Seventeen Years of the Canadian Arctic ACE/OSIRIS Validation Project at PEARL

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Introduction & Campaign Motivation

• Ground-based measurements provide critical data to validate satellite retrievals of atmospheric trace gases and to assess the long-term stability of these measurements.
  • Validation in the Arctic is needed for satellite measurements, because the region is so large and sparsely populated only satellites can see the “whole picture”.

• As of February 2020, the Canadian-led Atmospheric Chemistry Experiment (ACE) satellite mission has been making measurements of the Earth's atmosphere for sixteen years and Canada's Optical Spectrograph and InfraRed Imager System (OSIRIS) instrument on the Odin satellite has been operating for over eighteen years.

• As ACE and OSIRIS continue to operate far beyond their planned two-year missions, there is an ongoing need to validate the trace gas profiles from the ACE-Fourier Transform Spectrometer (ACE-FTS), the Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (ACE-MAESTRO) and OSIRIS.
  • In particular, validation comparisons are needed during Arctic springtime to understand better the measurements of species involved in stratospheric ozone chemistry.
To this end, seventeen Canadian Arctic ACE/OSIRIS Validation Campaigns have been conducted during the spring period (February - April in 2004 - 2020) at the Polar Environment Atmospheric Research Laboratory (PEARL).

- The spring period coincides with the most chemically active time of year in the Arctic, as well as a significant number of satellite overpasses.

- The PEARL Ridge Lab, pictured at right, is one of the three PEARL sites [Fogal et al., 2013]. Since 2005, this facility has been operated by the Canadian Network for the Detection of Atmospheric Change (CANDAC).

- Eureka is located on Ellesmere Island in the Canadian high Arctic (80 °N, 86 °W). PEARL is situated near the Environment Canada Weather Station (that has been in operation since 1947).
### ACE on SCISAT

**Launched:** August 2003  
**Orbit:** 74° inclination at 650 km  
**Measurement mode:** solar occultation (~6-150 km)

**ACE-FTS** [Bernath et al., 2005]:  
- FTIR spectrometer, 2-13 microns at 0.02 cm\(^{-1}\) resolution  
- 2-channel visible/NIR imager, 0.525 and 1.02 microns

**MAESTRO** [McElroy et al., 2007]:  
- dual UV / visible / NIR grating spectrophotometer, 285 to 1030 nm at ~1-2 nm resolution

**Pointing:** suntracker in ACE-FTS

### OSIRIS on Odin

**Launched:** February 2001  
**Orbit:** 98° inclination at 600 km  
**Measurement mode (in limb):** scattered sunlight (10-100 km)

**OSIRIS** [Llewellyn et al., 2004]:  
- Optical grating spectrograph (280-810 nm, 1 nm resolution)  
- Narrow horizontal slit (1 arc minute)  
- Three channel filtered vertical imager (1.26 and 1.27 micron \(\Delta\) O\(_2\); 1.53 micron OH Meinel)

**Pointing:** Odin moves to point OSIRIS instrument
**Campaign Measurements**

**IR Fourier Transform Spectrometers (FTSs):** CANDAC Bruker 125HR FTS, EM27/SUN, E-AERI, PARIS-IR, and EC DA8 FTS
- Total and partial columns of O\textsubscript{3}, CH\textsubscript{4}, H\textsubscript{2}O, NO, NO\textsubscript{2}, ClONO\textsubscript{2}, HNO\textsubscript{3}, N\textsubscript{2}O, HCl, CCl\textsubscript{3}F, CCl\textsubscript{2}F\textsubscript{2}, HF, CO and CO\textsubscript{2}

**UV-Visible Spectrometers:** SPS-G, SAOZ, MAESTRO-G, UT-GBS, PEARL-GBS, Pandora spectrometer, and Brewer spectrometers
- Total columns and (some) partial columns of O\textsubscript{3}, NO\textsubscript{2}, H\textsubscript{2}O, OClO, BrO, SO\textsubscript{2}

**Profiling Lidars:** Ozone Differential Absorption Lidar (DIAL) and Rayleigh-Mie-Raman (CRL)
- Profiles of O\textsubscript{3}, H\textsubscript{2}O, temperature, aerosols, and clouds

**Balloon Sondes:** Ozonesondes and radiosondes
- Profiles of O\textsubscript{3}, H\textsubscript{2}O and temperature
# Campaign Data Set

- **Pre-campaign phase:** early February – mid February (pre-sunrise lidar measurements)
- **Intensive phase:** mid February – early-mid March (full team on site, daily ozonesondes)
- **Extended phase:** early-mid March – early-mid April (operators only, weekly ozonesondes)

## Instrument Table

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Abbreviations for spectral regions are as follows: IR: infrared; UV: ultra-violet; Vis: Visible

* Following extensive intercomparisons with Bruker FTS, DA8 FTS was removed in February 2009
** Laser failed at end of 2009 campaign and repair / rebuilding of lidar was tested during 2015 campaign
*** On balloon campaign in Kiruna during spring 2011
**** Being prepared for balloon campaign in Timmins during late summer 2015
Recent validation comparison results

- Comparison of ozone total columns from GBS (GV), SAOZ (SA), 125HR FTS (BK) and PARIS-IR (PA) to satellite-derived columns from OSIRIS (OS), ACE-FTS (AF) and MAESTRO (MA).

- Nearest ozonesonde profile is used for altitudes below lowest satellite measurement to produce a satellite-plus-sonde total column.

- Best fit lines (dashed) are shown from both ordinary least squares (red) and reduced major axis (blue) methods.

Results from Bognar et al. [2019].
• Seasonal comparison of 12-40 km partial columns of NO₂

• Absolute differences between OSIRIS (OS) or ACE-FTS (AF) and UV-GBS (GU), Vis-GBS (GV), SAOZ (SA) and 125HR FTS (BK) are shown

• Dashed lines show mean absolute differences

• Errors shown for the mean differences and RMSD values are the standard error

Results from Bognar et al. [2019].
Interesting 2020 Conditions at Eureka

- The polar vortex was over Eureka for a significant portion of the 2020 ACE/OSIRIS Arctic Campaign – through March and into April
- Data from the campaign are in the process of being analyzed to explore ozone depletion and chemistry during this interesting winter!

The goal of the Canadian Arctic Validation Campaign project is to build a time series of measurements with a well characterized set of instruments that will extend throughout the life of ACE and OSIRIS.

- To use these in identifying and investigating changes in satellite instrument performance and in assessing new data versions and data products.
- To utilize these in collaborative validation efforts for international missions such as Envisat, GOSAT/GOSAT-2, OCO-2/OCO-3 and TROPOMI.

Characterizing and understanding differences between instruments has improved data processing techniques for the ground-based instruments and has furthered satellite comparison techniques.

Please get in touch if you are interested in the campaign data sets. We are very happy to collaborate on validation and scientific studies using these high Arctic data!
**2004 – 2020 Campaign Team**

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- Matt Okraszewski, U. Toronto

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References


Bognar, K. et al. (2019), Updated validation of ACE and OSIRIS ozone and NO₂ measurements in the Arctic using ground-based instruments at Eureka, Canada, J. Quant. Spectrosc. Ra., 238, 106571.

