Report on CANDAC Activities at Eureka, Nunavut during 2021

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 the Polar Environment Atmospheric Research Laboratory (PEARL). 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)”, expired on 30 June 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. However, in October 2021 we were able to visit the site with a three-person team to carry out a significant number of instrument repairs and continue on with some measurement programs. The judicious use of funds has permitted us to extend our operating period at PEARL through 2021. We have been approached by an anonymous private donor that has indicated they wish to support PEARL operations in a major way. While negotiations continued throughout 2021, we are still awaiting the reception of funds. The pandemic continues to greatly impact our presence in Eureka resulting in only 123 person-days in Eureka for 2021, a large decrease from previous years. In February 2022, we will submit a proposal to the Canada Foundation for Innovation Major Science Initiatives (MSI) Fund.for long-term (2023-2029) support for the PEARL facility. Unlike most of our funding, this would directly address facility needs rather than science needs, as the MSI provides support for the ongoing operating and maintenance needs of research facilities of national importance. 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. We continue to maintain active lines of communication with the ECCC upper management.

Aside from the 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. We are currently operating with Andrew Hall continuing as our sole operator and we will actively recruit for more operators once funding is secured. We also continue our efforts directed at putting as much of our data as possible into national and international data catalogues. We were unable to hold a typical Polar Sunrise campaign due to travel restrictions imposed by COVID-19. However, the Fall campaign substituted in part and it was also funded by the Canadian Space Agency.

In 2021, we had three visitors to the laboratory, and it should be noted that this small number is a direct consequence of travel restrictions imposed by the need to undergo a two-week quarantine period before arriving at Eureka. 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 (https://www.pearl-candac.ca/website/index.php/publications/education-outreach/) as well as continuing to participate in teacher training conferences and science outreach events for students, although activities have been affected by the pandemic.

Current funding remains insufficient for re-establishing full-time on-site operations. We were unable to run our extended spring and summer campaigns to operate instruments, take new CANDAC members to Eureka, and carry out necessary repairs. CANDAC instrumentation continued to degrade during the early part of 2021, but with the fall visit, at the end of 2021 most instruments are operating as expected.

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 2022, if funding permits, 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

2021 is the ninth year of 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. It is the second year of operations that have been substantially impacted by the COVID-19 pandemic. 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. During 2019-2021, Professors James Drummond and Kimberly Strong have shared the responsibilities as PAHA Principal Investigator (PI) .

As we began 2020 in our typical operating mode, all but one of our instruments were in near-continuous operation whether autonomous, remotely operated, or operated on site. By January 2021, several instruments had suffered faults that prevented them from operating. Our inability to travel to Eureka to effect repairs resulted in a significant break in the long-term data records for some of them. We have maintained the remote operations 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 PEARL Site Manager and PEARL Data Manager. During 2020 and 2021, we experienced a typical rate of hardware instrument problems and failures, but it was not possible to fix the failures until the Fall of 2021. Overall, the increasing age of our instrumentation continues to be a concern and we monitor them very carefully. In October 2021, during the Fall campaign, a new CANDAC instrument was installed. This instrument is known as a Micro-Pulse Lidar (MPL) and it makes measurements that are complementary to our CRL lidar and Cimel photometer.

As noted earlier, not having an operator on site since March of 2020 has meant that there was a significant decrease in instrument performance and up-time. As of the end of Summer 2021, we had 12 instruments that were not operating or operating at less than full capability. These included the millimeter cloud radar (MMCR) and the WindTracker radar (computer failures), the Bruker IFS125HR Fourier Transform Spectrometer and the Extended-range Atmospheric Radiometric Emission Interferometer (E-AERI) (internal laser failures), the Thermo 49i Surface Ozone monitor and the Pandora (mechanical components), the SAOZ and Precipitation suite (internal electronics), the microwave water vapor radiometer and the Baseline Surface Radiation Network (computer/software problems). All of these were repaired and returned to service during our Fall campaign. In addition, the CANDAC Raman Lidar and the Differential Absorption Lidar (DIAL) only operate when operators are on site and both did make Fall measurements while there was 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 and the MicroPulse Lidar, PEARL will also be represented in the Pandonia network (HTTP://www.pandonia-global-network.org/) and the NASA Micro-Pulse Lidar Network (MPLNET) respectively. PEARL continues to be an important site for satellite validation, and the Canadian Space Agency (CSA) continues to support our operations by funding the

springtime Canadian Arctic ACE/OSIRIS Validation campaigns. During the Fall campaign, we made minor investments in our infrastructure, through the upgrading of the local network that links the various sites and expect to continue to invest in our infrastructure as the need arises. We continue to host several guest instruments 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 although the Cimel sun photometer was not placed into service. We expect it will return once full access to Eureka is permitted. The Pandora pointing system was repaired with some minor upgrades. The Bruker IFS125HR metrology laser was replaced after it failed in July 2020. The cable connecting SAOZ and its computer was severed by ice and was repaired. Its GPS was also replaced.

The Zero Altitude PEARL Auxiliary Laboratory (ØPAL)

There was one new instrument installation at 0PAL during 2021. The Micro-Pulse Lidar (MPL) was installed in the location formerly used for the Arctic High Spectral Resolution Lidar. The MPL will be a part of the NASA Micro-Pulse Lidar Network (MPLNET) a network of MPL systems around the world designed to measure aerosol and cloud vertical structure, and boundary layer heights. The data are collected continuously, day and night. More information can be found at https://mplnet.gsfc.nasa.gov/ The CANDAC Raman Lidar was restarted after operations ceased with the departure of the CANDAC operator in March of 2020. The E-AERI metrology laser was replaced and the instrument returned to operation. The Thermo Scientific 49i Surface Ozone Monitor needed a pump replaced, and adjustment made to its lamp intensity. The MMCR was returned to service after repairs to its computer and its control system. The MWR had continued to operate but data had not been received from it since 2020 because it must be manually transferred. The Precipitation Occurrence Sensor System (POSS) which forms one third of the Precipitation Suite had failed at some point in 2021 and was repaired by replacing its control electronics.

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 VHF radar computer power supply had failed and that was replaced returning the instrument to operation. At that time it was apparent that there was a significant amount of accumulated damage to antennas so that the profiler can only operate at a degraded level of performance. Most of these problems can be easily repaired with a typical service visit. The flux tower and Baseline Solar Radiation Network

(BSRN) instruments continued in operation but there are some logging problems that fortunately do not seem to have resulted in a loss of data. Unfortunately, the same is not the case for the flux tower as a computer problem there has resulted in some losses.

On-going Research

On-site operations for 2021 were similar to 2020, with only a single on-site period of a few weeks. With no travel to Eureka between 1 April 2020 and 13 October 2021, our person-days on site remained significantly below our pre-pandemic levels. Andrew Hall has continued in his role as PEARL operator and is now our most senior operator. Remote control of our instruments together with occasional assistance from Eureka Weather Station staff meant that we have been able to maintain something of a “normal” slate of activities through winter spring, and summer. The lack of an on-site operator had the most significant impact on the measurement program for the CRL as it does not operate unless there is an operator on-site. Bruker IFS125HR operations were not possible due to the laser failure and so both The Total Column Carbon Observing Network (TCCON) observations and Network for Detection of Atmospheric Composition Change (NDACC) measurements could not carried out. As we progressed through 2021, the maintenance issues accumulated and at one point we had a total of 12 instruments that were no longer operating. All of these were returned to operation. However, at the end of the Fall Campaign, the DIAL ozone system developed a fault as did the All Sky Camera. Neither could be repaired before departure.

The pandemic affected the undertaking of the Canadian Arctic ACE/OSIRIS Validation Campaign 2021 (aka the Polar Sunrise Campaign). On-site access at PEARL was not possible in springtime because of ECCC COVID-19 protocols, so a “remote” campaign was undertaken. With sunrise on 20 February 2021, measurements were setup for all of the automated and remotely operable instruments. Researchers from University of Toronto, Dalhousie University and CANDAC, in collaboration with ECCC, facilitated the operation of six instruments from early March to early April to collect atmospheric composition measurements. These instruments were those permanently installed on-site that were able to be left in operation at the end of March 2020 when the last campaign team left PEARL. 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, which 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.

Outreach

Despite the global pandemic, we continued our active virtual outreach program in 2021. Given the on-going travel limitations, our focus was on using virtual outreach activities to highlight Arctic research at PEARL. In March, we facilitated a one-hour hands-on workshop for Youth Enrichment Academy (YEA!), an organization for middle school youth in Regent Park (a priority neighbourhood in Toronto). The 20 grade 6 and 7 students built their own

spectroscopes and conducted observations around their homes in collaboration with their peers, mentors and the facilitators (Participants: Kristof Bognar, Ali Jalali, Erin McGee, John Saunders, Laura Saunders, Laurie Seifried, Zahra Vaziri Zanjani, Yuan You). In June, we led another spectroscope workshop for InspireHER Niagara. This is a student-led organization for high school girls that promotes and encourages interest STEM fields and serves girls in the city of Niagara Falls and the region of Niagara. Our team of Rica Cruz, Ruth Huang, John Saunders, Laura Saunders, Ana-Maria Zamrii, Zahra Vaziri Zanjani, Yuan You, and Kaley Walker worked with 15 students and 2 facilitators from InspireHer Niagara for this session. In July, Kaley Walker gave a 45-minute interactive talk on atmospheric measurements from space, balloons and the Arctic for the PursueSTEM program at the University of Toronto. This is a new initiative from the university to encourage and facilitate black high school students from the Greater Toronto Area to continue in the STEM fields (Science, Technology, Engineering and Mathematics). This presentation was followed by a 1.5 hour version of our spectroscope workshop for 22 students and 3 facilitators (Participants: Aleksandra Elias, Ali Jalali, Ahmed Rayyan, John Saunders, Laura Saunders, Ana-Maria Zamrii, Zahra Vaziri Zanjani, Kaley Walker). For the virtual University of Toronto “Science Unlimited Summer Camp” in August, we provided a half-day of activities for two sessions of 25 grade 10 and 11 students (Participants: Aleksandra Elias, Paul Jeffery, John Saunders, Laura Saunders, Ana-Maria Zamrii, Zahra Vaziri Zanjani, and Kaley Walker). Amateur radio activity with the Eureka Amateur Radio Club (callsign VY0ERC) began again with the arrival of licensed amateurs VE3KTB and VE1RUS in October. There was once again participation in several world-wide events as well as general on-the-air availability. There continue to be inquiries from around the world as to when more consistent amateur radio operations from VY0ERC might resume.

Summary of Plans for 2022

We are exploring with ECCC 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 April to May time period. Beyond that, we hope to return to our normal on-site operator presence with further campaigns in summer and fall. It would be highly beneficial to re-establish our data records and to be able to actively resume instrument repairs and enhancements. In 2022, our outreach activities will likely continue in a manner similar to 2020-21, with participation in virtual workshops.

Concluding Remarks

Despite the COVID-19 pandemic, as of the end of 2021, we have continued to pursue our goal of carrying out a program of state-of-the-art scientific measurements in the Arctic. Even with minimal on-site presence, CANDAC/PEARL/PAHA has demonstrated that it has a solid core complement of instrumentation, facilities and personnel. Operationally, the pre-pandemic 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 2020-2021 given that we have been unable to perform repairs to instruments in a timely fashion. 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 continuing challenges of COVID during 2020-2021 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 2021

There were no non-CANDAC personnel visiting PEARL in 2021.

CANDAC Personnel visiting PEARL in 2021

1. Pierre Fogal, PEARL Site Manager, U Toronto
2. Alexey Tikhomirov, Research Associate, Dalhousie U
3. Andrew Hall, operator, Dalhousie U.

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
MPL	Micro-Pulse Lidar
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.