WGCV-51

SCISAT & OSIRIS Cal/Val Activities, including PEARL Instruments

M. Dejmek, CSA

Agenda Item 3.9

WGCV-51, Tokyo, Japan

6th October 2022

Committee on Earth Observation Satellites

SCISAT & OSIRIS Cal/Val activities, including PEARL instruments

NATIONAL CAL/VAL TEAM LEADS:
Profs. K. Walker, K. Strong
University of Toronto

PRESENTER:
M. Dejmek
Program Lead, Earth System Sciences
Canadian Space Agency

CEOS WGCV-51, TOKYO, JAPAN/VIRTUAL

2022-10-06

Canadian Assets Monitoring Earth

CSA Atmospheric Sciences +

Terra (1999)

Canadian Instrument

Measurement of Pollution in the Troposphere (**MOPITT**)

Measurements

The instrument measures emitted and reflected radiance from the Earth to monitor sources, distribution and sinks of carbon monoxide.

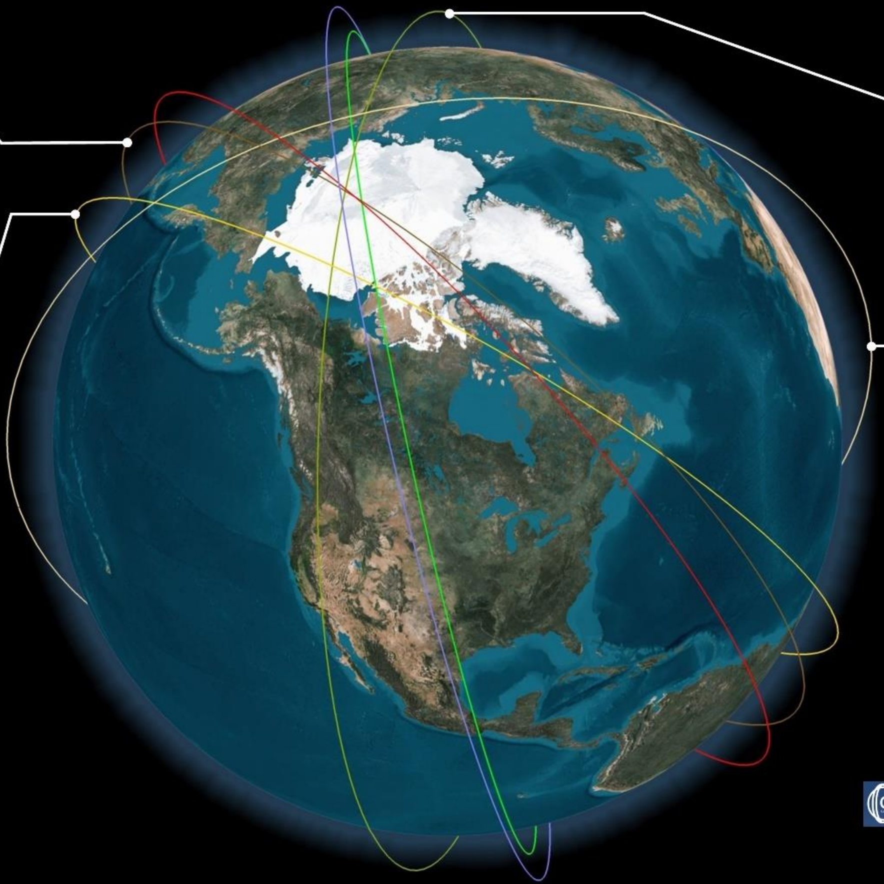
SCISAT (2003)

Instruments

1. Atmospheric Chemistry Experiment (**ACE – FTS**)
2. Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (**MAESTRO**)

Measurements

These instruments measure temperature, pressure and volume mixing ratio profiles of over 60 trace gas molecules (FTS) and vertical distribution of O_3, NO_2, H_2O and aerosols (MAESTRO) to understand ozone distribution.



Odin (2001)

Canadian Instrument

Optical Spectrograph and InfraRed Imager System (**OSIRIS**)

Measurements

Measures vertical profiles of spectrally dispersed, limb scattered sunlight to study stratospheric and mesospheric ozone, NO_2, BrO and aerosols.

CloudSat ('06)

Instrument

Cloud Profiling Radar (**CPR**)

Measurements

The instrument measures the three dimensional structure of clouds and water vapour to study the relationship between clouds and climate.

GHGSat D, 1-5 ('16-'22)

GHGSat Constellation

Fabry-Perot Spectrometers measuring CH_4.

SCISAT/ACE Validation Activity

- As SCISAT has moved from a 2-year to a 1.9+ decade-long project
  - There has been a continuing need for validation of the ACE-FTS and ACE-MAESTRO data products
  - Verifying quality of existing products over time and assessing new data products that are developed
- This on-going validation phase builds on the initial phase efforts
  - The work assessing the 14 baseline species resulted in the special issue of Atmos. Chem. Phys. on ACE validation
- Intercomparison studies using satellite data sets form the core of the on-going validation
- Ground-based and balloon-borne measurements complement these space-based comparisons

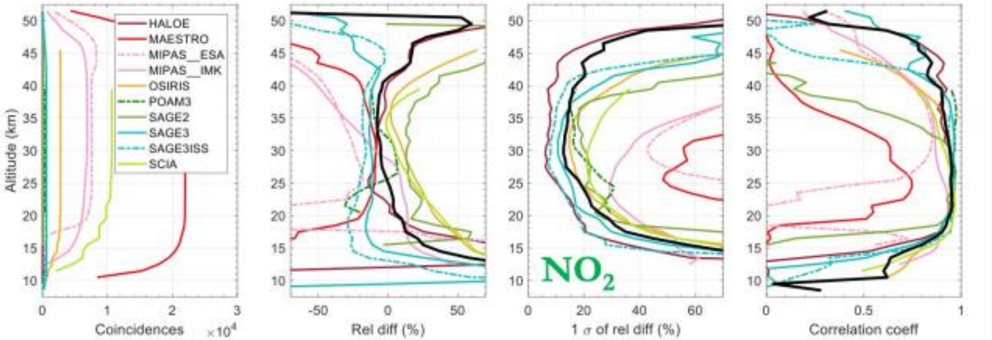
ACE Data Products

- ACE-FTS profiles (current version 4.1/4.2, original species, newly added in v4):
  - Tracers: H_2O, O_3, N_2O, NO, NO_2, HNO_3, N_2O_5, H_2O_2, HO_2NO_2, N_2, SO_2
  - Halogen-containing gases: HCl, HF, $ClONO_2$, CFC-11, CFC-12, CFC-113, COF_2, $COCl_2$, COFCl, ClO, CF_4, SF_6, CH_3Cl, CCl_4, HCFC-22, HCFC-141b, HCFC-142b, HFC134a, HFC-23
  - Carbon-containing gases: CO, CH_4, CH_3OH, H_2CO, HCOOH, C_2H_2, C_2H_4, C_2H_6, OCS, HCN acetone, CH_3CN, peroxyacetyl nitrate (PAN), CO_2 (5-18 km and >60 km), pressure / temperature from CO_2 lines
  - Isotopologues: Minor species of H_2O, CO_2, O_3, N_2O CO, CH_4, OCS, NO_2, HNO_3
- MAESTRO profiles (current version 3.13, new version 4 nearing release):
  - O_3, NO_2, optical depth, aerosol and water vapor (v31)
- IMAGERS profiles (current version 4.1/4.2):
  - Atmospheric extinction & aerosol extinction at 0.5 and 1.02 microns

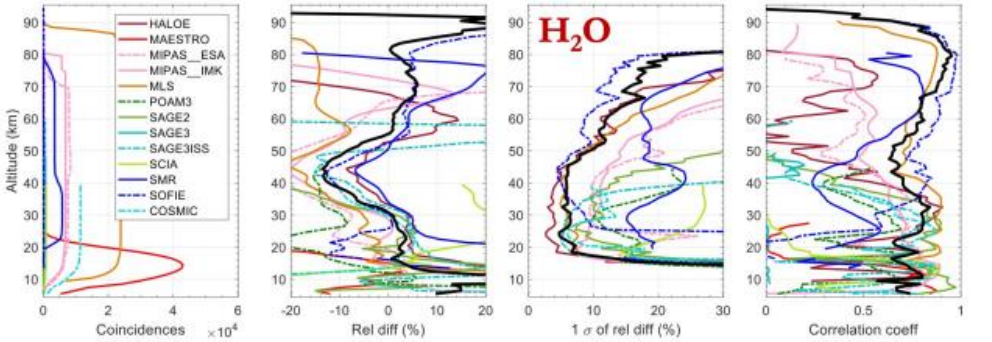
ACE-FTS v4.1 versus Satellite Limb Sensors

- Comparisons routinely done to monitor performance of ACE-FTS and as new version produced
- Coincidences used within 500 km and 5 hours, global average shown
- Differences "ACE-INST" with respect to ACE-FTS
- Average difference calculated over all INST in thick black (weighted using std. dev. of differences)
- ACE-FTS profiles were filtered using v4.1 data quality flags

Comparison of ACE-FTS v4.1 nitrogen dioxide with other satellites-no diurnal scaling

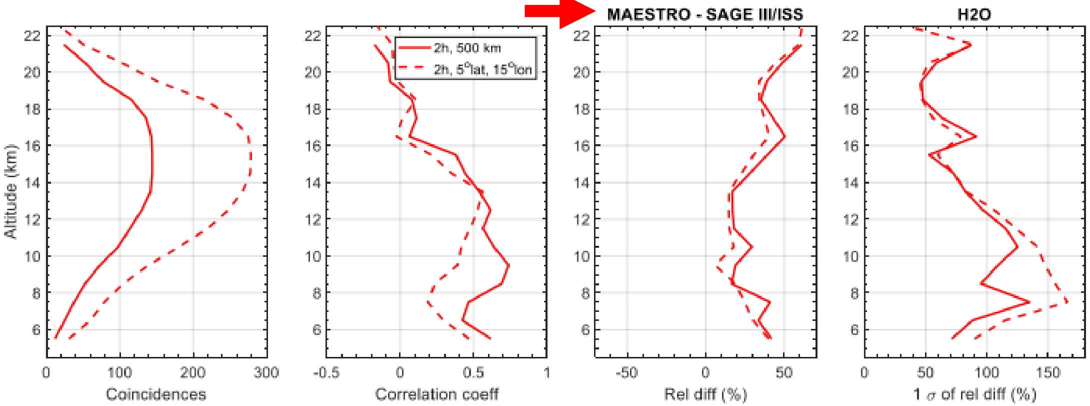


Comparison of ACE-FTS v4.1 water vapour with other satellites.



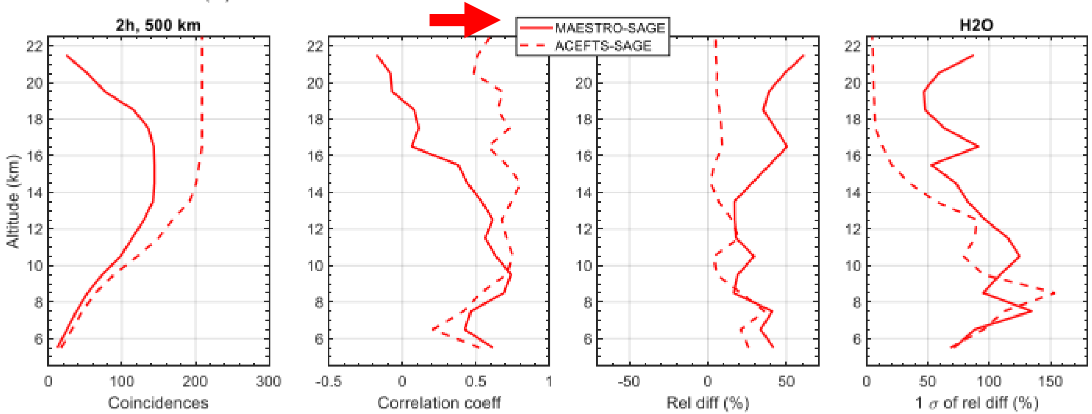
P. E. Sheese.

Comparisons for ACE-MAESTRO v31 H_2O



- SAGE III/ISS began routine observations in June 2017
- Tighter spatial coincidence improves correlation between SAGE III/ISS and MAESTRO

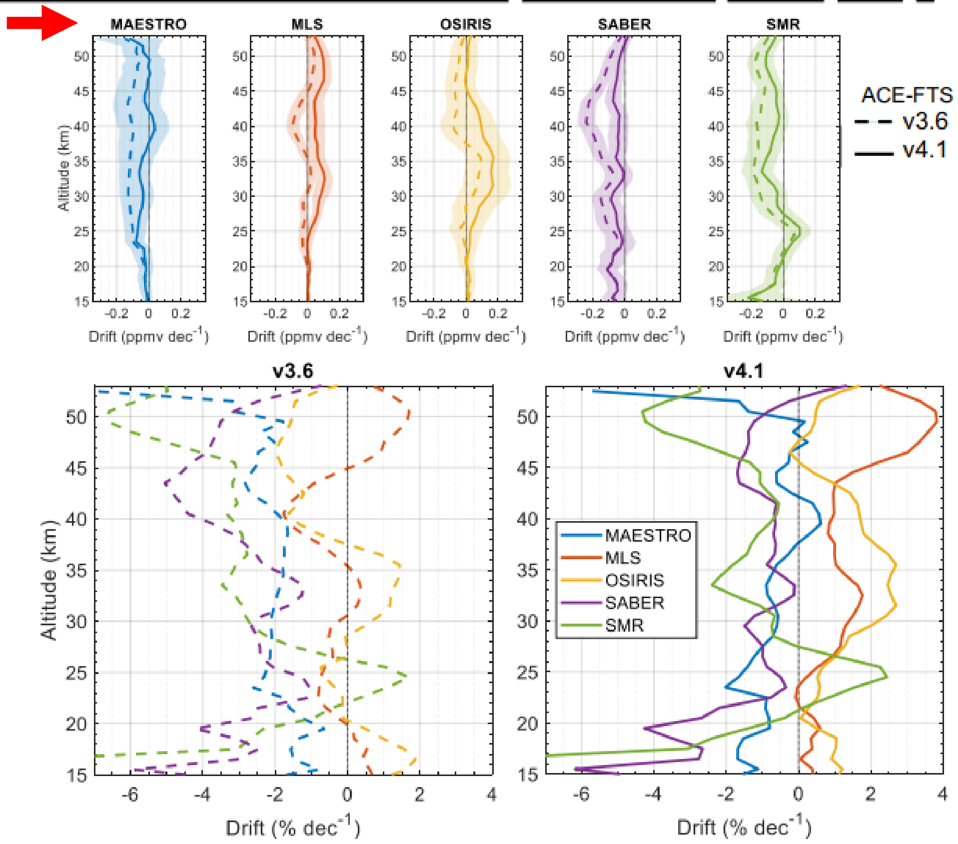
- SAGE III/ISS beta version H_2O
- MAESTRO shows better correlation with SAGE III than ACE-FTS below 9 km



P. Sheese, C. Sioris, and J. Zou.

Examining Drift in ACE-FTS Ozone

- Using satellite profiles collocated with ACE-FTS within 6 hours and 300 km – comparing v3.6 and v4.1
- Comparison time period covering essentially all of 2004-2020
- Drift calculated from 30-day mean difference time series to a linear model using iterative reweighting least-squares method
- Positive shift seen in calculated drift between ACE-FTS v3.6 and v4.1

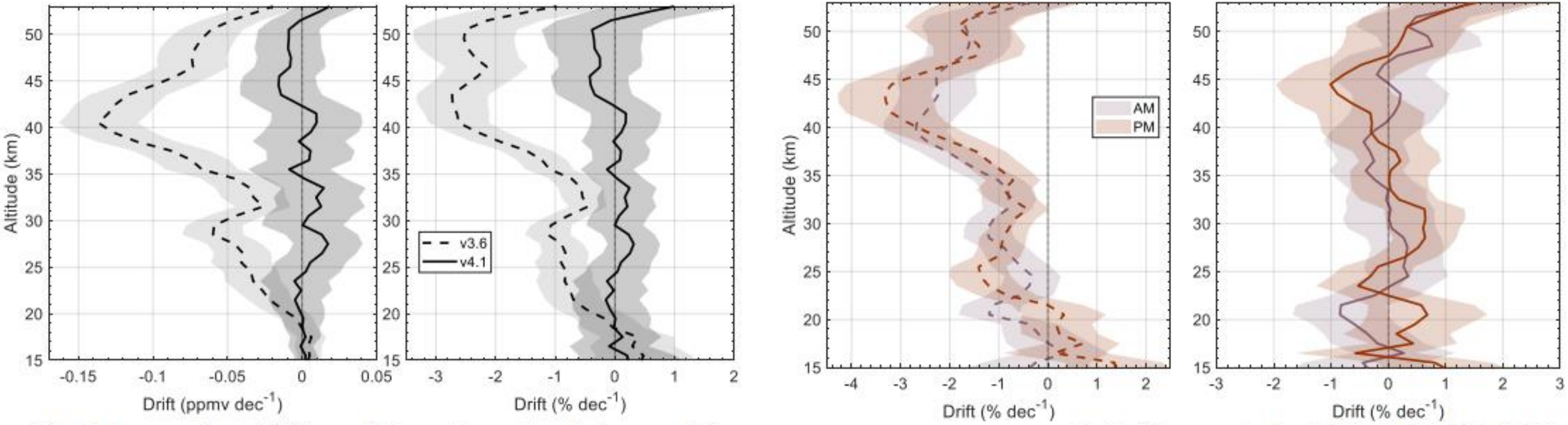


Shaded area shows 99% confidence bounds

P. E. Sheese et al., AMT, 15, 1233–1249, 2022.

Examining Drift in ACE-FTS Ozone

- Multi-instrument averages calculated using inverse square uncertainty of drift as weights
- Drift in ACE-FTS v3.6 due to inaccurate trend in CO_2 concentrations used in retrieval
  - Improved in v4 with retrieval below 18 km and more accurate stratospheric CO_2 used
- ACE-FTS v4.1 from 15-50 km meets stability recommendations for trend studies from GCOS (better than 1% dec^{-1}) and ESA ozone_CCI (less than 1-3% dec^{-1})

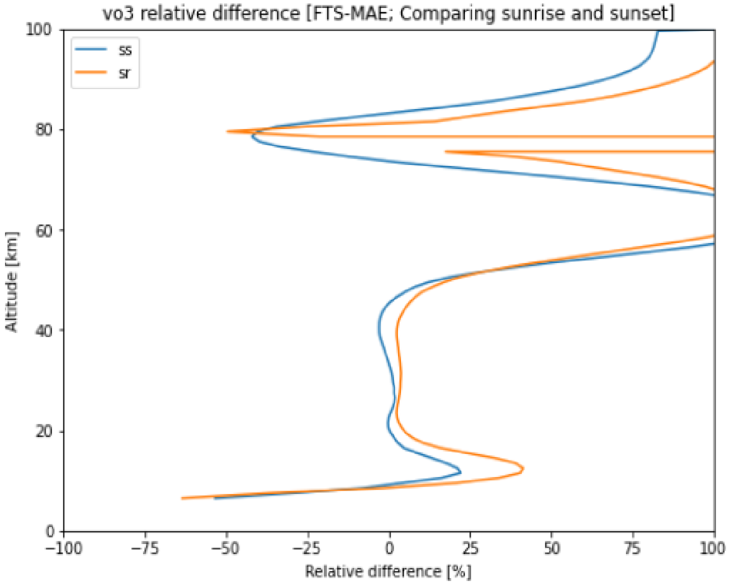


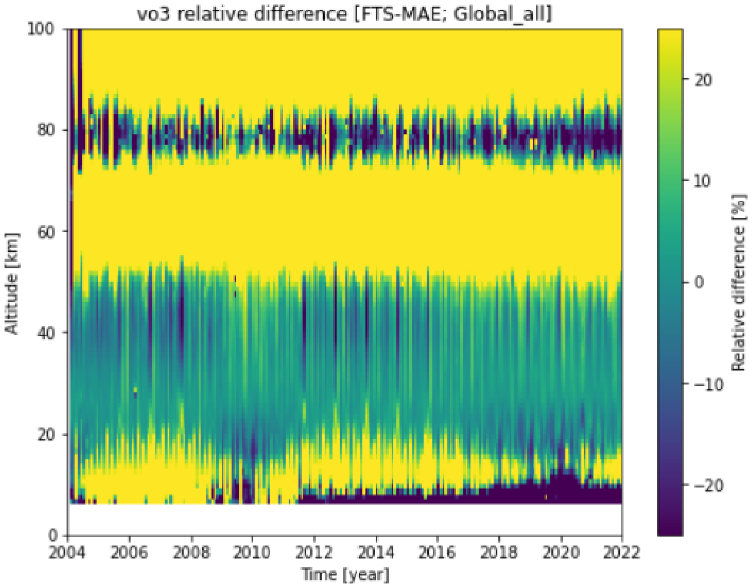
Shaded areas show 99% confidence bounds; v3.6 – – ; v4.1 —

P. E. Sheese et al., AMT, 15, 1233–1249, 2022.

Comparisons for ACE-MAESTRO v4 O_3

- Assessing development of new MAESTRO O_3 processor – showing MAESTRO VIS channel results compared to ACE-FTS v4.1/4.2
- Performance looking quite good 17-50 km – relative differences from ACE-FTS 5-10 %
- Global data from all years (2004-2022) are shown as average (split by sunrise / sunset) in left panel and as time series in right panel





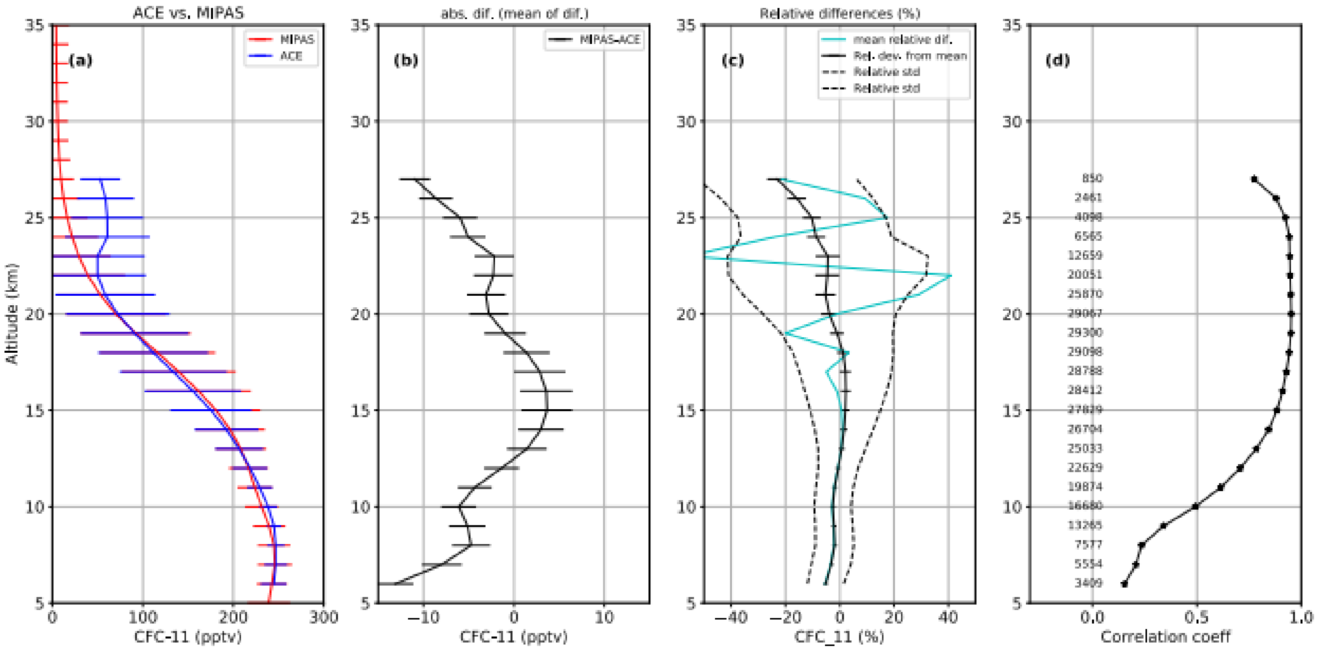
P. Jeffery and J. Zou.

MIPAS and ACE-FTS CFC-11 Comparisons

- ACE-FTS v4.1 and new MIPAS IMK-IAA v8 retrievals between 2005 and 2012, global comparisons within 24 hours and 1000 km for CFC-11 and CFC-12
- Max. ACE-FTS retrieval altitude varies with lat. (~24-27 km from polar to tropics)

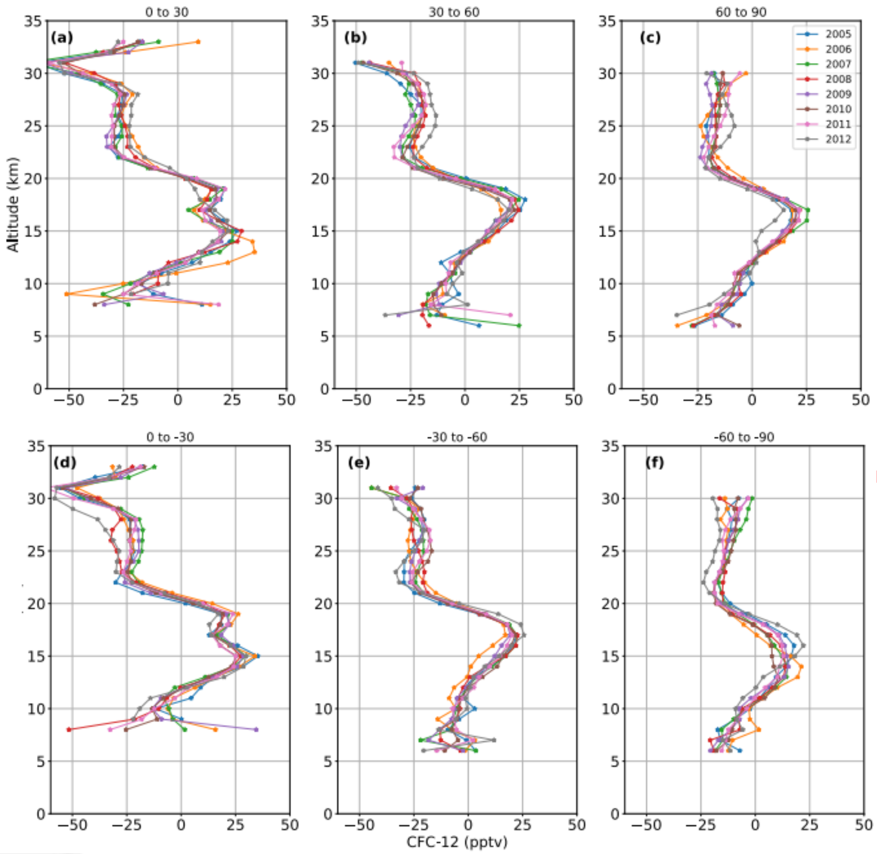
Typical differences of less than 10 pptv and within 10%

- Improved agreement – previous comparison differences showed MIPAS ~10-20 pptv higher than ACE-FTS



A. Jalali et al., in preparation.

MIPAS and ACE-FTS CFC-12 Comparisons

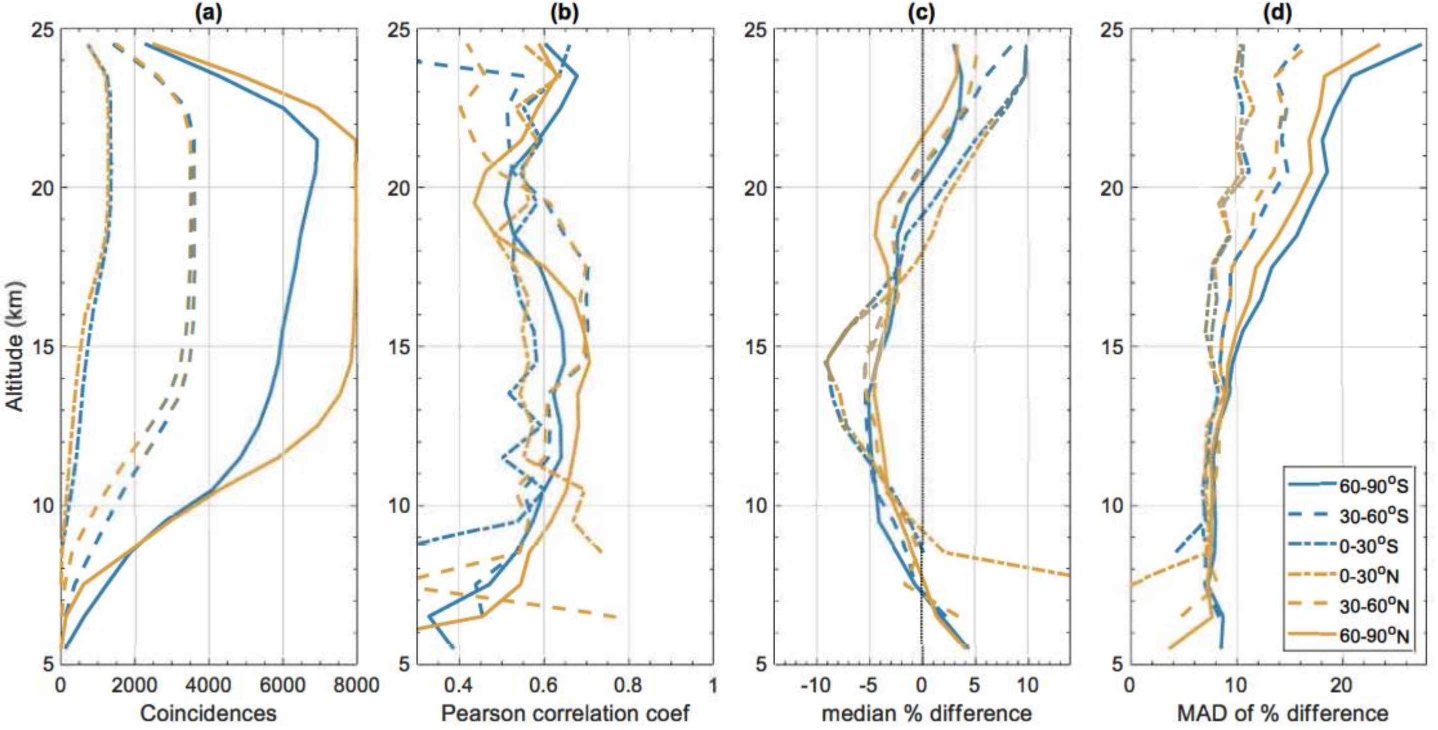


- ACE-FTS v4.1 and new MIPAS IMK-IAA v8 retrievals between 2005 and 2012
- Dividing comparisons by year and latitude range – all within 24 hr and 1000 km
  - Showing only absolute differences
- Variation in ACE-FTS maximum retrieval altitude with latitude evident
- Differences typically within ±25 pptv over much of altitude range – larger differences at lower latitudes
- Improvement of differences at lower altitudes (~8-17 km) seen globally, slightly worse by few pptv at higher altitudes

A. Jalali et al., in preparation.

Validation of ACE-FTS HCFC-22

- Comparisons with ACE-FTS v4.2 with MIPAS IMK/IAA v8
- ACE-FTS biased low up to ~5-10% from 10-20 km
- Similar results with MkIV balloon FTIR and CARBIC aircraft in situ measurements



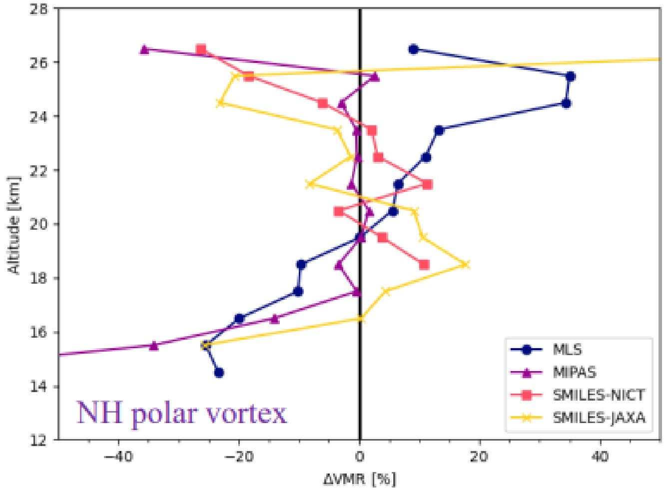
ACE-FTS – MIPAS for 2004-2012, within 12 hours, 10° latitude, 20° longitude, NH, SH

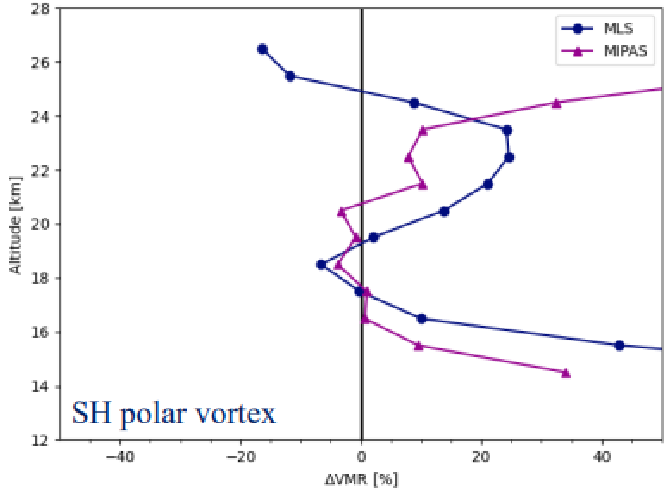
P. Sheese, F. Kolonjari, et al., in preparation.

v4.2 ClO versus MIPAS, Aura-MLS and SMILES

- Comparison of daytime profiles taken within 300 km of ACE-FTS, within polar vortex
- Used PRATMO chemical box model to scale comparison profiles to ACE local solar time
- Time periods for comparison vary; several months for SMILES to 2004-2020 for MLS

➡ Differences found from 17 - 24 km are within approx. ±10 - 20% for NH and between -10 and +25% for SH





Medians of differences (ACE-FTS – comp.) shown for comparisons.

L. Saunders, N. Ryan et al., in preparation.

ACE/OSIRIS Arctic Validation Campaign Project

- To obtain validation measurements for ACE and OSIRIS in the Canadian Arctic (Eureka, Nunavut – 80 ˚N, 86 ˚W) from February to April 2004 - present for all ACE baseline species
- To make daily measurements at high temporal resolution to give context to the sparse (in time and space) ACE occultation measurements (Arctic science is priority 1 for ACE)
- To use data to validate ACE, OSIRIS and other satellite missions, including GOSAT, OCO-2, and TROPOMI

- To maintain the continuity of measurements from the NDSC/NDACC-validated FTIRs at Eureka, which have been made since 1993

ACE/OSIRIS Arctic Campaign in 2020

Location: Polar Environment Atmospheric Research Laboratory (80˚N)

ON-SITE INSTRUMENTS (location)	CAMPAIGN INSTRUMENTS
• CANDAC DIAL/SOLID (Ridge Lab.) • EC ozonesondes (weather station) • EC Brewers (Ridge Lab./weather station) • CANDAC Bruker 125HR FTS (Ridge) • CANDAC grating spectrometer (Ridge) • CANDAC E-AERI (0PAL) • CANDAC RMR Lidar (0PAL)	• York SPS-G • U of T grating spectrometer (UT-GBS) • LATMOS/CNRS SAOZ • ECCC Pandora spectrometer • U of T EM27/SUN spectrometer

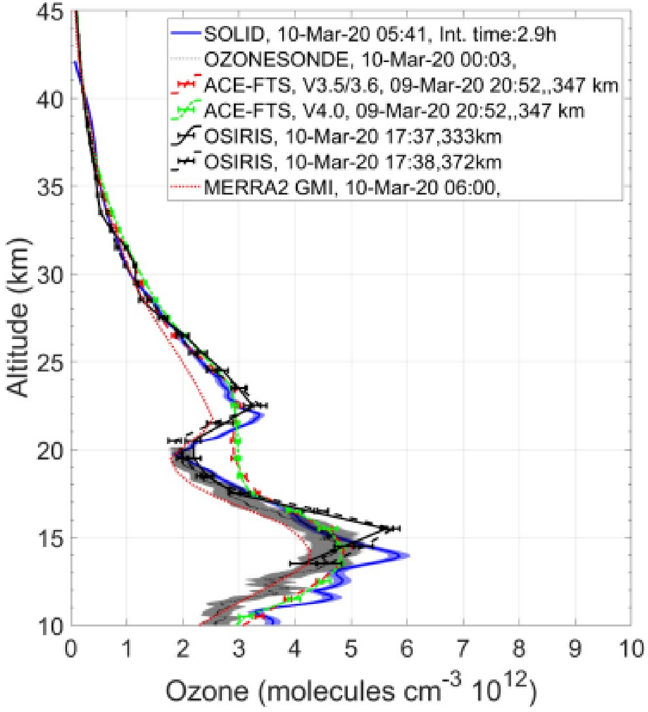
Last year of full campaign before global pandemic impacted operations ←

- Pre-campaign phase: 3 – 21 February: Operation of DIAL and CRL
- Intensive phase: 22 February – 11 March
  - Measurements by all 12 instruments with daily ozonesondes
- Extended phase: 12 March – 28 March
  - Continued measurements with all instruments at PEARL/0PAL and weekly ozonesonde flights

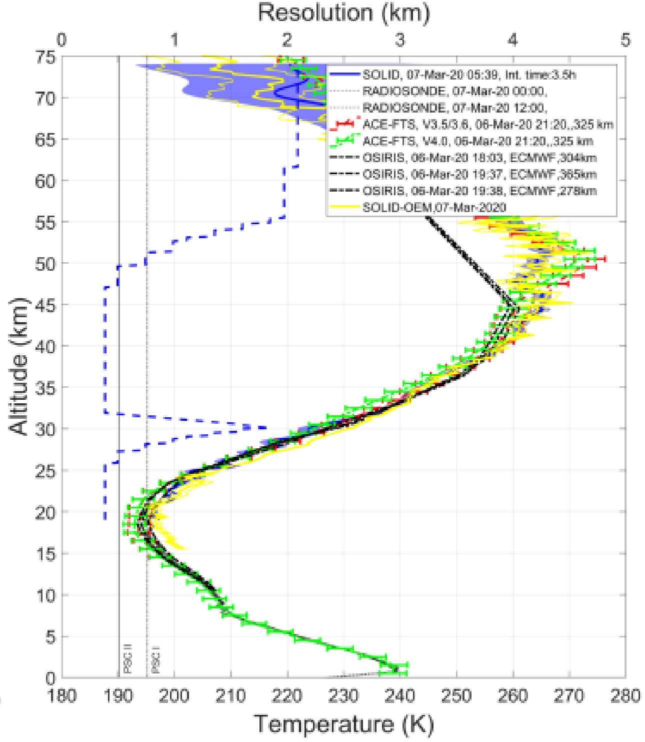
SOLID (DIAL) Comparison Example: 2020

- Differential absorption lidar measurements during campaign
- Profile comparisons with ACE-FTS and OSIRIS for each night of measurements along with closest sonde
- Temperature is retrieved product for ACE-FTS and input from ECMWF used for OSIRIS retrieval

Ozone (10 – 45km)



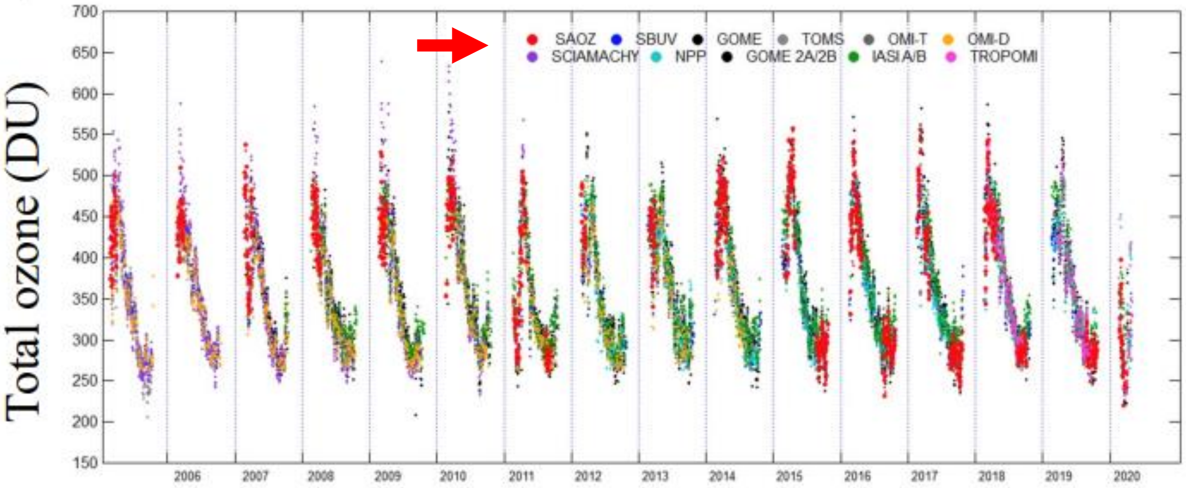
Temperature (18 – 80km)



Alexey Tikhomirov

SAOZ Nadir Ozone Comparisons

- Total ozone comparison with nadir satellite instruments (UV/VIS and IR)
- Reprocessed SAOZ retrieval using new reference spectrum on 10 April 2016
- Using full timeseries from ACE/OSIRIS campaigns for SAOZ – starting 2005



RELATIVE DIFFERENCES

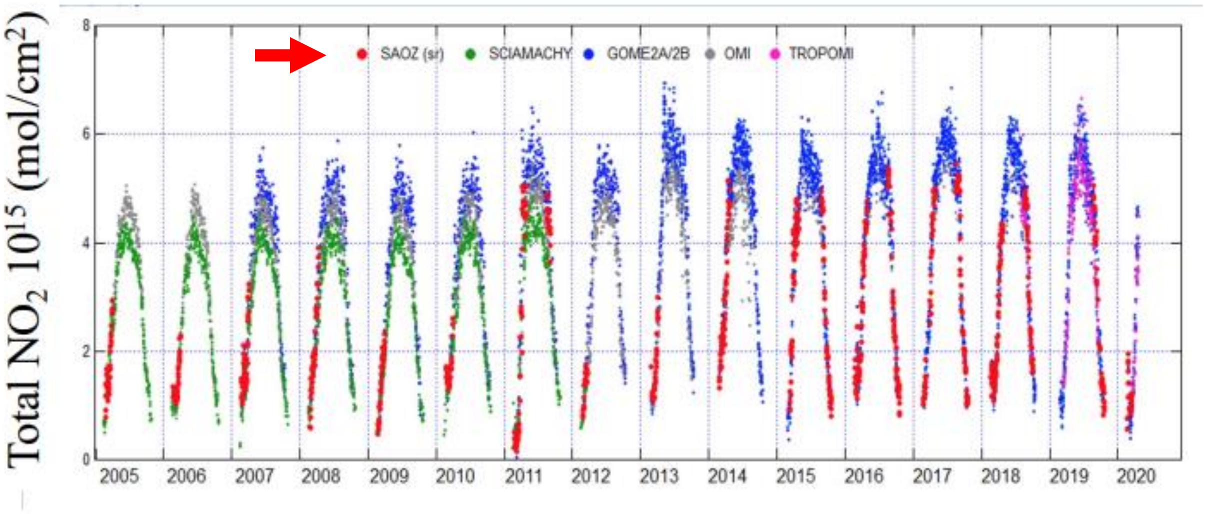
SCIAMACHY	-1.2%	**GOME**	-0.5%	**GOME 2** A/B	-0.3%
SBUV	-0.4%	**OMI**-TOMS	-1.3%	**OMPS-NPP**	+1.1%

IASI A/B (reprocessed with new filter): 7% **TROPOMI:** +1.2%

Andrea Pazmiño & Florence Goutail

SAOZ Nadir NO_2 Comparisons

- Total NO_2 comparison with nadir satellite instruments (UV/VIS)
- Reprocessed SAOZ retrieval using new ref. spectrum on 10 April 2016
- Using full timeseries from ACE/OSIRIS campaigns for SAOZ – starting 2005



ABSOLUTE DIFFERENCES (mol/cm²)

SCIAMACHY: -0.15e15 **GOME 2A**: 0.1e15 **GOME 2B**: 0.e15 **OMI:** -0.3e15
TROPOMI: -0.4e15

Andrea Pazmiño & Florence Goutail

2020 ACE/OSIRIS Campaign Team

ACE/OSIRIS Validation Team Co-Leaders

- Kimberly Strong, U. Toronto
- Kaley Walker, U. Toronto

Co-Investigators

- Adam Bourassa, U. Sask.
- Doug Degenstein, U. Sask.
- James R. Drummond, Dalhousie U.
- C. Thomas McElroy, York U.
- R. J. Sica, U. Western Ontario
- Debra Wunch, U. Toronto

Collaborators

- Florence Goutail, LATMOS/CNRS
- Mahesh Kumar Sha, BIRA-IASB
- Andrea Pazmiño, LATMOS/CNRS
- David Tarasick, ECCC
- Corinne Vigouroux, BIRA-IASB

Team Members

- Ramina Alwarda, U. Toronto
- Kristof Bognar, U. Toronto
- Ellen Eckert, U. Toronto
- Beatriz Herrera, U. Toronto
- Ali Jalali, U. Toronto
- Emily McCullough, Dalhousie U.
- Nasrin Pak, U. Toronto
- Sebastien Roche, U. Toronto
- Alexey Tikhomirov, Dalhousie U.
- Tyler Wizenberg, U. Toronto
- Xiaoyi Zhao, ECCC

ACE/CANDAC Operators

- Pierre Fogal
- John Gallagher
- Andrew Hall

Acknowledgements

Funding and support for this work was provided by:

- Canadian Space Agency
- Environment and Climate Change Canada
- Natural Sciences and Engineering Research Council of Canada
- Northern Scientific Training Program
- Centre National d'Etudes Spatiales
- Canadian Network for Detection of Atmospheric Change (funding partners: ARIF, AIF/NSRIT, CFCAS, CFI, CSA, ECCC, GofC IPY, NSERC, OIT, ORF, INAC, and PCSP)

Special thanks to:

- Eureka Weather Station staff for their support during our eighteen spring campaigns and pandemic challenges

PEARL Update and Cal/Val Activities

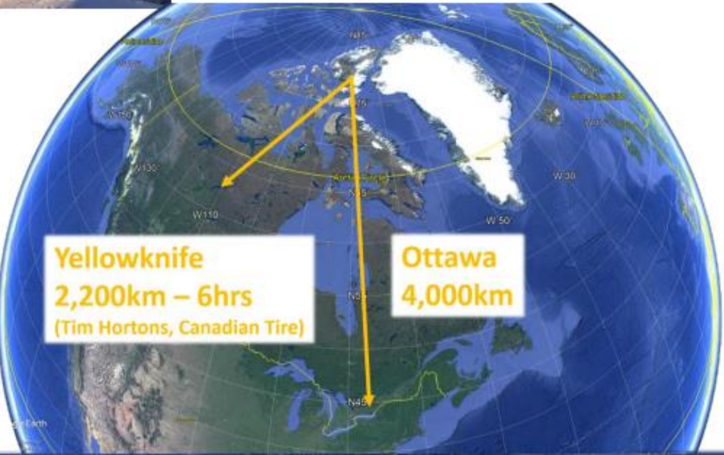
Kimberly Strong, **PEARL Project Leader** (Department of Physics, University of Toronto)
Kaley Walker, **PEARL Deputy Project Leader** (Department of Physics, University of Toronto)
James Drummond, **PEARL Project Mentor and former PEARL Principal Investigator** (Department of Physics & Atmospheric Science, Dalhousie University)
Pierre Fogal, **PEARL Site Manager** (Department of Physics, University of Toronto)

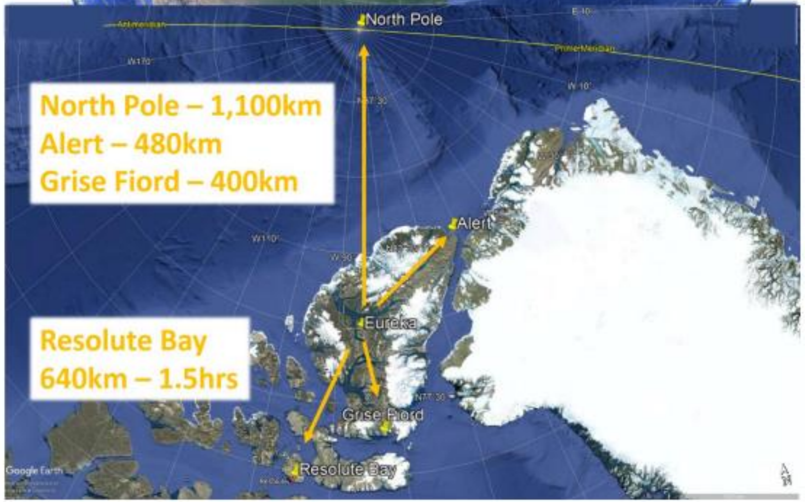
1. Brief Overview of PEARL
2. Current Status of PEARL
3. Examples of Recent Validation Studies

CEOS WGCV-51 Meeting
3-6 October 2022

Photo Credit: Dan Weaver

The PEARL Facility

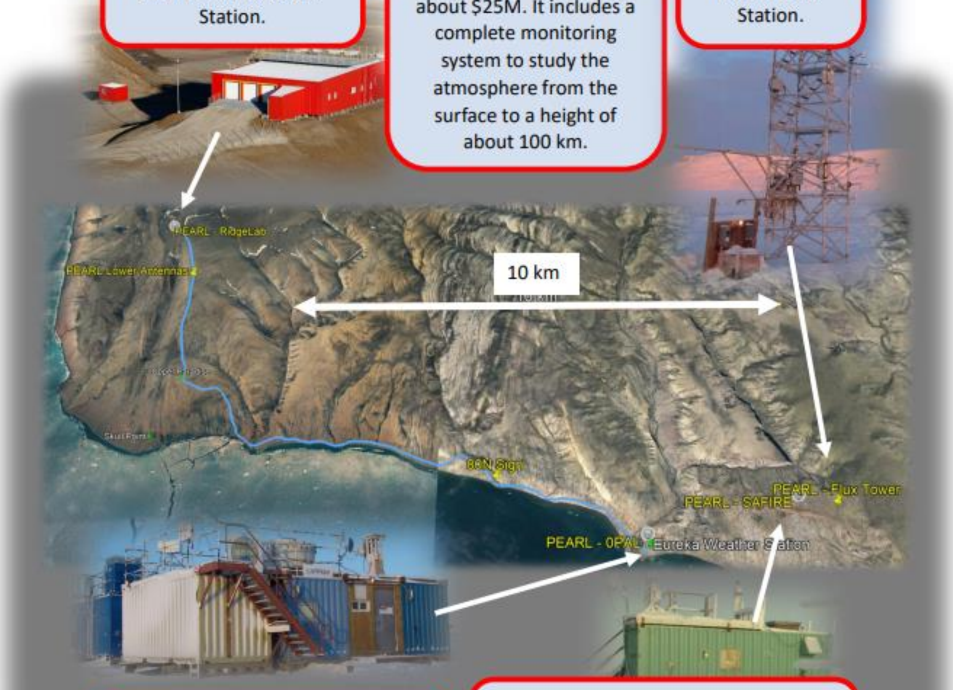




The PEARL Ridge Lab is 610 m above sea level and 15 km from the Weather Station.

The infrastructure installed at PEARL is worth about $25M. It includes a complete monitoring system to study the atmosphere from the surface to a height of about 100 km.

The 10m Flux Tower is located about 6 km from the Weather Station.



The Zero-altitude PEARL Auxiliary Laboratory (ØPAL) is located next to the Weather Station at sea level.

The Surface and Atmospheric Flux, Irradiance and Radiation Extension (SAFIRE) is located about 5 km from the Weather Station.

The Two Phases of PEARL

CANDAC
Canadian Network for the Detection of Atmospheric Change

2005-2012 – CANDAC

Four themes:

- Arctic Troposphere Transport and Air Quality
- The Arctic Radiative Environment: Impacts of Clouds, Aerosols, and "Diamond Dust"
- Arctic Middle Atmosphere Chemistry
- Waves and Coupling Processes

2013-2021 – PAHA (Probing the Atmosphere of the High Arctic)

Three themes:

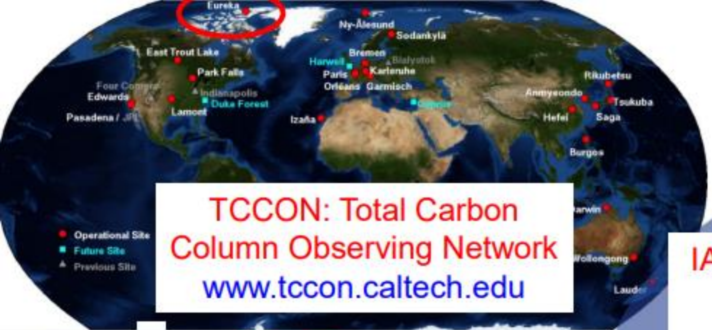
- Composition Measurements
  - Greenhouse Gases Related to the Carbon Cycle
  - Ozone and Related Species
  - Biomass Burning and Continental Influence on the Arctic
  - Clouds, Aerosols and Precipitation
- Polar Night
- Satellite Validation

Photo Credit: Dan Weaver

PEARL Facilities

➡ PEARL has the most northerly set of geostationary communication antennas on the planet and a new (August 2022) Galaxy/OneWeb ground station.

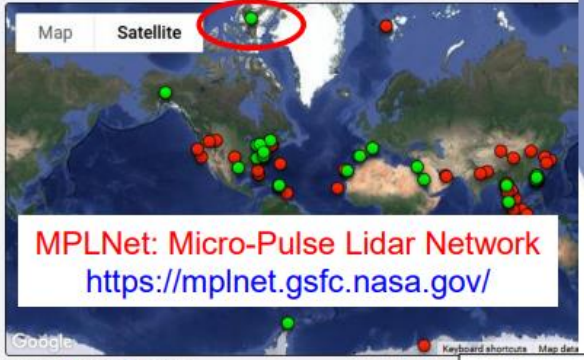
Global Networks



TCCON: Total Carbon Column Observing Network
www.tccon.caltech.edu

https://aeronet.gsfc.nasa.gov/

IASOA: International Arctic Systems for Observing the Atmosphere
http://www.iasoa.org/



MPLNet: Micro-Pulse Lidar Network
https://mplnet.gsfc.nasa.gov/

Map Legend: Active Inactive

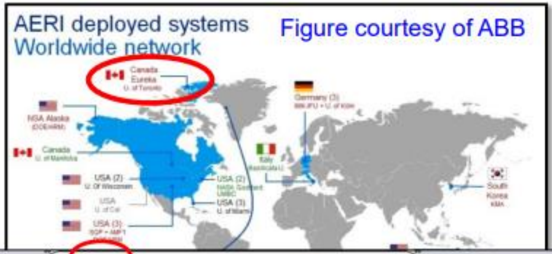
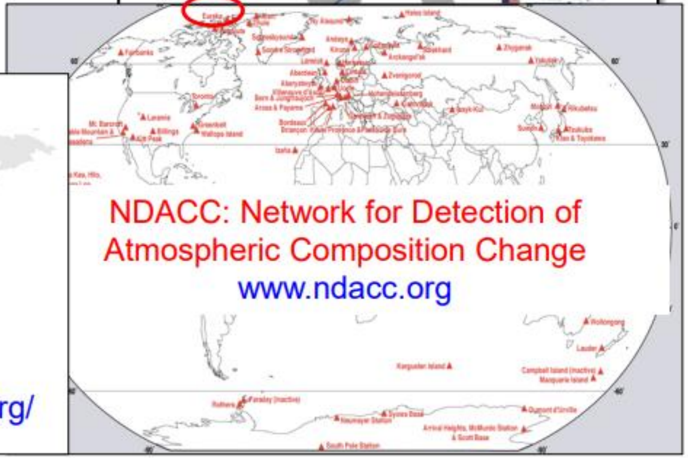


Figure courtesy of ABB



NDACC: Network for Detection of Atmospheric Composition Change
www.ndacc.org

Figure courtesy of E. Sepúlveda, M. Schneider

Pandonia Global Network
https://www.pandonia-global-network.org/

PEARL Instruments (*=NDACC, ↑=TCCON)

PEARL Ridge Lab

- * Bomem DA8 FTIR (1993-2008)
- * ↑ Bruker 125HR FTIR (2006-)
- * Two UV-Vis Spectrometers
- Aerosol Mass Spectrometer
- Scanning Mobility Particle Sizer
- Condensation Nuclei Counter
- Two Photo-acoustic Extinctiometers
- Aerodynamic Particle Sizer
- Cimel Sun Photometer
- E-AERI (2008-2009)
- Meteorological Station
- Brewer Spectrophotometer (guest)
- SAOZ Spectrometer (guest)
- Pandora Spectrometer (guest)

Ridge Lab Night-time:

- * DIAL Ozone Lidar (1993-)
- E-Region Wind Interferometer (ERWIN)
- Spectral Airglow Temperature Imager (SATI)
- All Sky Imager
- Two Fabry-Perot Interferometers (guest)

SAFIRE

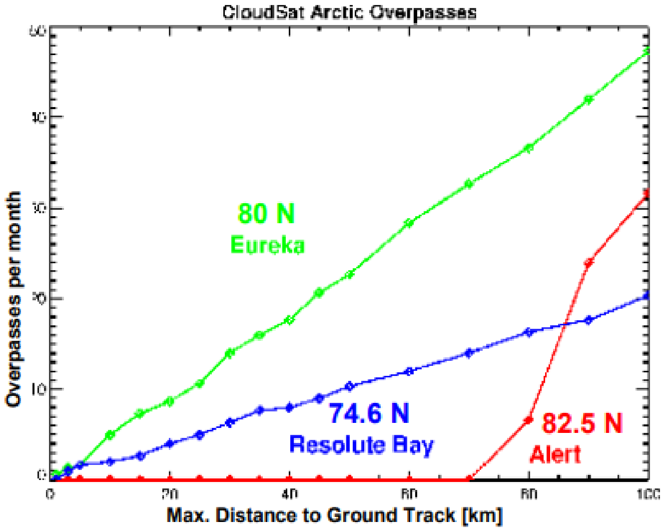
- Baseline Surface Radiation Network station
- Flux Tower
- VHF Wind Profiler/Radar
- Meteor Radar

ØPAL

- Millimeter Cloud Radar
- High Spectral Resolution Lidar (2006-2011)
- Polar AERI (2006-2009)
- Extended-range Atmospheric Emitted Radiance Interferometer (E-AERI; 2009-)
- Microwave H_2O Radiometer
- Tropospheric Ozone Lidar
- Rayleigh/Mie/Raman Lidar
- Cimel Sun/Moon Photometer
- Star Photometer
- Precipitation Sensor Suite
- ThermoScientific TEI49i Ozone Sensor

Satellite Validation at PEARL

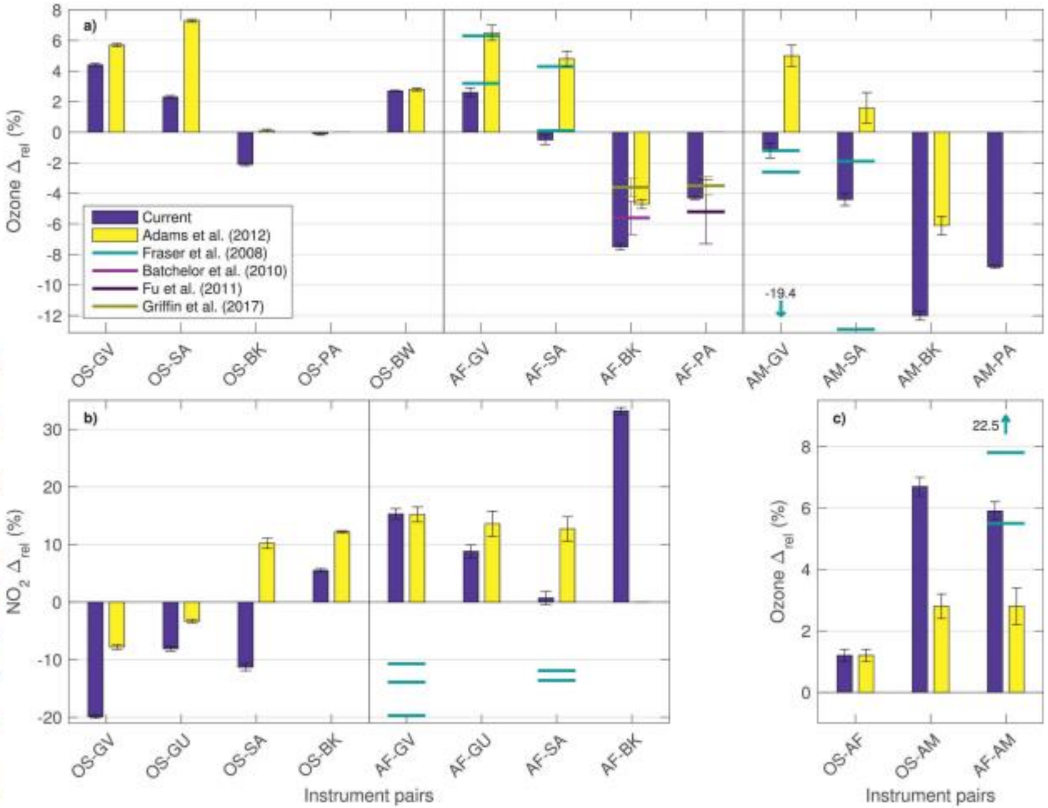
- PEARL is an **important location for validation** of Arctic satellite measurements
  - ➢ Satellite data are integral to Arctic research and monitoring but there are **unique difficulties in interpreting Arctic satellite measurements** due to low temperatures and snow cover
  - ➢ **Validation is needed throughout the lifetime of a satellite mission**; Arctic validation data are scarce
  - ➢ **PEARL is in a "sweet-spot"**, as 80°N has frequent overpasses by many polar-orbiting satellites
- PEARL has contributed to validation of data from **15 national/international** instruments
  - ➢ ACE-FTS and ACE-MAESTRO on SCISAT (CSA)
  - ➢ OSIRIS on Odin (CSA, SNSB)
  - ➢ MOPITT on Terra (CSA, NCAR, NASA)
  - ➢ MIPAS and SCIAMACHY on EnviSat (ESA)
  - ➢ TROPOMI on Sentinel-5 Precursor (ESA)
  - ➢ OCO-2 (NASA)
  - ➢ CrIS on Suomi NPP (NASA, NOAA)
  - ➢ IASI on MetOp (CNES, EUMETSAT, ESA)
  - ➢ TANSO-FTS on GOSAT and GOSAT-2 (JAXA, NIES, MOE)
  - ➢ AIRS on Aqua (NASA) and MLS and TES on Aura (NASA)
- **Future (only if PEARL doesn't close)**: NASA's Atmosphere Observing System (including CSA's HAWC instruments) and Canada's proposed Arctic Observing Mission, plus other new missions



Plot from David Hudak (ECCC)

OSIRIS & ACE O_3 & NO_2 vs. PEARL

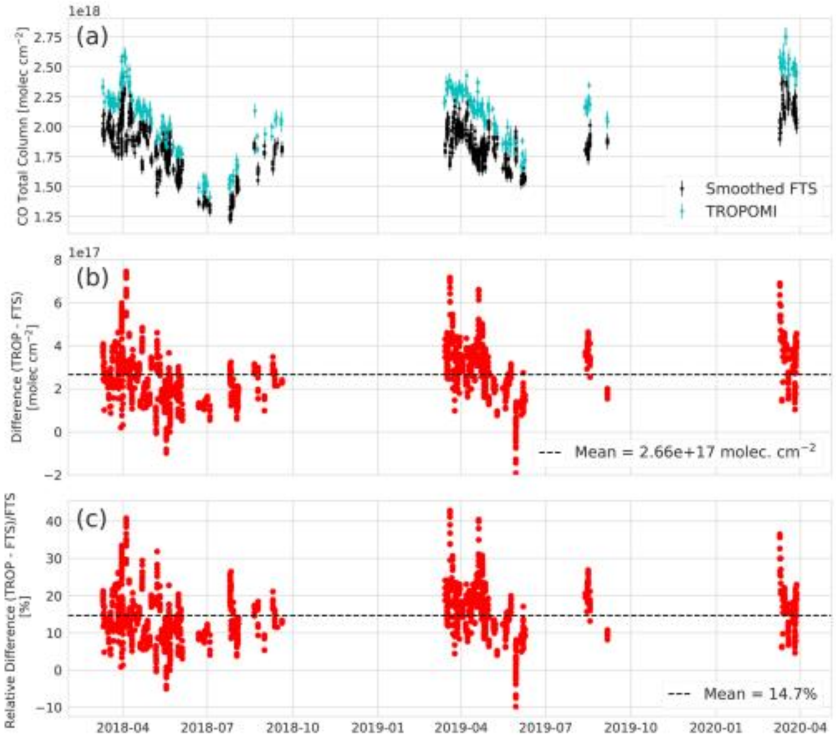
OSIRIS (OS), ACE-FTS (AF), and ACE-MAESTRO (AM) vs. Eureka UV-VIS zenith-sky DOAS (GV, GU, SA), FTIR (PA, BK), and Brewer (BW).



Mean relative differences between (a) satellite-plus-sonde surface-52 km ozone columns and ground-based total columns, (b) 12-40 km satellite NO_2 partial columns and ground-based partial columns, and (c) 14-52 km satellite ozone columns.

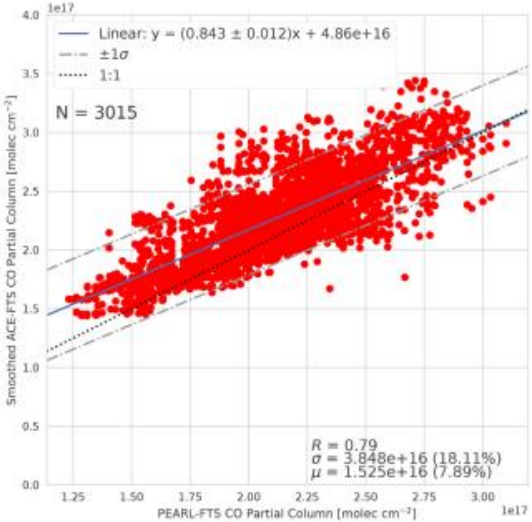
Kristof Bognar et al,, Updated validation of ACE and OSIRIS ozone and NO_2 measurements in the Arctic using ground-based instruments at Eureka, Canada. *J. Quant. Spec. Rad. Transfer*, **238**, 106571, 2019. https://doi.org/10.1016/j.jqsrt.2019.07.014

ACE-FTS & TROPOMI CO vs. PEARL



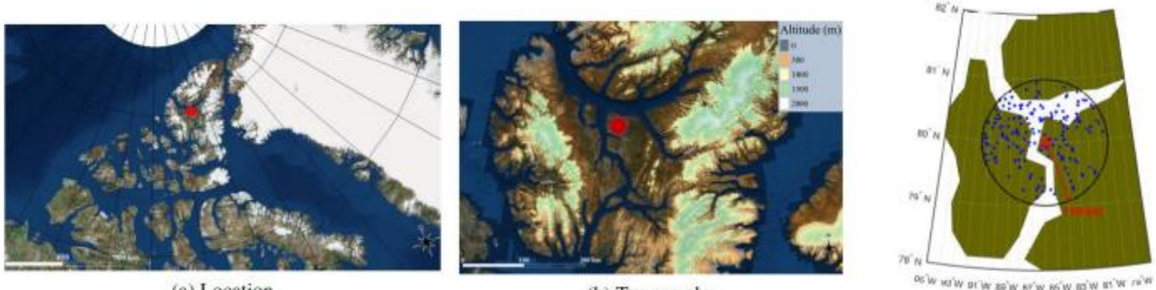
Time series of (a) TROPOMI and smoothed PEARL NDACC FTIR total columns, (b) absolute column differences (in molec. cm^{-2}), and (c) relative differences (in %).

ACE-FTS vs. PEARL-FTS CO 9-67 km partial columns for the period from 25 February 2007 to 18 March 2020.



Tyler Wizenberg et al., Intercomparison of CO measurements from TROPOMI, ACE-FTS, and a high-Arctic ground-based Fourier transform spectrometer. *Atmos. Meas. Tech.*, **14**, 7707-7728, 2021. https://doi.org/10.5194/amt-14-7707-2021

MOPITT CO vs. PEARL



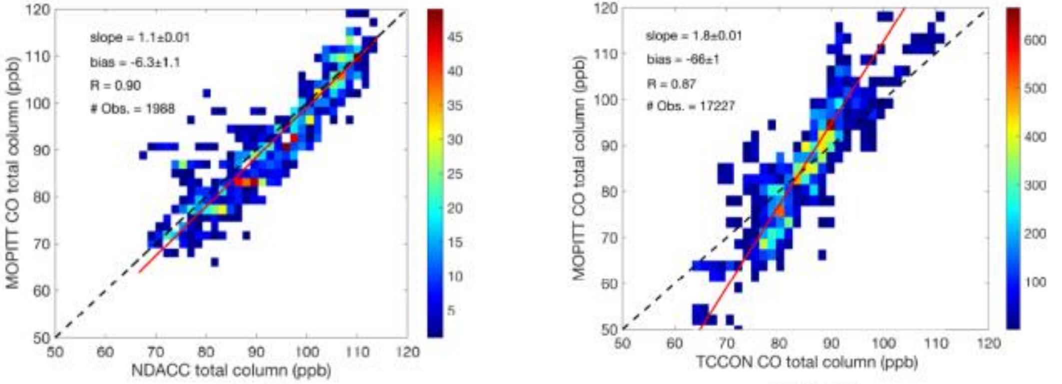
(a) Location

(b) Topography

(c) Daily measurements

(a) Location of PEARL at Eureka. (b) Topography around PEARL. (c) Example of daily MOPITT CO measurements near Eureka on 20 July 2007 within 110 km radius.

➡ Sample correlation plots for MOPITT TIR pixel 2 CO over land versus PEARL (a) NDACC and (b) TCCON measurements. The colors indicate the number of points in each bin to represent the density of points.

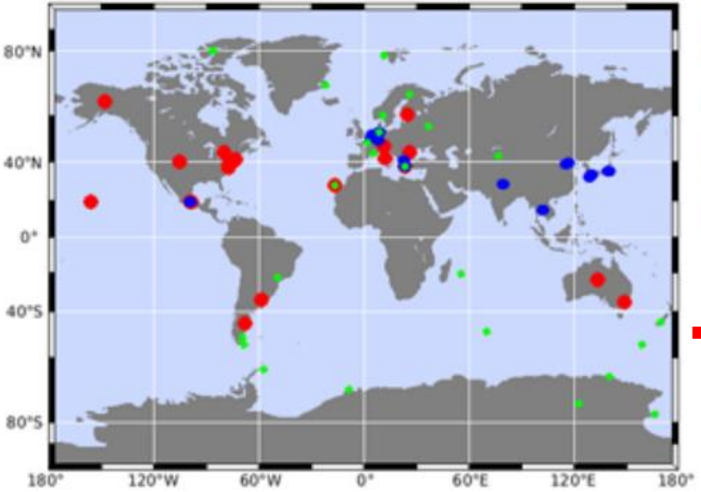


(a) NDACC

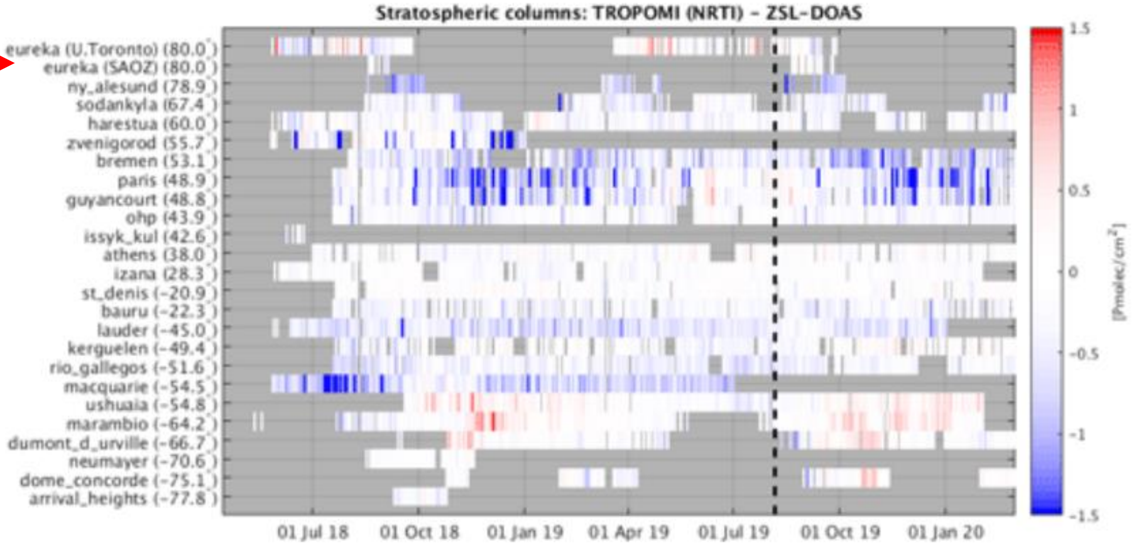
(b) TCCON

Ali Jalali et al., A comparison of carbon monoxide retrievals between the MOPITT satellite and Canadian High-Arctic ground-based NDACC and TCCON FTIR measurements, *Atmos. Meas. Tech. Discuss.* https://doi.org/10.5194/amt-2022-68, in review, 2022. Also: Hedelius et al., Evaluation of MOPITT Version 7 joint TIR–NIR XCO retrievals with TCCON, AMT 2019, and Buchholz et al., Validation of MOPITT carbon monoxide using ground-based Fourier transform infrared spectrometer data from NDACC, AMT 2017

TROPOMI NO_2 vs. NDACC UV-VIS



UV-VIS DOAS spectrometers contributing correlative measurements: 26 NDACC ZSL-DOAS instruments in green, 19 MAX-DOAS instruments in blue, and 25 Pandonia Global Network instruments in red

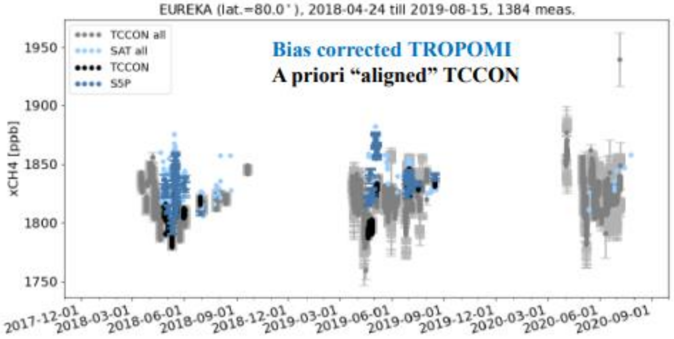


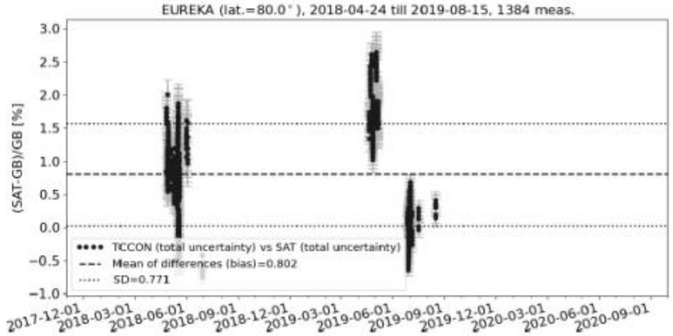
Differences between TROPOMI and NDACC Zenith-Scattered-Light DOAS NO_2 stratospheric columns

Tijl Verhoelst et al., Ground-based validation of the Copernicus Sentinel-5P TROPOMI NO_2 measurements with the NDACC ZSL-DOAS, MAX-DOAS and Pandonia global networks, *Atmos. Meas. Tech.*, **14**, 481–510, 2021. https://doi.org/10.5194/amt-14-481-2021

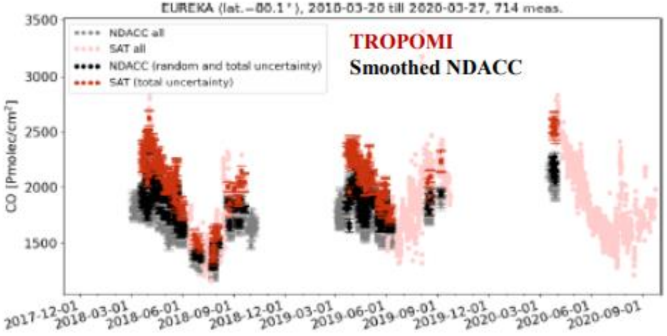
TROPOMI XCH_4 & XCO vs. FTIR

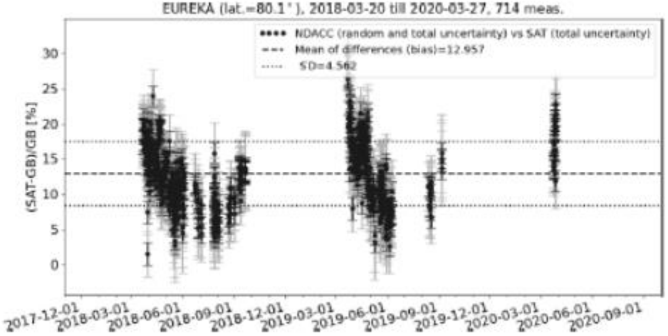
S5P-TROPOMI RemoTeC-S5P algorithm vs. Eureka-PEARL TCCON XCH_4





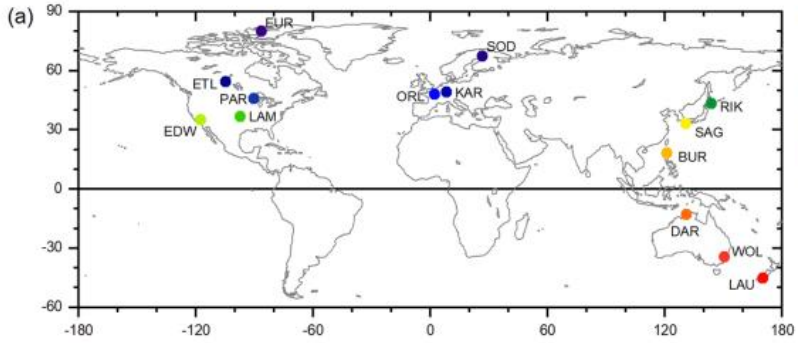
S5P-TROPOMI SICOR vs. Eureka-PEARL NDACC total column CO



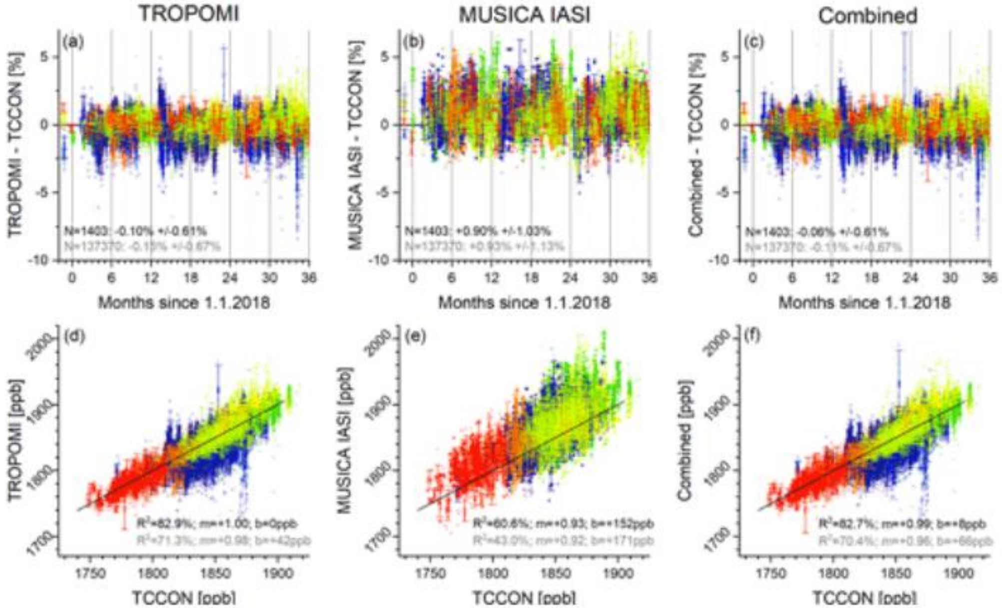


Mahesh Sha et al., Validation of methane and carbon monoxide from Sentinel-5 Precursor using TCCON and NDACC-IRWG stations, *Atmos. Meas. Tech.*, **14**, 6249-6304, 2021. https://doi.org/10.5194/amt-14-6249-2021

TROPOMI & IASI XCH_4 vs. TCCON



14 TCCON stations providing validation measurements to this study, including East Trout Lake and Eureka (PEARL).

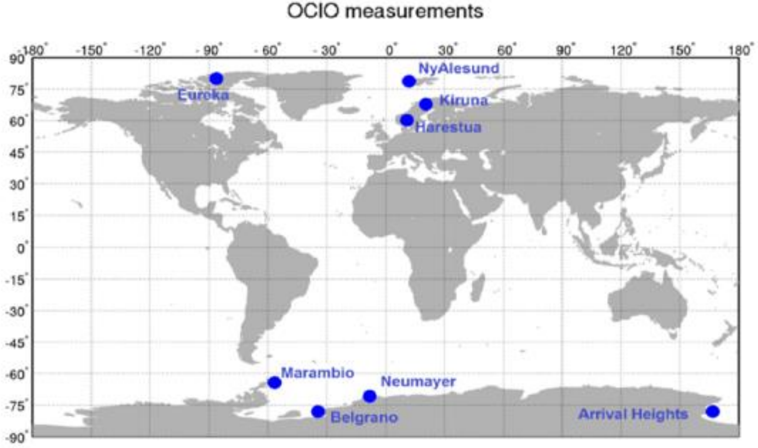


(a–c) Time series of the differences

(d–f) Correlations between TCCON and satellite data

Matthias Schneider et al., Synergetic use of IASI profile and TROPOMI total-column level 2 methane retrieval products. *Atmos. Meas. Tech.*, **15**, 4339-4371, 2022. https://doi.org/10.5194/amt-15-4339-2022

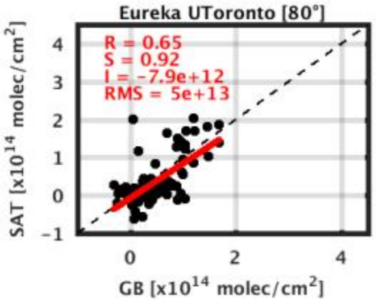
MetOp-A/B GOME-2 OClO vs. UV-VIS

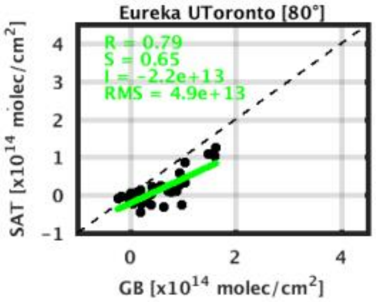


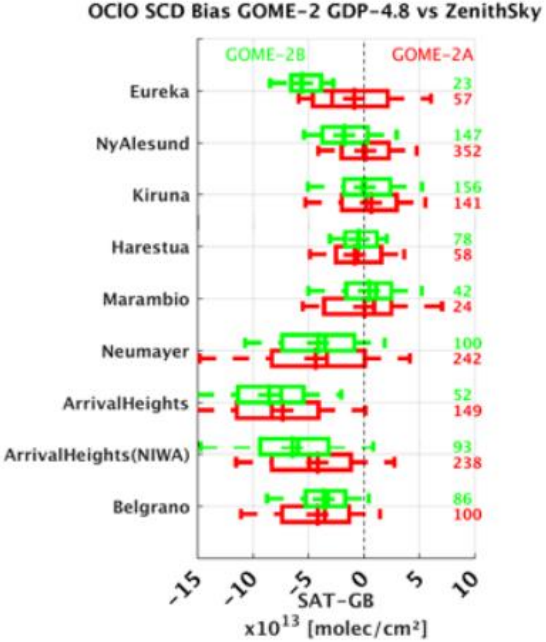
NDACC UV-VIS Zenith-Sky DOAS instruments providing correlative OClO measurements, including Eureka (PEARL)

GOME-2A (red) and GOME-2B (green) correlations for Eureka.

Box and whisker plot of GOME-2 vs. UV-VIS OClO slant columns





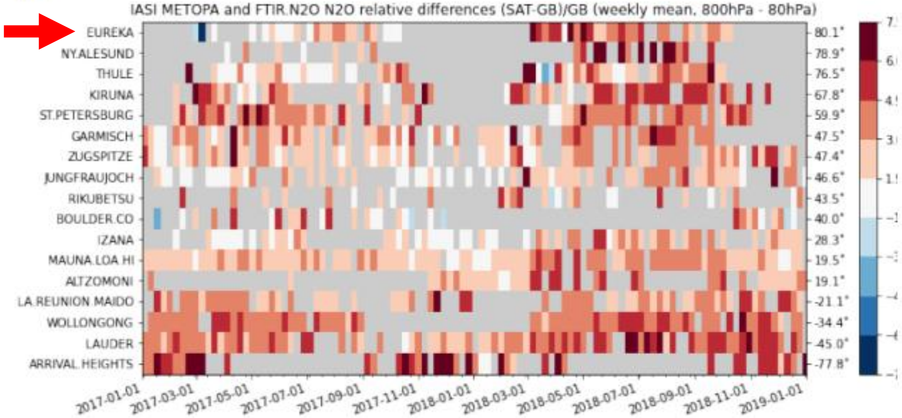


Gaia Pinardi et al., Ground-based validation of the MetOp-A and MetOp-B GOME-2 OClO measurements. *Atmos. Meas. Tech.*, **15**, 3439-3463, 2022. https://doi.org/10.5194/amt-15-3439-2022

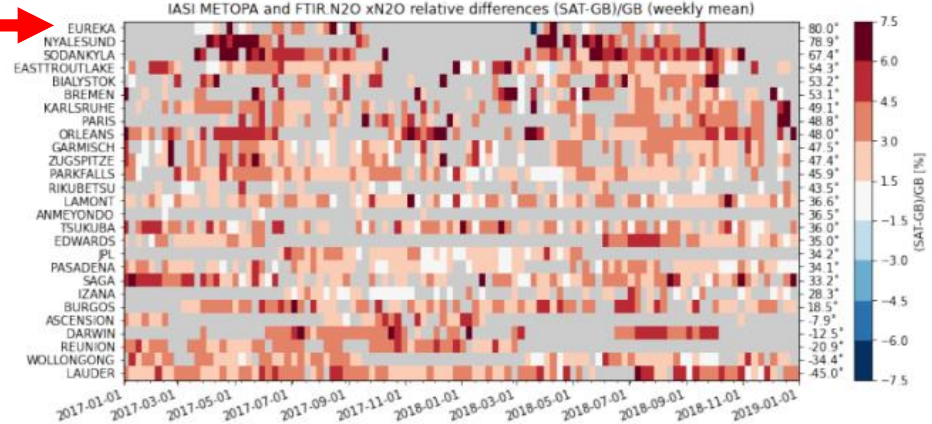
IASI N_2O vs. NDACC and TCCON

Relative bias of IASI N_2O at (a) NDACC and (b) TCCON stations: weekly average for the years 2017 and 2018.
Eureka (PEARL) contributes data to both networks.

(a)

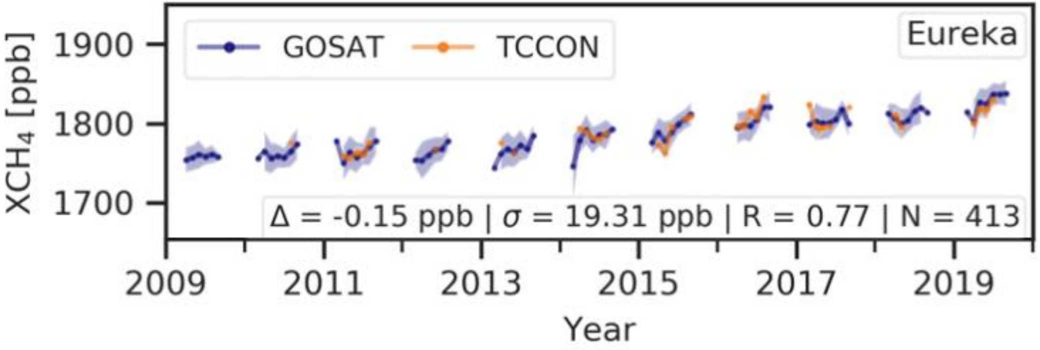


(b)



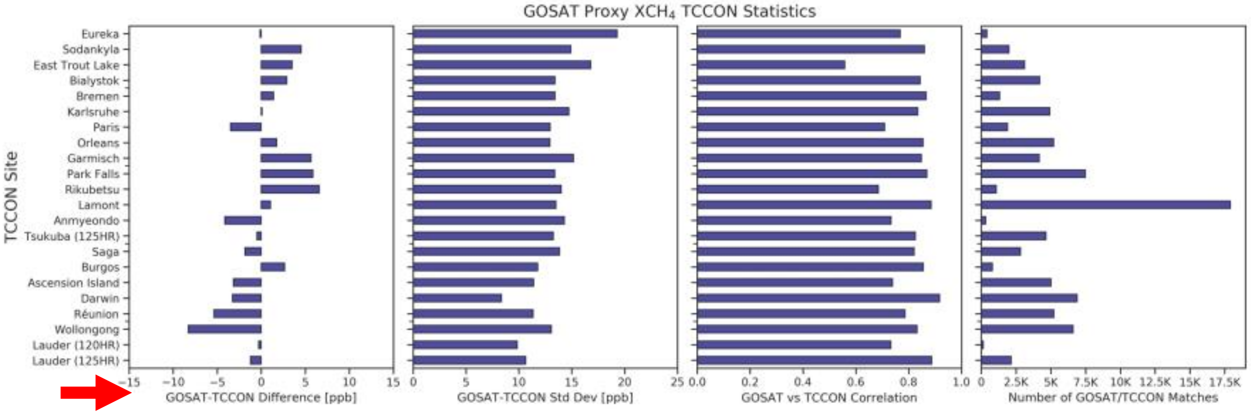
Sophie Vandenbussche et al., Nitrous Oxide Profiling from Infrared Radiances (NOPIR): Algorithm Description, Application to 10 Years of IASI Observations and Quality Assessment. *Remote Sensing*, **14**, 1810, 2022. https://doi.org/10.3390/rs14081810

GOSAT XCH_4 vs. TCCON



Time series for University of Leicester GOSAT Proxy GOSAT XCH_4 product and TCCON. Statistics are same as in panels below.

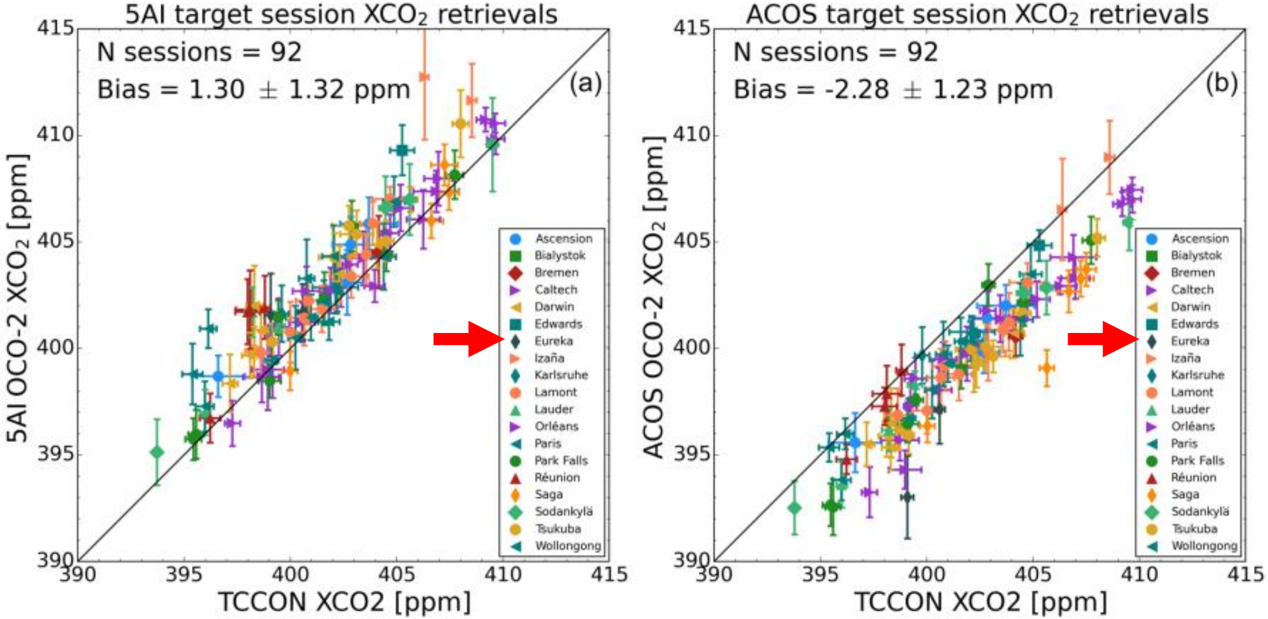
Panels show GOSAT–TCCON difference, GOSAT–TCCON standard deviation, correlation coefficient, and number of co-locations.



Robert J. Parker et al., A decade of GOSAT Proxy satellite CH_4 observations. *Earth Syst. Sci. Data*, **12**, 3383-3412, 2020.
https://doi.org/10.5194/essd-12-3383-2020

OCO-2 XCO_2 vs. TCCON

OCO-2 target retrieval results compared to the TCCON official product (including Eureka-PEARL): (a) 5AI and (b) raw ACOS B8r OCO-2 retrieval algorithms



Matthieu Dogniaux et al., The Adaptable 4A Inversion (5AI): description and first XCO_2 retrievals from Orbiting Carbon Observatory-2 (OCO-2) observations, *Atmos. Meas. Tech.*, **14**, 4689-4706, 2021. https://doi.org/10.5194/amt-14-4689-2021

Concluding Thoughts

- Measurements at PEARL have contributed to validation of 15 satellite instruments since the first springtime ACE validation campaign in 2004
- PEARL instruments are affiliated with multiple international networks involved in satellite validation, including NDACC, TCCON, AERONET, Pandonia, and MPLNet
- PEARL is one of very few Arctic stations able to provide correlative data in the high Arctic, a region where such measurements are particularly important given the challenges for satellite retrievals
- New missions are being proposed and planned in Canada and elsewhere, e.g., HAWC on AOS, AOM, CASS
- PEARL will not be available to support Arctic validation of current and new missions unless new funding is found very soon
- Stable and predictable support is essential for maintaining expertise and operations
  - This includes avoiding the assumption that "someone else will pay for it"
- **Closure of PEARL is imminent without new funding**

Canadian Space Agency

Agence spatiale canadienne