 and was replaced by John Gallagher in June of 2017. John Gallagher and Peter McGovern will continue as our on-site operators. Through out 2017 the weather was occasionally a negative factor allowing for mostly "normal" slate of activities through spring, fall and winter. However, it was a fairly wet summer making on-site travel difficult in the mud. The extended "wet" days also resulted in significant damage to the road to the PEARL Ridge Laboratory. Most problematic was the failure of a road culvert requiring us to stage a truck on either side, walking across the damaged section. Between the road and washout, we lost approximately 6 person-days for our visiting scientists. We also continue to assist NavCan in their efforts to upgrade the Eureka airport weather and runway conditions reporting in any way that we can.

Most of the activity of our summer campaign dealt with instrument repairs and new installations. A service visit was made for the meteor radar and the VHF Wind tracker radar, with damaged radio frequency feed-lines repaired and various tests performed to improve performance. We were also able to install a computer control system to manage the temperature in the "Cottage" the enclosure that houses the meteor radar control systems. Temperatures that were too hot or too cold were the single largest impediment to meteor radar operations in 2016-17. A few small repairs were carried out at the flux tower, but operation was mostly normal throughout. Cable repairs were once again needed for the Baseline Surface Radiation Network (BSRN) site.

The fall sunset campaign was held from 14 October to 11 November. During this visit the focus was on the operation of the Differential Absorption Lidar (DIAL) and the CANDAC Raman Lidar (CRL) as well as gathering a few measurements with the Bruker FTS. All were carried out very successfully. Some minor maintenance activity was carried out for all three as well. We also re-activated the ASI, ERWIN and SATI instruments that had been service during the summer, as well as the visiting Optical Mesospheric Thermal Imager (OMTI) and the Fabry-Perot interferometer. We continued with test flights of a small unmanned aerial vehicle (UAV) to study the features of the polar night-time atmospheric temperature inversion near Eureka. Our UAV is Matrice 100 quad-copter made by DJI. This model can fly with up 1 kg of payload for about 20 minutes. The UAV has been equipped with a data acquisition system which includes Raspberry Pi 2 microcomputer, GPS receiver, pressure sensor and three resistance temperature detectors to monitor atmospheric conditions during the flight. There are no cameras or other sensors included. We continue to deal with the challenges of operating this equipment in the High Arctic. While results to date are not optimal, we have had gathered enough information to feel confident that there is interesting science to be acquired via the drone.

For the most part, all our instruments have been working as expected and the results are being reported in the scientific literature (19 papers published, 1 recently submitted) as well as being presented at various national and international conferences and workshops (more than 60). In addition, we hold monthly telecons with scientists and managers at Environment Canada to ensure they are kept current with our efforts and that we are responding to their requirements as dictated by the PAHA grant. These are increasingly well attended by ECCC scientists.

PEARL and the Eureka Weather Station continue to be excellent examples of how the existence of quality facilities provides synergies that lead to research projects not previously considered, and that may have a real impact on the lives of Canadians in remote communities.

Outreach Activities

We continued to have an active outreach program in 2017. The main program we undertook this year was the Student-Researcher Atmospheric Collaboration with Grade 3, 4, and 5/6 students in 5 classes at Joamie Ilinniarvik School and with Grade 10 students in 1 class at Inuksuk High School in Iqaluit, Nunavut. These elementary and high school students monitored the atmosphere using a variety of scientific instruments and shared and compared their data and analyses. The elementary student researchers made and recorded daily temperature and wind speed measurements using a thermometer, an anemometer and a weather vane. The high school students made and recorded daily solar radiation and aerosol optical thickness measurements using a pyranometer and a sun photometer, respectively. At the end of the eight-week measurement program, they shared their results with the PAHA participants at each of the schools. In parallel, kindergarten and Grade 4 students at da Vinci School in Ajax, Ontario and Grade 10 students in 2 classes at Medway High School in Arva, Ontario made similar measurements in southern Canada. The PAHA participants included Aubyn O'Grady, Whitney Bader, Ali Jalali, Shannon Hicks, and Dan Weaver (also Paul Godin). In addition, Aubyn O'Grady, Whitney Bader and Ralf Bauer conducted two workshops on atmospheric science for Grade 10 students as part of a Climate Change Event at the University of Toronto Schools; and Aubyn O'Grady, Whitney Bader, Shoma Yamanouchi, Laura Saunders and Hayden Johnson participated in the Science Rendezvous festival at the University of Toronto (presenting demonstrations and hands-on activities for the public on atmospheric science). For the University of Toronto "Science Unlimited Summer Camp", we provided a half-day of activities (PAHA participants: Kaley Walker, Kristof Bognar, Paul Jeffery, Dan Weaver and other participants: John Saunders, Alex Bercik, Hayden Johnson, Romina Piunno, and Laura Saunders).

Additionally, Aubyn O'Grady had been our outreach coordinator and has moved on to undertake graduate studies.

Summary of Plans for 2018

At this time, our level of activity in 2018 is somewhat uncertain and depends greatly on the final form and time line of the promised funding. We anticipate a full sunrise campaign as in previous years. Given a workable funding package, we expect that summer and fall activities will also be at a level equal to that under the PAHA funding. We expect to put significant effort into AMS repairs and to replace the BSRN radiometers in support of Year of Polar Prediction (YOPP) measurements. As has been the case for some years, at the time of the writing of this report, we are still in the process of negotiating our Memorandum of Understanding with Environment Canada. We are hopeful that the process will be completed in at some point but do not expect that its completion will result in a materially different operating scenario. Aside from the standard operations, measurements, and maintenance, we will be continuing our efforts to develop the remote controlled drone capability for measurements of the temperature field at a greater spatial extent in the vicinity of the flux tower. We will continue to refine the automation of instrument operation with the goal of general improvement to, and expansion of the measurement capabilities. We continue to find ourselves in discussion with multiple new groups beyond the CANDAC family that are considering installing instruments at PEARL. 2018 will also see the continuation of on-site activity in support of the CSA funded "Arctic Validation And Training for Atmospheric Research in Space" (AVATARS) program based largely at PEARL. AVATARS is lead by PAHA Deputy PI Professor Kimberly Strong and includes many of the PEARL/CANDAC/PAHA team. This program is aimed at building Canadian capacity in support of science and technology. Over the next 3 years, this will result in further development of PEARL instrumentation and operation.

While we do not have a full year-round operator presence at PEARL, we are aiming to maintain a presence for approximately11 months of the year to facilitate acquiring more data with those instruments (mostly daytime instruments) that are least automated. We continue to work towards decreasing the amount of human intervention required by those instruments. With the return to full operation of the DIAL we will increase our manned days on site during the polar night in support of our polar night theme. In 2017 we achieved 283 days on site. We have again chosen to not have an operator on site during the period spanning roughly mid December to mid January as this tends to be a quiescent period for both instruments and operations

The ACE/OSIRIS team is anticipating funding for 2018 and so we expect to host the Canadian Arctic Validation Campaign, at PEARL for the fourteenth year of operation. The time period will be very similar as in previous years and we will be continuing to validate the ACE/OSIRIS results during polar sunrise.

CANDAC hopes to continue its outreach effort in the form of contact with Nunavut communities principally through school visits if funding permits. The CANDAC Student-Researcher Collaboration project is designed to enable students to become co-investigators in atmospheric research. The program gives students an opportunity to gather data and conduct inquiry-based investigations about current atmospheric conditions using scientific instruments located at their own school. CANDAC researchers partner with students and staff to provide training and assistance and ensure that the data collected throughout the project is analysed and understood.

Concluding Remarks

Making state of the art scientific measurements in the Arctic is challenging and keeping equipment on line continues to be our major concern. CANDAC continues to push forward with the PAHA project, demonstrating that it has a solid core complement of instrumentation, facilities and personnel. Operationally, 2017 is characterized by a high level of instrument operation with expanded measurement capabilities. We continue to have a significant amount of research dissemination while continuing with our development of highly qualified personnel. We have continued to improve instrument automation and our continued partnerships with NOAA, ECCC and various universities both in Canada and abroad show that we remain well-equipped to support both our own research and other research that might benefit from our facilities. PEARL based research results are continuously making their way into the scientific world and are contributing to a greatly-improved understanding of the Arctic atmosphere. We continue to extend the PEARL data record and for many instruments it is approaching a significant length such that they will be useful for trends analyses. This is where the benefits of an enduring and well-instrumented site such as PEARL will become apparent as we continue with our efforts. Our outreach activities continue to educate future generations of Canadians. We are determined to continue our small part in asserting that the Arctic is an important part of Canada through our presence, our research, and through education. As always, the CANDAC team is working hard to ensure a continuation of these efforts in the future.

Appendix A: Visitors to PEARL in 2017

** denotes first time visitors*

Non-CANDAC Personnel visiting PEARL in 2017

1. Sergio Dempsey, grad student, Western U.
2. Gurpreet Singh, grad student, York U. *
3. Stephen Brown, technician, York U.

CANDAC Personnel visiting PEARL in 2016

1. Patrick Hayes, Assistant Professor, U. Montreal
2. Pierre Fogal, PEARL Site Manager, U Toronto
3. Wayne Hocking, CANDAC Co-Investigator, U Western Ontario
4. Liviu Ivanescu, graduate student, U Sherbrooke
5. Sam Kristoffersen, graduate student, UNB
6. John Gallagher, operator, Dalhousie U. *

7. Peter McGovern, operator, Dalhousie U
8. Alexey Tikhomirov, Research Associate, Dalhousie U
9. Sebastien Roche, graduate student, U Toronto
10. Samantha Tremblay, grad student U. Montreal
11. Emily McCullough, Dalhousie
12. Kristof Bognar, grad student, U. Toronto
13. Eric Lutsch, grad student, U. Toronto*
14. Ghazal Farhani, grad student, Western U.
15. Dustin Gamblin, grad student, UNB*
16. Paul Jeffrey, grad student, U. Toronto *

Appendix B: Glossary of Acronyms

0PAL	Zero-altitude PEARL Auxiliary Laboratory
ACE	Atmospheric Chemistry Experiment
AMS	Aerosol Mass Spectrometer
ASI	All Sky Imager
AVATARS	Arctic Validation And Training for Atmospheric Research in Space
BSRN	Baseline Surface Radiation Network
CANDAC	Canadian Network for the Detection of Atmospheric Change
CCAR	Canadian Climate and Atmospheric Research
CRL	CANDAC Raman Lidar
CSA	Canadian Space Agency
DIAL	Differential Absorption Lidar
ECCC	Environment and Climate Change Canada
ERWIN	E-Region Wind INterferometer
FTS	Fourier Transform Spectrometer
IASOA	International Arctic Systems for Observing the Atmosphere
LIDAR	Laser Induced Differential Absorption Radar
MoU	Memoranda of Understanding
NDACC	Network for the Detection of Atmospheric Composition Change
NSERC	Natural Sciences and Engineering Research Council of Canada
OCO-2	Orbiting Carbon Observatory - 2
OMTI	Optical Mesosphere and Thermosphere Imager
OPC	Optical Particle Counter
OSIRIS	Optical Spectrograph and InfraRed Imager System
PAHA	Probing the Atmosphere of the High Arctic
PEARL	Polar Environment Atmospheric Research Laboratory
PI	Principal Investigator
SAON	Sustaining Arctic Observing Network
SAFIRE	Surface and Atmospheric Flux, Irradiance and Radiation Extension
SATI	Spectral Airglow Temperature Imager
SCOSTEP	Scientific Committee on Solar-Terrestrial Physics
SMPS	Scanning Mobility Particle Sizer
TCCON	Total Carbon Column Observing Network
UAV	Unmanned Aerial Vehicle
UQAM	Université de Quebéc à Montréal
YOPP	Year of Polar Prediction

Appendix C:

The dissemination list is provided as a separate document.