Report on CANDAC Activities at Eureka, Nunavut during 2018

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)", with the funding program extended to Fall 2019. The PAHA grant permits CANDAC to continue a significant presence in Eureka with approximately 737 person-days in Eureka for 2018, an increase of 70 person days from 2017. We are once again facing funding uncertainty beyond the Fall of 2019 as we await announcement of relevant Government of Canada funding initiatives. 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 up approximately 10% this year, due to full operator coverage as well as an increase in days on-site by graduate students. 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 2018, we had 20 visitors to the laboratory, 9 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 offer 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.

In 2018 our funding allowed us to maintain the number of days of operator manned operation at 339 as has been typical under PAHA funding. 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 we have not experienced any new failures in 2018. We continue to make improvements to instruments as appropriate. This year, the Baseline Surface Radiation Network radiometers were replaced by new units as part of the Year of Polar Prediction (YOPP) work supported with our National Oceanic and Atmospheric Administration (NOAA) partners. .

We continue to experience typical challenges including the normal turn-over in personnel, including operators, graduate students, and 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 2019 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

2018 is the sixth 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 Fall 2018, Professor James Drummond of Dalhousie University began to turn over some of the responsibilities as PAHA Principal Investigator (PI) to Professor Kimberly Strong of the University of Toronto, who has been the Deputy PI.

In 2018, 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 hardware instrument problems and failures, but unfortunately we were affected by a significant malware intrusion affecting computers for two of our instruments. We are fortunate that in the case of the Bruker IFS125HR Fourier Transform Spectrometer (FTS) that the infection occurred after sunset so that no measurement opportunities were lost. This is not the case with our millimeter wave cloud radar (MMCR) which was taken off-line and will remain so likely until February. The increasing age of our instrumentation continues to be a concern and we monitor them very carefully. In 2018 we again updated our aerosol measuring instruments, to include an automated particle sizer to operate in conjunction with 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 update the alignment on the Bruker IFS125HR FTS. We are happy to say that the procedure was carried out successfully and the instrument operation was improved. We also began a new collaboration with Dr. Xin Yang of the British Antarctic Survey to carry out a snow survey in hopes of understanding better the phenomenon known as “Bromine Explosions”. When such events happen, surface level ozone is destroyed to a large exent. Our ground-based UV spectrometers have measured such events several times in the past, but this is our first attempt to explore the potential reason for their occurrence by measuring the composition of snow. This year, as in previous years, we introduced three new graduate students to Arctic operations.

Our research program continues to be highly relevant to international partnerships and our collaborators in various global efforts such as the Total Carbon Column Observing Network (TCCON), the Network for the Detection of Atmospheric Composition Change (NDACC) and the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) are continuing their interest in our data and science products. PEARL continues to be an important site for satellite validation, and the Canadian Space Agency (CSA) continues to support our operations by contributing to the infrastructure costs and have committed to continued support for 0PAL and SAFIRE power, as well as four more years of support (2018-2021) for the springtime Canadian Arctic ACE/OSIRIS Validation campaigns We continue to invest in our infrastructure through the upgrading of the local network that links the various sites. In 2018, we replaced several pieces of network equipment, improving the health, stability, and hopefully security of

our local network. We continue to host several guest instruments and remain open to discussions with non-CANDAC/PAHA scientists who are looking for Arctic research sites. We anticipate at least two new instruments will join us in early 2019 during the sunrise campaign.

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

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. Also, this summer we extended our "outreach" into the House of Commons through an invitation to visit PEARL given to, and accepted by, the Member of Parliament for Guelph, Ontario, Lloyd Longfield, who subsequently visited from July 22-27, 2018.

Instrument Installations, Removals, and Modifications

Ridge Laboratory
In October/November 2018, the photo-acoustic extinctiometers were re-installed at the RidgeLab, having been removed in the summer and sent south for laser replacements. An automated particle sizer (APS) was installed to improve the size sampling range. The Bruker IFS125HR FTS alignment was improved. One of our visiting instruments, the Optical Mesospheric Temperature Imager (OMTI) operated by the University of Electro-Communications in Tokyo, Japan, had been removed in February after a camera failure and returned in October. It is once again fully operational.

The Zero-Altitude PEARL Auxiliary Laboratory (ØPAL)
In July, an Automated Particle Sizer (APS) instrument was installed at 0PAL and operated there through the summer and fall. It was later moved to the RidgeLab as described above. The CANDAC Raman Lidar (CRL) was serviced and is set for continuous operation. In July, its automated hatch system experience a control system failure. For some time, the hatch was operated manually by the on-site operator and in October a secondary control system was implemented that once again allows for remote operation. The pump on the Thermolabs ozone sensor was replaced, returning that instrument to full operation. We sent the Radiometrics Water Vapor Radiometer back to the manufacturer for recalibration. It was returned and re-installed and is now again in full operations. As mentioned earlier, the MMCR is currently off-line as we configure new computers for it.

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. At SAFIRE, the VHF and meteor radars both had a maintenance visit with repairs made to cabling and antennas damaged by weather or wildlife. A Department of National Defense (DND) experimental radar installation has been built near our flux tower. A series of antenna screens were place in hopes of blocking any interfering radio frequency

energy from reaching our radars. After the initial test, it appears that they are effective, but we cannot be sure until further testing is carried out.

The Baseline Surface Radiation Network (BSRN) instruments were replaced with new versions as the calibrations on the old ones were no longer valid. A microwave link to the upwelling tower near the SAFIRE container was installed to permit the data logger installed there to send its data to the computer collecting the BSRN data.

On-going Research

Once again for what was the 15th consecutive year, the Intensive Phase of the Canadian Arctic ACE/OSIRIS Validation Campaign 2018 (aka the Polar Sunrise Campaign) took place from 24 February to 13 March at PEARL, with the Extended Phase immediately following between 14 March and 1 April. 2018 once again had some "pre-campaign" activity as team members went in early February to establish LIDAR operations. As per the previous campaigns, the team of researchers from the University of Toronto, Dalhousie University, 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 are being 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. This year we were joined by Dr. Xin Yang a visiting scientist from the British Antarctic Survey. Dr. Yang carried out a snow sampling experiment, selecting snow at various locations and sampling it from the top surface to ground level. The snow was transported back to the United Kingdom for analyses and we await further results.

On-site operations for 2018 are similar to those of 2015/2016, a significant increase over the 2012-2014 time frame with on-site operator coverage from early January through to mid December. John Gallagher and Peter McGovern continue as our on-site operators. Through out 2018, the weather was mostly quite good and only occasionally a negative factor, allowing for mostly "normal" slate of activities through spring, fall and winter. Once again, it was a fairly wet summer making on-site travel difficult in the mud. The road to the PEARL Ridge Laboratory was repaired and the damaged culverts replaced.

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. A few small repairs were carried out at the flux tower, but operation was mostly normal throughout. The instruments that make up the Baseline Surface Radiation Network (BSRN) site were replaced with newer versions as the

calibrations on the existing units were no longer valid. Their mounting enclosures were also replaced with an improved version. The data logging system has been modernized and can now be monitored directly over the network rather than relying on an intermediate local computer. Lloyd Longfield, Member of Parliament for Guelph, Ontario joined the campaign team for an approximately one week visit to PEARL. During that time, Mr Longfield was exposed to the various aspects of High Arctic Weather Station life and operations and the operations of PEARL and the work of scientists as part of the campaign. Mr. Longfield also applied his previous industry experience and contributed to the efforts to repair the CRL hatch.

The fall sunset campaign was held from 14 October to 11 November. During this visit, the focus was on performing service on the CANDAC Raman Lidar (CRL), operating the Differential Absorption Lidar (DIAL) and as well as gathering a few measurements with the Bruker FTS. All were carried out very successfully although persistent cloud cover meant very few Bruker measurements before sunset on 20 October. During this visit, we also were able to create a replacement remote control system to operate the CRL hatch. We also re-activated the ASI, ERWIN and SATI instruments that had been off since March, and did the same for 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 a 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 that includes Raspberry Pi 2 microcomputer, GPS receiver, pressure sensor and three resistance temperature detectors to monitor atmospheric conditions during the flight. These are the only sensors in use, and specifically no cameras are used.. 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. During the fall campaign, we were required to medivac Professor Drummond after he experienced a stroke. We are happy to report that Professor Drummond was taken south and later home to Halifax where he continues to contribute to the project.

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 and Climate Change 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 2018. Given funding and personnel limitations, the main focus this year was on local outreach activities to highlight Arctic research at PEARL. Peter

McGovern gave a talk on PEARL and life and work in Eureka to a grade 12 class in Hearst, Ontario via FaceTime. The course was funded by College Boreal and is geared towards students considering careers in environment/natural resources. Ellen Eckert, Simran Nerval, Lei Liu, and Kristof Bognar 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 for 50 grade 10 and 11 students (PAHA participants: Kristof Bognar, Ellen Eckert, Paul Jeffery, Simran Nerval, Sebastien Roche, Tyler and other participants: Jacob Hedelius, Niall Ryan and Laura Saunders). As part of the Nuit Blanche event at the Ontario Science Centre, Dan Weaver presented a short virtual tour of PEARL and photos from fieldwork in Eureka to a public audience. PEARL Site Manager Pierre Fogal was invited to give a talk at the November meeting of the Mississauga Amateur Radio Club, where he presented PEARL research to a group of approximately 30 people.

Summary of Plans for 2019

Going into 2019, we anticipate a full sunrise campaign as in previous years, followed by a summer campaign. The nature of that summer campaign and the existence of the usual fall campaign will be greatly impacted by our funding situation. Our "bridge" funding provided jointly by NSERC and ECCC will expire in September 2019 and as of the time of writing this report, no suitable replacement program has been announced. 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 hope to put significant effort into AMS repairs and to support any ongoing requests for 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 and Climate Change Canada. We are hopeful that the process will be completed 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. 2019 will also see third and final year 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 led by PAHA Deputy PI Professor Kimberly Strong and includes many of the PEARL/CANDAC/PAHA team. This program is maximizing the use of PEARL for instrument development and automation, satellite validation, and training of HQP through six distinct but inter-related projects that are contributing to the validation of data from current satellite missions.

While we do not have a full year-round operator presence at PEARL, we are aiming to maintain a presence for approximately 11 months of the year to facilitate the acquisition of 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 PAHA Polar Night theme. In 2018 we achieved 339 days on site. We have again chosen to not have an operator on site during the period spanning roughly mid December to early January as this tends to be a quiescent period for both instruments and operations

The ACE/OSIRIS validation team has received approval of funding for 2019 and we are in the proocess of planning the Canadian Arctic ACE/OSIRIS Validation Campaign, at PEARL for the fifthteenth 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. This year we expect two new instruments, one from ECCC and another from the University of Toronto, to also participate.

CANDAC would like to continue its outreach effort in the form of contact with Nunavut communities as 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. Given our current funding situation, we expect to be limited to southern schools for 2019.

Concluding Remarks

The events of 2018 remind us that life in the Arctic is challenging on all fronts and at all times. In 2019 we will pursue our goal of carrying out a program of state-of-the-art scientific measurements in the Arctic. Keeping equipment on line and taking care of our personnel remain our major concerns. CANDAC will continue to push forward with the PAHA project for as long as possible. CANDAC/PEARL/PAHA has demonstrated that it has a solid core complement of instrumentation, facilities and personnel. Operationally, 2018 was characterized by a high level of instrument operation with near complete measurement capabilities. We expect to expand measurement capabilities during 2019 sunrise and hope that the increased capability persists beyond the campaign. As in previous years, we have a significant amount of research dissemination while continuing to train and develop the skills of highly qualified personnel. We have improved instrument automation, and our ongoing partnerships with NOAA, ECCC and various universities both in Canada and abroad demonstrate 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 trend analyses. This is where the benefits of an enduring and well-instrumented site such as PEARL will become increasingly apparent as we continue with our efforts. Our outreach activities are educating future generations of Canadians. We are determined to have a role in asserting that the Arctic is an important part of Canada through our presence, our research, and 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 2018

** denotes first time visitors*

Non-CANDAC Personnel visiting PEARL in 2018

1. Tom McElroy, Professor, York University
2. Xin Yang, Scientist, British Antarctic Survey *
3. Colin Lester, grad student, Western University *
4. Lloyd Longfield, Member of Parliament, Guelph, Ontario *
5. Keisuke Hosokawa, University of Electro-Communications, Tokyo, Japan.

CANDAC Personnel visiting PEARL in 2016

1. James Drummond, Professor, Dalhousie U.
2. Pierre Fogal, PEARL Site Manager, U Toronto
3. Wayne Hocking, CANDAC Co-Investigator, U Western Ontario
4. Andy Vicente-Luis, graduate student, U Montreal
5. Keyvan Ranjbar, graduate student, U Sherbrooke
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. 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
APS	Automated Particle Sizer
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.