Report on CANDAC Activities at Eureka, Nunavut during 2022

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). Funding for site visits, student participation, and staff salaries has come from Canadian Space Agency (CSA) satellite validation campaign funds, as well as CSA and Natural Sciences and Engineering Research Council (NSERC) research grants, and funds at the University of Toronto and Dalhousie University. Due to the impact of the COVID-19 pandemic, our on-site costs have remained low, albeit with an ongoing impact on operations and instrument health. We were able to visit the site with a two-person team in July and August 2022 to carry out a significant number of instrument repairs and continue on with some measurement programs. During that visit, we also made a significant upgrade to our internet based communications by installing a low-earth-orbit (LEO) satellite ground-station, giving us much greater band-width at a significantly lower cost when compared to the existing C-band system. The judicious combination of existing funding has permitted us to extend our operating period at PEARL through 2022. Considerable effort was invested in a proposal submitted to the Canadian Foundation for Innovation (CFI) Major Science Initiative (MSI) program in February 2022 and while the proposal received 30 letters of support from partners and was lauded by the external scientific review committee, it was ultimately rejected by the CFI. Our discussions continue with the anonymous private donor that has indicated they wish to support PEARL operations in a major way. While the process continued throughout 2022, we are still awaiting the reception of funds. The pandemic continues to greatly impact our presence in Eureka, resulting in only 44 person-days in Eureka for 2022, a large decrease from previous years. We have had several meetings with senior Environment and Climate Change Canada (ECCC) and CSA managers who have all expressed their belief that PEARL is a worthwhile endeavour that should continue. 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 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. For the duration of 2022, Andrew Hall continued 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 in 2022 due to travel restrictions imposed by COVID-19. However, the Summer campaign substituted in part and it was also funded by the Canadian Space Agency.

In 2022, we had two 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 one-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). We are members of multiple multi-nation Arctic research coordination efforts such as SAON, the Sustaining Arctic Observing Network, and IASOA, and the International Arctic Systems of Observing the Atmosphere, and contribute PEARL measurements to the databases of several international observing networks.

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 reduced 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 2022, but with the summer visit, at the end of 2022 many instruments operated 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 2023, 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 seeking funding to extend our outreach activities into Nunavut communities.

Introduction

2022 is the third year of operations that have been substantially impacted by the COVID-19 pandemic. Our program of research has seen us continue with the core observations and enables us to continue to maintain our instruments. During 2022, Professor Kimberly Strong has fully assumed the role of PEARL Principal Investigator (PI), supported by Professor Kaley Walker as Deputy PI, and Professor James Drummond as PI Emeritus. Dr. Pierre Fogal continues as the PEARL Site Manager and Andrew Hall was the PEARL operator.

At the completion of our Fall 2021 site visit, we fully expected to resume on-site operations in a manner more typical of the pre-pandemic years. However, it became apparent in early 2022 that once again that would not be possible. Most of the PEARL instruments were functional at the end of 2021, but with the continuing prolonged absence, instrument failures again became a factor. Our remote monitoring and operation capabilities permitted the continuation of some aspects of the measurement program, but those measurements requiring the presence of the PEARL operator were again not possible. In late July, PEARL Site Manager Pierre Fogal and PEARL operator Andrew Hall were able to return to PEARL and effect repairs and carry out maintenance for several instruments. Additionally, they were able to install a Galaxy OneWeb Low Earth Orbit (LEO) satellite ground station for added internet communications capabilities. Overall, the increasing age of our instrumentation continues to be a concern and we monitor them very carefully, while the need to operate on a campaign basis rather than full-time operation exacerbates those problems. The primary instrument problems were with the Bruker IFS125HR and associated systems. A replacement laser had been installed in Fall 2021, but because that work was completed after the Sun had set in October, it was not possible to check the operation of the whole system.

Our research program and data products continue 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), the Pandonia Global Network (PGN), the Aerosol Robotic Network (AERONET), and the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). With the addition in 2021 of the MicroPulse Lidar, PEARL is now also represented in 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 Summer campaign, we made a major investments in our infrastructure, through the installation of the LEO ground-station. A power outage also resulted in a significant reconstruction of our access protocols and the local router that links the various PEARL sites. We 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 scientists who are looking for Arctic research sites.

Our partners from the United States at the National Oceanic and Atmospheric Administration (NOAA) have indicated that they need to move from actively participating in measurement programs to more of a support role and have transferred ownership of several instruments to PEARL CANDAC scientists. This will not greatly impact the science from these instruments as they will remain involved with the analyses of the data records.

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 Cimel sun photometer was not placed into service and we expect it will return once full access to Eureka is permitted. The Bruker IFS125HR metrology laser was replaced during our Fall 2021 trip, after it failed in July 2020. However, given that the repair was completed after the Sun set for the last time in October, it was not possible to test the complete system. When we returned to PEARL we discovered that the solar tracker was no longer in proper alignment and considerable effort was invested in returning it to operation. Operation was then possible using our short wavelength infrared channel. Unfortunately, our liquid nitrogen plant (LN2) was also not functioning and we were unable to verify operation on the long wavelength infrared channel. Consequently, the LN2 plant was packed up and returned to the manufacturer for refurbishment. We expect to re-install this during our first visit in 2023.

The visiting Systeme D'Analyse par Observation Zenithale (SAOZ) UV spectrometer had also been repaired during Fall 2021 but as it is also an instrument that uses sunlight it could not be fully tested. During the Summer campaign it was returned to its position on the roof deck and returned to operation. The Pandora tracker refurbishment started in 2021 was finished and the Pandora instrument was re-installed on the roof. Subsequently, an unrelated problem was discovered impacting operation in some directions, but the instrument was left in place. We also installed a webcam to monitor the state of the dome for the PEARL UV Grating Spectrometer as part of our efforts to improve remote operation capability. The heater that helps keep the dome clear was also replaced.

The Scanning Mobility Particle Sizer (SMPS) that draws outside air into itself so that the sizes of particles can be measured experienced a failure in an internal pump. The pump was returned south for repair. The All Sky Imager (ASI) that was unable to operate in Fall 2021 was removed from its location and disassembled, at which point it was found to have a defective shutter. After re-installation, we were not able to initialize the instrument so it will require further repair.

The Zero Altitude PEARL Auxiliary Laboratory (ØPAL)

There were no new instrument installations at ØPAL, but several instruments had minor adjustments made to them and all instruments other than the lidars remain in operation. The lidars only function while there is available and sufficient support on site. The Galaxy OneWeb LEO system was installed on the top of one of the seatainers that make up ØPAL. This system consists of two tracking antennas in small radomes. These antennas follow the satellites as they travel through the field-of-view of the system, switching to the antenna that provides the best connection. The system had to be installed so that it was properly leveled

and properly oriented to the north. Heaters were also installed in the radomes and thus far the system has worked very well. Current throughput is a factor of 10 better and 25% of the cost of what was paid for the C-band system.

The Surface and Atmospheric Flux, Irradiance and Radiation Extension (SAFIRE) Laboratory

There were no new instruments added at SAFIRE. For the second consecutive year, neither the meteor radar nor the VHF radar had their annual service visit. At some point in 2021, the VHF radar computer power supply had failed and that was replaced in October 2021, 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. One of the modules controlling the radar subsequently failed, perhaps due to the degraded antennas, or possibly due to age. We expect to repair that module on our next visit but the system needs the deferred maintenance to be carried out. The flux tower and Baseline Solar Radiation Network (BSRN) instruments continued in operation, however the BSRN tracker did not resume operation after being switched out of winter mode.

On-going Research

On-site operations for 2022 were similar to 2021, with only a single on-site period of a few weeks. With no travel to Eureka between mid-November 2021 and late July 2022, our person-days on site remained significantly below our pre-pandemic levels. 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 into the summer. The repair and re-installation of the instruments mentioned earlier resumed the respective contributions to the UV and IR datasets. 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 resumed using the short IR wavelength channel to carry out TCCON observations but the long-wavelength IR channel could not operate because of the problems with the LN2 plant, so NDACC measurements could not carried out. As we progressed through 2022, the maintenance issues again accumulated but fortunately not at the rate of 2020-2021. The ASI is currently unable to operate due to an unknown problem. The Differential Absorption Lidar (DIAL) for ozone measurements has also not returned to operation, and Dr. Alexey Tikhomirov, the Technical Specialist that operated the instrument has left our organization. Our solar panel monitoring experiment continues and we continue to gain insight into what might be possible with solar power.

The pandemic affected the undertaking of the Canadian Arctic ACE/OSIRIS Validation Campaign 2022 (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 2022, measurements were setup for all of the automated and remotely operable instruments. In a manner similar to what was done in 2021, researchers from University of Toronto, Dalhousie University, and CANDAC, in collaboration with ECCC, facilitated the operation of four 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 Activities

Despite the global pandemic, we continued our active virtual outreach program in 2022 and transitioned to in-person activities over the year. Given the on-going travel limitations, our focus was on using virtual outreach activities to highlight Arctic research at PEARL. In virtual events in April, Kaley Walker gave a 45-minute interactive talk on atmospheric measurements from space, balloons and the Arctic for the Pursue STEM program at the University of Toronto. This is an 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 45-minute version of our spectroscope workshop for 42 students and 2 facilitators (Participants: Alexandre Audette, Aleksandra Elias, Paul Jeffery, Ahmed Rayyan, Evelyn Macdonald, John Saunders, Laura Saunders, Sreekar Voleti, Kaley Walker, David Wandler). In this month, we also gave a one-hour online interactive talk about research at PEARL and Eureka, Nunavut for the Girls SySTEM “Discovery Stream” program on Physics. Girls SySTEM is a mentorship program in Toronto and Kingston for girls in grades 7 to 12. Our team of Kaley Walker, Laura Saunders and Paul Jeffery presented to 11 mentees and 1 mentor in this session. For the in-person 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: Darby Bates, Joseph Hung, Paul Jeffery, and Laura Saunders). In November, we facilitated two 1 hour and 15-minute in-person workshops on atmospheric physics including Arctic measurements for the University of Toronto Girls in STEM program. The two groups of 25 girls in grades 6-8 built their own spectroscopes and conducted observations in the laboratory (Participants: Alexandra Corapi, Laura Saunders, and Kaley Walker). The Eureka Amateur Radio Club (EARC) continues to operate when a licensed amateur radio operator is on site, and continues to give talks to interested groups on request. Membership in the club also continues to grow.

Summary of Plans for 2023

We have had a meeting exploring with ECCC the possibilities for travel to Eureka. As a result, we are planning a trip for two persons in early to mid-March of 2023 that will last approximately four weeks. During this visit, we will carry out a reduced ACE/OSIRIS sunrise validation campaign, and work at restoring the operation of as many of the problematic instruments as possible. Beyond that, we expect to have rather more person-days on-site with further campaigns in Summer and Fall. If possible, we would like to return to having an on-site operator at some point during 2023, as it would be highly beneficial to sustaining our data records and to be able to actively resume instrument repairs and enhancements in an active manner. In 2023, our outreach activities will likely continue in a manner similar to 2021-22, with participation in virtual workshops.

Concluding Remarks

We continue to work within the ongoing constraints imposed by the COVID-19 pandemic. As of the end of 2022, 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 has demonstrated that it has a solid core complement of instrumentation, facilities and personnel. We have experienced some losses on the personnel front, but we will be actively seeking to replace the personnel that have left. Operationally, the pre-pandemic years under our now-completed Probing the Atmosphere of the High Arctic (PAHA) grant from NSERC have been characterized by a high level of instrument operation with near complete measurement capabilities. That has suffered somewhat in 2020-2022 given that we have been unable to perform repairs to instruments in a timely fashion. As is the case for many Canadians, we are unsure of what the post-pandemic situation will be. 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 2020-2022 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 2022

** denotes first time visitors*

Non-CANDAC Personnel visiting PEARL in 2022

There were no non-CANDAC personnel visiting PEARL in 2022.

CANDAC Personnel visiting PEARL in 2022

1. Pierre Fogal, PEARL Site Manager, U Toronto
2. Andrew Hall, operator, Dalhousie U.

Appendix B: Glossary of Acronyms

0PAL	Zero-altitude PEARL Auxiliary Laboratory
ACE	Atmospheric Chemistry Experiment
ARQD	Air Quality Research Division
ASI	All Sky Imager
BSRN	Baseline Surface Radiation Network
CAMS	Copernicus Atmosphere Monitoring Service
CANDAC	Canadian Network for the Detection of Atmospheric Change
CFI	Canadian Foundation for Innovation
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
IR	Infra-red
LEO	Low Earth Orbit
LIDAR	Laser Induced Differential Absorption Radar
LN2	Liquid Nitrogen
MoU	Memoranda of Understanding
MMCR	MilliMetre Cloud Radar
MPL	Micro-Pulse Lidar
MPLNET	Micro-Pulse Lidar Network
MSI	Major Science Initiative
NDACC	Network for the Detection of Atmospheric Composition Change
NOAA	National Oceanographic and Atmospheric Administration
NSERC	Natural Sciences and Engineering Research Council of Canada
OSIRIS	Optical Spectrograph and InfraRed Imager System
PAHA	Probing the Atmosphere of the High Arctic
PEARL	Polar Environment Atmospheric Research Laboratory
PI	Principal Investigator
SAFIRE	Surface and Atmospheric Flux, Irradiance and Radiation Extension
SAON	Sustaining Arctic Observing Network
SAOZ	Systeme D'Analyse par Observation Zenithale
SCOSTEP	Scientific Committee on Solar-Terrestrial Physics
SMPS	Scanning Mobility Particle Sizer
STEM	Science Technology Engineering Math
TCCON	Total Carbon Column Observing Network
UV	Ultra-Violet
VHF	Very High Frequency

Appendix C:

The dissemination list is provided as a separate document.