Report on CANDAC Activities at Eureka, Nunavut during 2020

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) program, entitled "Research related to the Polar Environment Atmospheric Research Laboratory (PEARL): Probing the Atmosphere of the High Arctic (PAHA)", with the funding program now extended to 31 March 2021. Due to the impact of the COVID-19 pandemic, our on-site costs have significantly decreased, albeit with an equally significant impact on operations and instrument health. This together with judicious use of funds has permitted us to extend our operating period, although we are still facing the end of funding for operations at PEARL in 2021. The pandemic greatly impacted our presence in Eureka resulting in approximately 300 person-days in Eureka for 2020, a decrease of approximately 50% from 2019. We continue to explore the options provided by the relevant Government of Canada funding initiatives, as well as private donations. 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.

Aside from the notable impact of the COVID-19 pandemic, our operation remains targeted at approximately 330 manned operator days per year and we continue to remotely operate as many instruments as possible. John Gallagher our senior operator has decided to pursue other career options and because his end date was after the onset of the pandemic it has not impacted us thus far. Andrew Hall continues working with us as an 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 2020, we had 12 visitors to the laboratory, 4 of them students (Appendix A). These numbers are identical to 2019 and it demonstrates the importance of our satellite validation campaign. 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.

Current funding remains insufficient for re-establishing full-time on-site operations. We were unable to run our extended summer and fall campaigns to operate instruments, take new CANDAC members to Eureka, and carry out necessary repairs. CANDAC instrumentation continued to operate as anticipated during the early part of 2020, but by the end of 2020 we experienced significant degradation in several instruments that are now off-line and will remain so until we can return our team to Eureka to initiate repairs.

In addition to the impact of the pandemic, we continue to experience the more 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 increase our relevance and scientific output. In 2021, 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

2020 is the eighth 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 in 2013 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. Throughout 2019, Professors James Drummond and Kimberly Strong have shared the responsibilities as PAHA Principal Investigator (PI) .

As we began 2020, 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. The onset of the COVID-19 pandemic resulted in our taking the decision to recall our on-site operator at the end of March and due to restrictions within Nunavut, the North West Territories and especially at the Eureka Weather Station, we have been unable to return. During 2020 we experienced a typical rate of hardware instrument problems and failures, but the failures have had a much amplified impact due to our inability to have people at PEARL to carry out the needed repairs and replacements. Overall, the increasing age of our instrumentation continues to be a concern and we monitor them very carefully. In 2019, during the Polar Sunrise campaign, a new guest instrument from Environment and Climate Change Canada, Science and Technology Division was installed. This instrument is called Pandora and makes measurements that are complementary to our UV-Visible grating spectrometers. This year we introduced 2 new people to Arctic operations, both graduate students.

As noted earlier, not having an operator on site or a summer and fall campaign has meant that we now see a significant decrease in instrument performance. As of the end of 2020, we have 6 instruments that are not operating. The millimeter cloud radar (MMCR) and the WindTracker radar have both had computer failures, the Bruker IFS125HR Fourier Transform Spectrometer and the Extended-range Atmospheric Radiometric Emission Interferometer (E-AERI) have both had internal laser failures, and the Thermo 49i Surface Ozone monitor and the Pandora have both had failures of mechanical components. All of these can and will be repaired once we are able to return to PEARL. In addition, the CANDAC Raman Lidar ceased operations once the operator had left Eureka in March (this is standard practice) and the Differential Absorption Lidar (DIAL) did not make fall measurements as it also requires on-site support.

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. With the addition of the Pandora instrument, PEARL will also be represented in the Pandonia network(HTTP://www.pandonia-global-network.org/). 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 in early 2020 and have committed to continued support for 0PAL and SAFIRE power, as well as two more years of support (2020-2021) for the

springtime Canadian Arctic ACE/OSIRIS Validation campaigns We have not made significant investments in our infrastructure this year but expect to continue to invest in our infrastructure through the upgrading of the local network that links the various sites as the need arises. We continue to host several guest instruments having added another during the spring campaign, and remain open to discussions with 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. We are submitting Rapid Delivery data from the UV-visible spectrometers, FTS, and ozone lidar to the European Copernicus Atmosphere Monitoring Service (CAMS) as part of the quality assessment of the CAMS global forecast products.

Instrument Installations, Removals, and Modifications

Ridge Laboratory

No instruments were removed from the Ridge Laboratory this year. The Pandora was added during the ACE/OSIRIS Validation campaign. Our colleagues at ECCC Science and Technology Branch provided the Pandora instrument installed at the Ridge Lab. The installation of a Pandora at PEARL gives the Pandonia Network (HTTP://www.pandonia-global-network.org/) a second High Arctic measurement point, and the first in the Canadian Arctic. The Pandora is a relatively new instrument and makes measurements of NO2 in the atmosphere. These measurements will be compared to those of the UV-visible grating spectrometers that have been operating at the Ridge Laboratory since 2005. The Pandora also has the capability to make measurements during the polar night using light from the Moon.

The Zero Altitude PEARL Auxiliary Laboratory (ØPAL)

There were no new instrument installations at 0PAL during 2020 and no instruments were removed. The CANDAC Raman Lidar was restarted after operations ceased with the departure of the CANDAC operator in December. It underwent a major service with the re-installation of its “polarotor”, service of pump chambers and replacement of flash lamps. It operated from mid January to late March. The E-AERI detector was replaced and the instrument electronics were serviced and calibrated by a technician from ABB of Quebec City.

The Surface and Atmospheric Flux, Irradiance and Radiation Extension (SAFIRE) Laboratory
There were no new instruments added at SAFIRE. This year neither the meteor radar nor the VHF radar had their annual service visit. The flux tower and Baseline Solar Radiation Network (BSRN) instruments continued in operation.

On-going Research

On-site operations for 2020 began in a similar manner to those of 2015 to 2019, a significant increase over the 2012-2014 time frame with on-site operator coverage from early January through to the

anticipated mid December end. However, the COVID-19 pandemic resulted in the withdrawal of our site operator at the end of March. With no travel to Eureka since that time our person-days on site is down significantly this year. Our senior operator, John Gallagher left to pursue other opportunities, ending his last tour at the end of February. Andrew Hall has continued in his role and is now our most senior operator. Remote control of our instruments together with occasional assistance meant that we have been able to maintain something of a "normal" slate of activities through spring, fall and winter. The lack of an on-site operator had the most significant impact on the measurement program for the CRL as it ceased operation and the Bruker IFS125HR observations. The Total Column Carbon Observing Network (TCCON) observations can be carried out remotely, but the Network for Detection of Atmospheric Composition Change (NDACC) measurements could not, as they require the addition of liquid nitrogen to the instrument detectors on a daily basis. As we progressed through 2020, the maintenance issues accumulated and at this time, we have 6 instruments that are no longer operating. The operation and data-gathering of another 3 instruments has also been severely affected.

The Intensive Phase of the Canadian Arctic ACE/OSIRIS Validation Campaign 2020 (aka the Polar Sunrise Campaign) took place from 21 February to 11 March at PEARL, with the Extended Phase immediately following between 12 March and 28 March. 2020. Once again, we had some "pre-campaign" activity as team members went in early February to establish DIAL LIDAR operations. This campaign has taken place yearly since 2004. As per the previous 16 campaigns, the team of researchers from the University of Toronto, Dalhousie University, York University and CANDAC collected atmospheric composition measurements using a suite of 13 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 more than a decade. ACE has been in orbit since August 2003 and OSIRIS since February 2001.

Due to the COVID-19 pandemic, we were unable to carry out our typical summer and fall campaigns in 2020.

Outreach

Despite the global pandemic, we continued to have an active outreach program in 2020. Given travel limitations, the main focus this year was on virtual outreach activities to highlight Arctic research at PEARL. In June, Kaley Walker participated in a 20-minute online interview/chat on career paths, interest in science and how to become a scientist for the GIRLS (Girls for Innovation, Research, Leadership & Science) Initiative at Queen's University. In September, Ellen Eckert, John Saunders and Zahra Vaziri Zanjani facilitated a one-hour hands-on online
workshop on making clouds in a jar for Girls SySTEM, a mentorship program for girls in grades 7 to

12 based in Kingston and Toronto. 5 mentees and mentors participated in the workshop. 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 "Math and Physical Sciences In-school Virtual Workshops" program, we provided a one-hour online workshop on measuring the Arctic atmosphere for 23 grade 12 students at St. Michael's Choir School in Toronto. They built their own spectroscopes and conducted experiments with them (Participants: John Saunders, Zahra Vaziri Zanjani and Orfeo Colebatch. Amateur radio activity with the Eureka Amateur Radio Club (callsign VY0ERC) continued until late March, with participation in several world-wide events as well as general on-the-air availability. There have since been several inquiries from around the world as to when amateur radio operations from VY0ERC might resume.

Summary of Plans for 2021

We are constantly evaluating the possibilities for travel to Eureka. It is our hope that we will be able to attempt a reduced ACE/OSIRIS sunrise validation campaign, sometime in the time period from late February to April. Beyond that, a further campaign in summer is under consideration, and hopefully by the fall we can return to something approaching normal operations. In addition to our list of instrument repairs and enhancements, we have a new ceilometer system ready for installation and it will provide more insight into clouds and aerosol. In 2021, our outreach activities will likely continue in a manner similar to 2020, with participation in virtual workshops.

Concluding Remarks

Despite the COVID-19 pandemic, as of the end of 2020, we have continued to pursue our goal of carrying out a program of state-of-the-art scientific measurements in the Arctic. Even without our on-site presence, CANDAC/PEARL/PAHA has demonstrated that it has a solid core complement of instrumentation, facilities and personnel. Operationally, the years under our PAHA grant have been characterized by a high level of instrument operation with near complete measurement capabilities. That has suffered somewhat in 2020 given that we have been unable to perform repairs to instruments. Post pandemic, we hope to expand measurement capabilities during future Sunrise campaigns and in general to expand the PEARL instrumental and scientific capacity in years beyond that. As in previous years, we have a significant amount of research dissemination while continuing to train and develop the skills of highly qualified personnel. The challenges of 2020 aptly demonstrate that we have improved instrument automation, and we have enduring ongoing partnerships with NOAA, ECCC and various universities both in Canada and abroad. We continue to demonstrate that we are 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. Even though our on-site presence was greatly reduced, we continued 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. We are committed to doing this in a safe and sustainable fashion.

Appendix A: Visitors to PEARL in 2019

** denotes first time visitors*

Non-CANDAC Personnel visiting PEARL in 2019

1. Tom McElroy, Professor, York University
2. Guillame Gamache, technician, ABB, Quebec City

CANDAC Personnel visiting PEARL in 2019

1. Pierre Fogal, PEARL Site Manager, U Toronto
2. John Gallagher, operator, Dalhousie U.
3. Alexey Tikhomirov, Research Associate, Dalhousie U
4. Kristof Bognar, grad student, U. Toronto
5. Ali Jalali, Post-doctoral fellow, U.Toronto
6. Tyler Wizenburg, grad student, U. Toronto
7. Andrew Hall, operator, Dalhousie U.
8. Ramina Alwarda, grad student, U. Toronto *
9. Beatriz Herrera, grad student, U. Toronto *
10. Ellen Eckert, Post-doctoral fellow, U. Toronto, ECCC

Appendix B: Glossary of Acronyms

0PAL	Zero-altitude PEARL Auxiliary Laboratory
ACE	Atmospheric Chemistry Experiment
APS	Automated Particle Sizer
ARQD	Air Quality Research Division
ASI	All Sky Imager
BSRN	Baseline Surface Radiation Network
CANDAC	Canadian Network for the Detection of Atmospheric Change
CCAR	Canadian Climate and Atmospheric Research
CICA	Canadian Ice Core Archive
COVID-19	COrona VIrus Disease 2019
CRL	CANDAC Raman Lidar
CSA	Canadian Space Agency
DIAL	Differential Absorption Lidar
EARC	Eureka Amateur Radio Club
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
MMCR	MilliMetre Cloud Radar
MOSAIC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
NDACC	Network for the Detection of Atmospheric Composition Change
NOAA	National Oceanographic and Atmospheric Administration
NRCan	Natural Resources Canada
NSERC	Natural Sciences and Engineering Research Council of Canada
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
YOPP	Year of Polar Prediction

Appendix C:

The dissemination list is provided as a separate document.