Infrared Emission Measurements of Trace Gases and Clouds in the High Arctic based on the Extended-range Atmospheric Emitted Radiance Interferometer (E-AERI)

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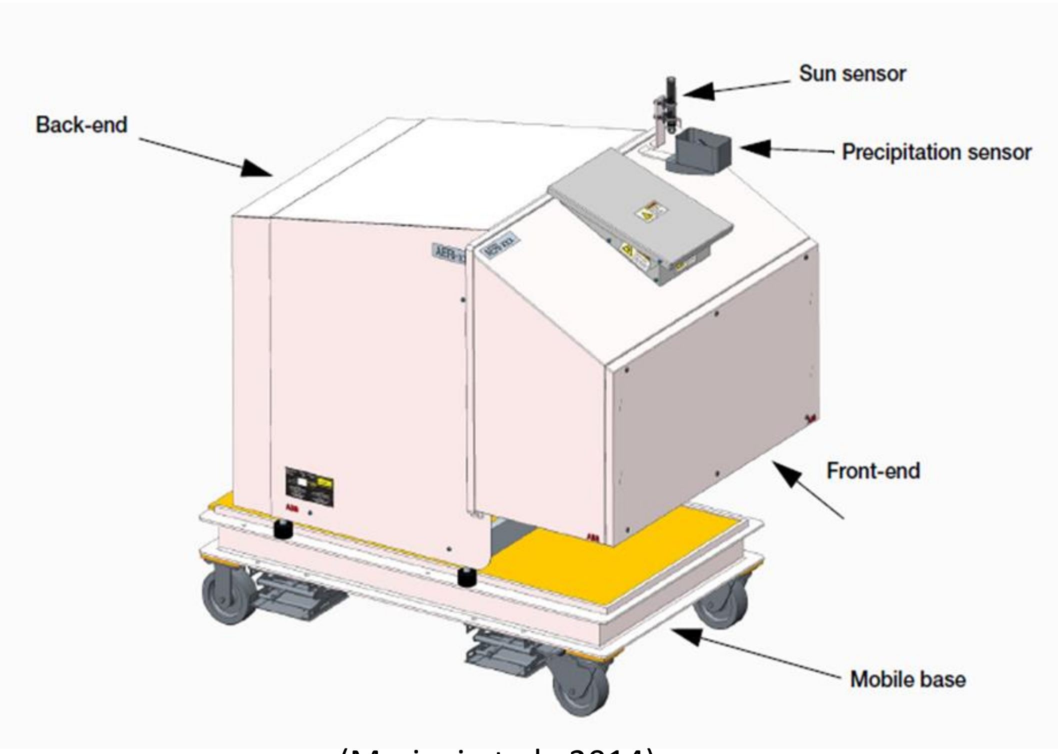
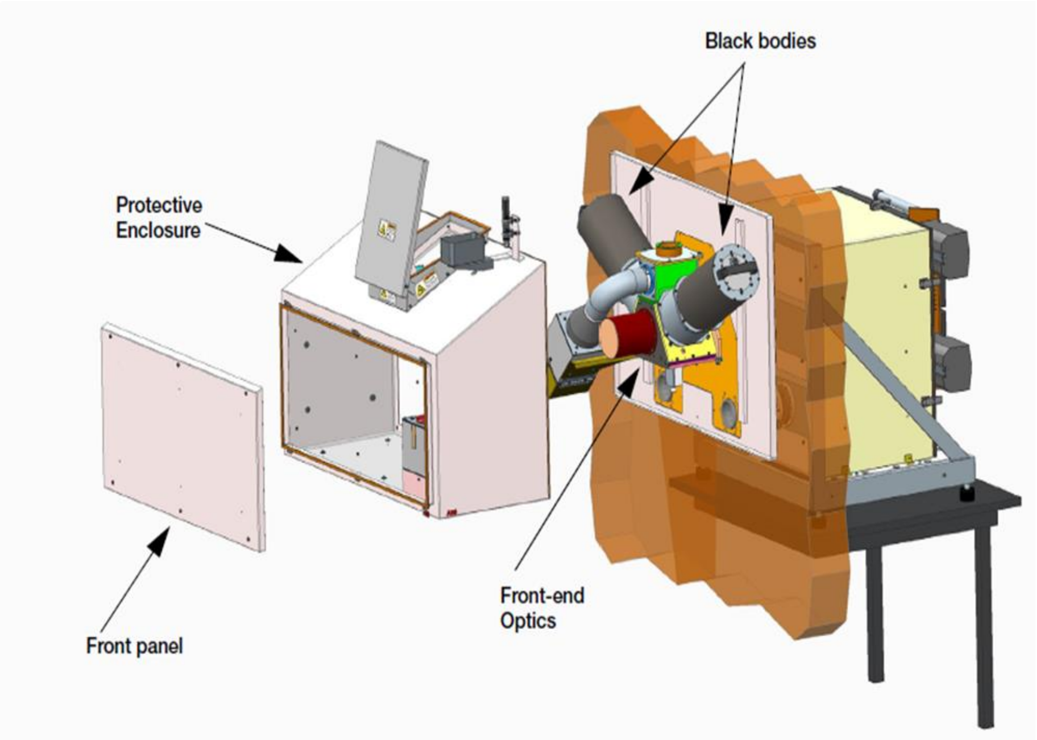
The Extended-Range Atmospheric Emitted Radiance Interferometer (E-AERI)



(Mariani et al., 2014)

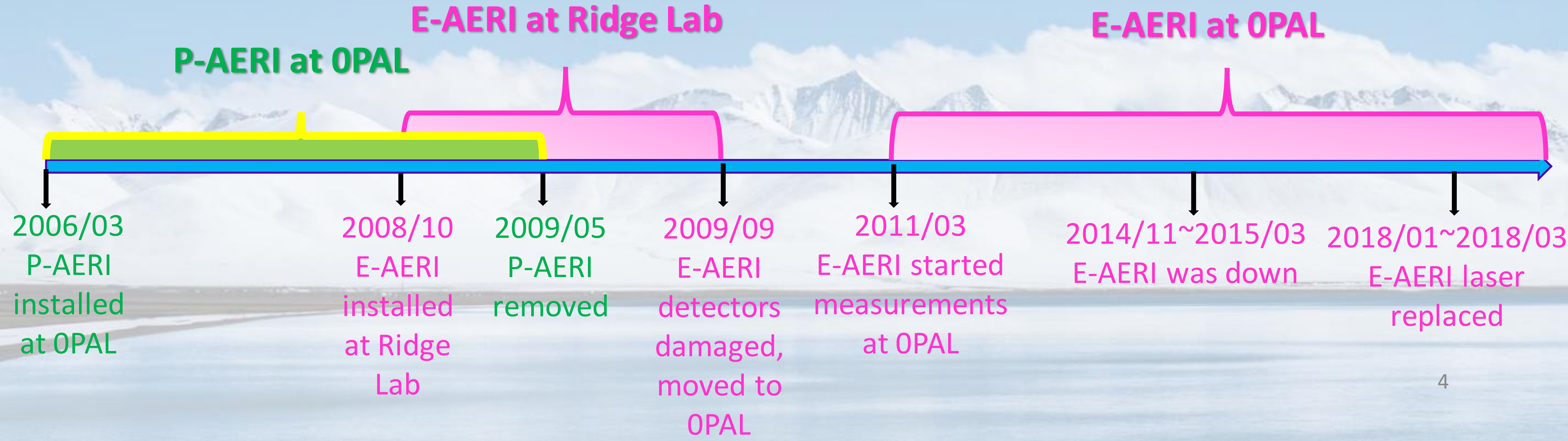


(ABB Bomem)

- ❖ Developed by the University of Wisconsin Space Science and Engineering Centre (UW-SSEC); Manufactured by ABB Bomem (Quebec).
- ❖ Measures accurately calibrated downwelling infrared thermal emission from the atmosphere over region of the infrared spectrum at spectral resolution of 1 cm^{-1}. <u>radiative balance</u> <u>trace gases</u> <u>clouds properties.</u>
- ❖ The E-AERI extends the spectral coverage range of a standard AERI (520-3000 cm^{-1}) to 400-3000 cm^{-1} (3-25 μm). This spectral range includes the “dirty window” (around 400 cm^{-1}, or 25 μm), where much of the infrared cooling occurs due to the dryness of air in the Arctic.
- ❖ Spectra are recorded every 7 min, 24 hours a day, 365 days a year (precipitation permitting), independent of sunlight.

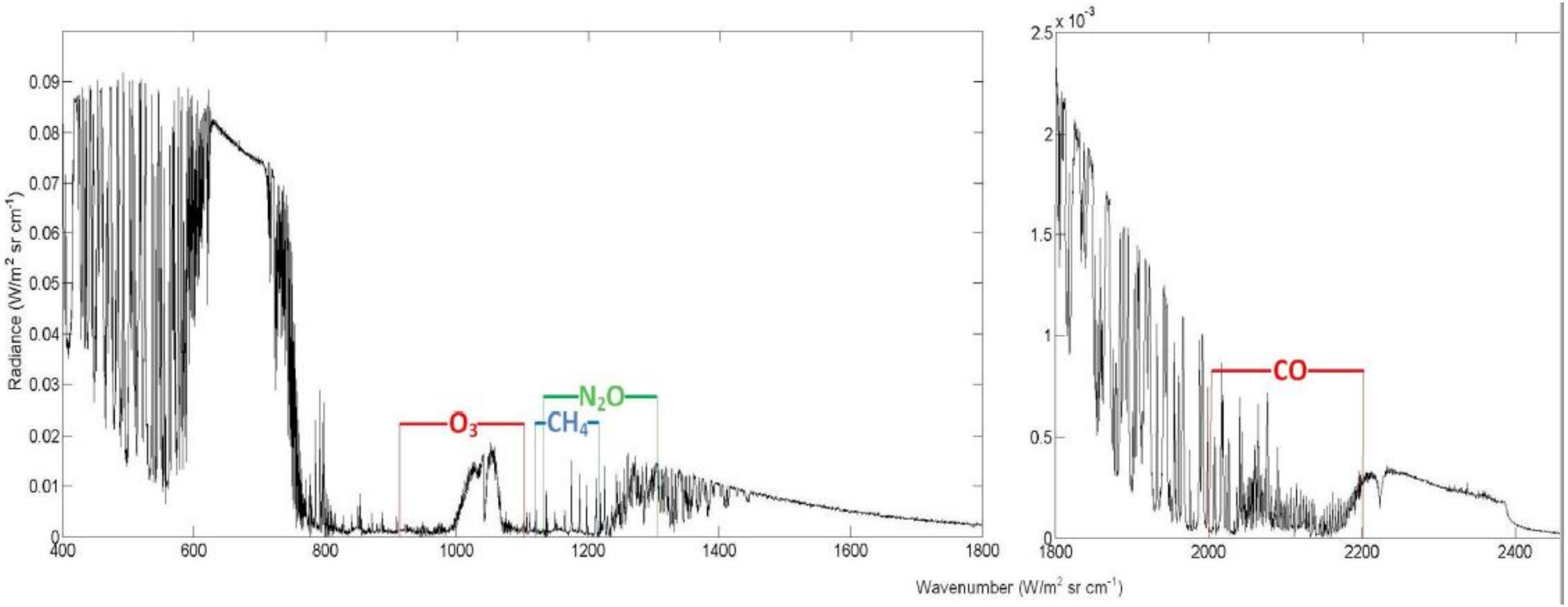
E-AERI Data Sets @ PEARL

- The E-AERI was Initially installed and took measurements at the PEARL Ridge Lab (610 m a.s.l.) between October 2008 and September 2009.
- From March 2011 onwards, the instrument has been at the Zero Altitude PEARL Auxilary Laboratory (0PAL) (10 m a.s.l.), 15 km away from the Ridge Lab.
- P-AERI = Polar AERI (Von Walden, deployed by NOAA's SEARCH program)



E-AERI Trace Gas Retrieval Technique

- The Arctic experiences prolonged periods of total darkness in the winter and continuous daylight in the summer, influencing its atmosphere and composition in ways that are still not fully understood.
- Solar absorption FTIR measurements have improved knowledge of the atmospheric composition at Eureka but are limited to 8 months when the sun is up.
- The AERI is sensitive to tropospheric trace gases and measurements are independent of sunlight.
- Mariani et al. (2013) implemented the retrieval of carbon monoxide, ozone, methane and nitrous oxide using AERI emitted radiance spectra.

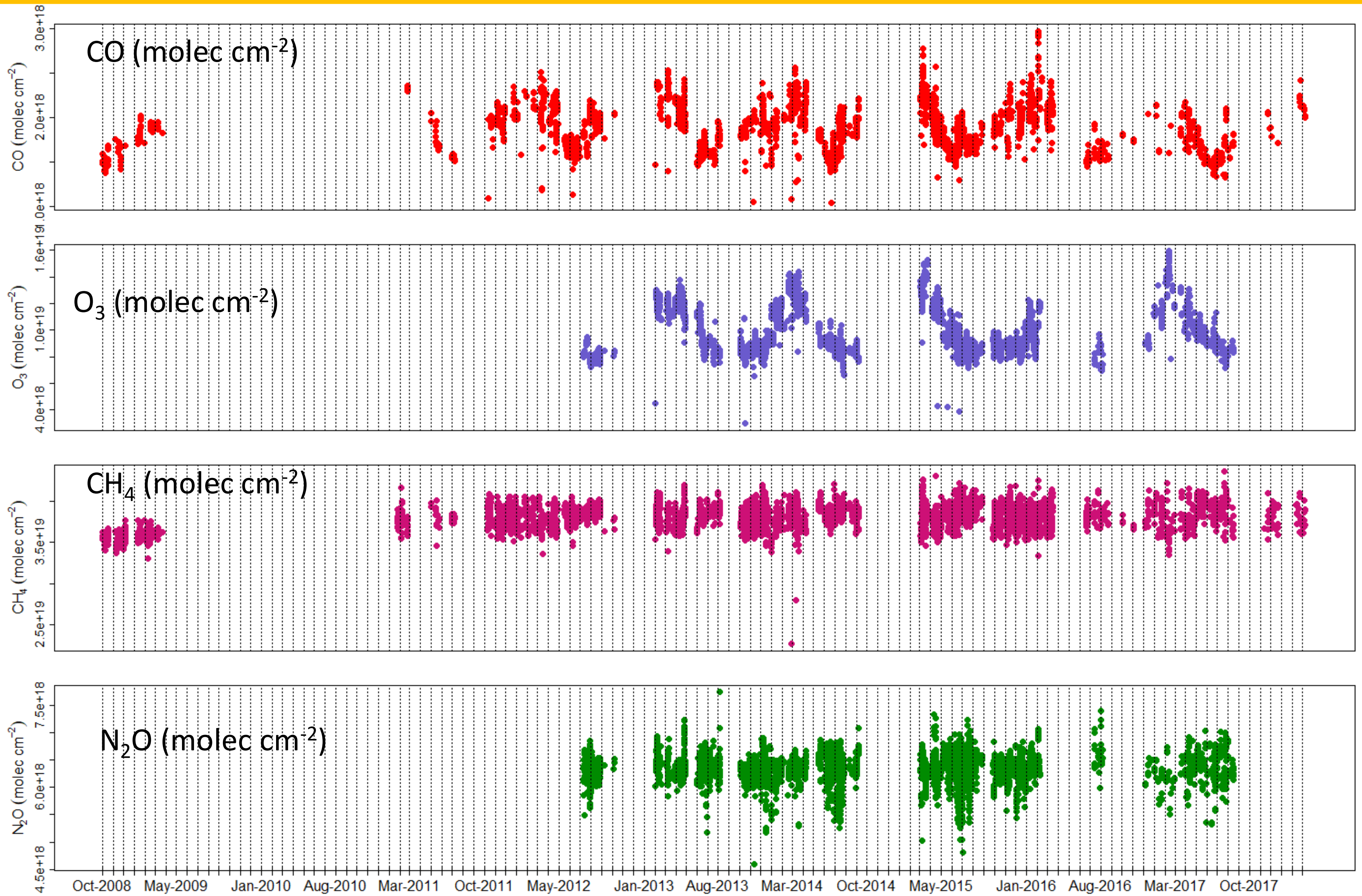


Retrieval Windows, Mariani et al. (2012)

E-AERI Trace Gas Retrieval Technique

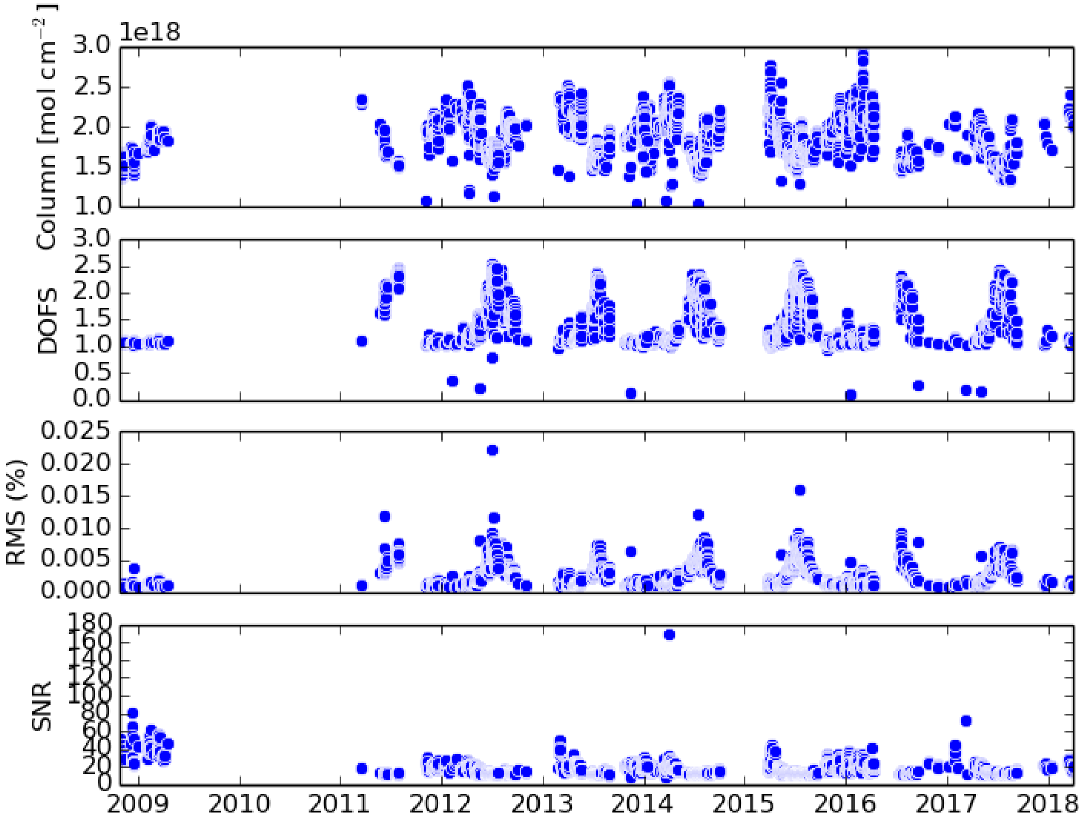
- The retrieval methodology to calculate atmospheric CO, O_3, CH_4 and N_2O total column amounts is based on the Optimal Estimation Method (OEM).
- The retrieval algorithm been upgraded from an SFIT2 add-on module (Mathias Palm, U Bremen) into SFIT4.
- The spectroscopic parameters are taken from the High-Resolution Transmission Molecular Absorption Database (HITRAN 2008).
- The retrieved vertical profiles were obtained on a 39-level altitude grid (from 0.01 to 100 km) for 0PAL measurements and on a 38-level altitude grid (from 0.61 to 100 km) for Ridge Lab measurements.
- Daily profiles of pressure and temperature were obtained from a combination of two daily launches of radiosondes at Eureka (0-35km), the National Centre for Environmental Prediction (NCEP) analyses (35-50 km), and the 1976 US Standard Atmosphere for the information above 50 km.

Trace Gas Analysis – Time Series

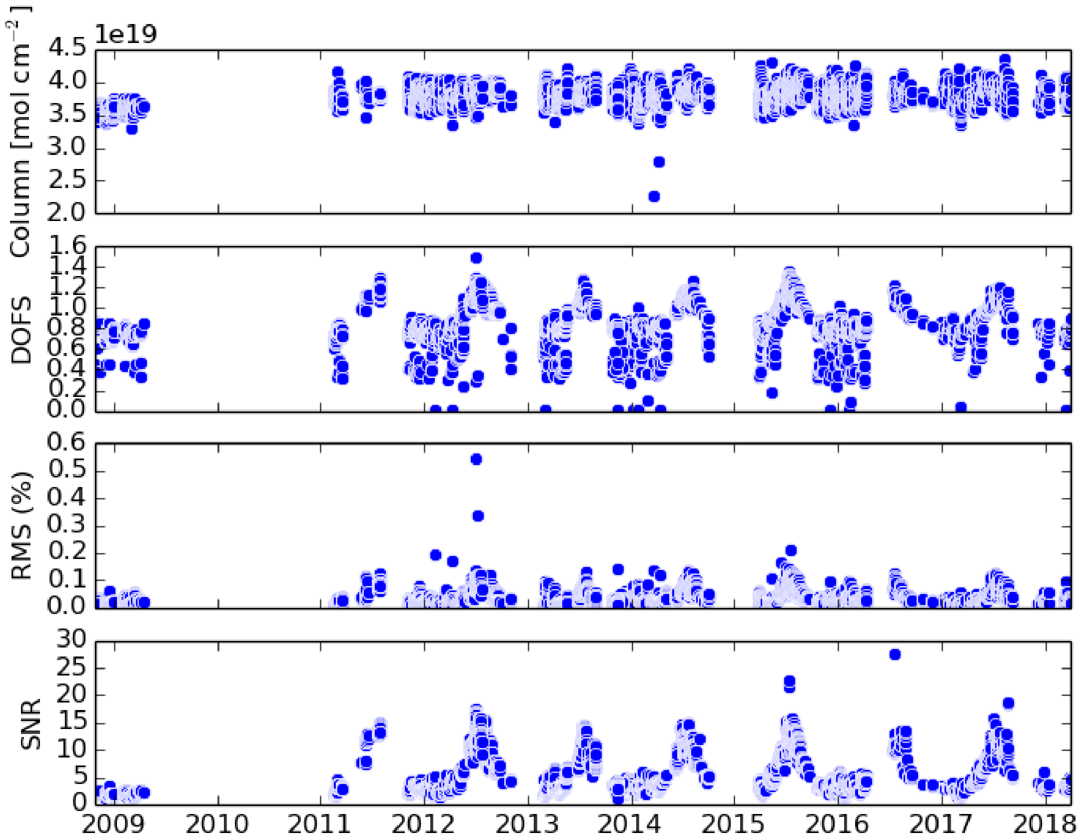


Trace Gas Analysis – Time Series

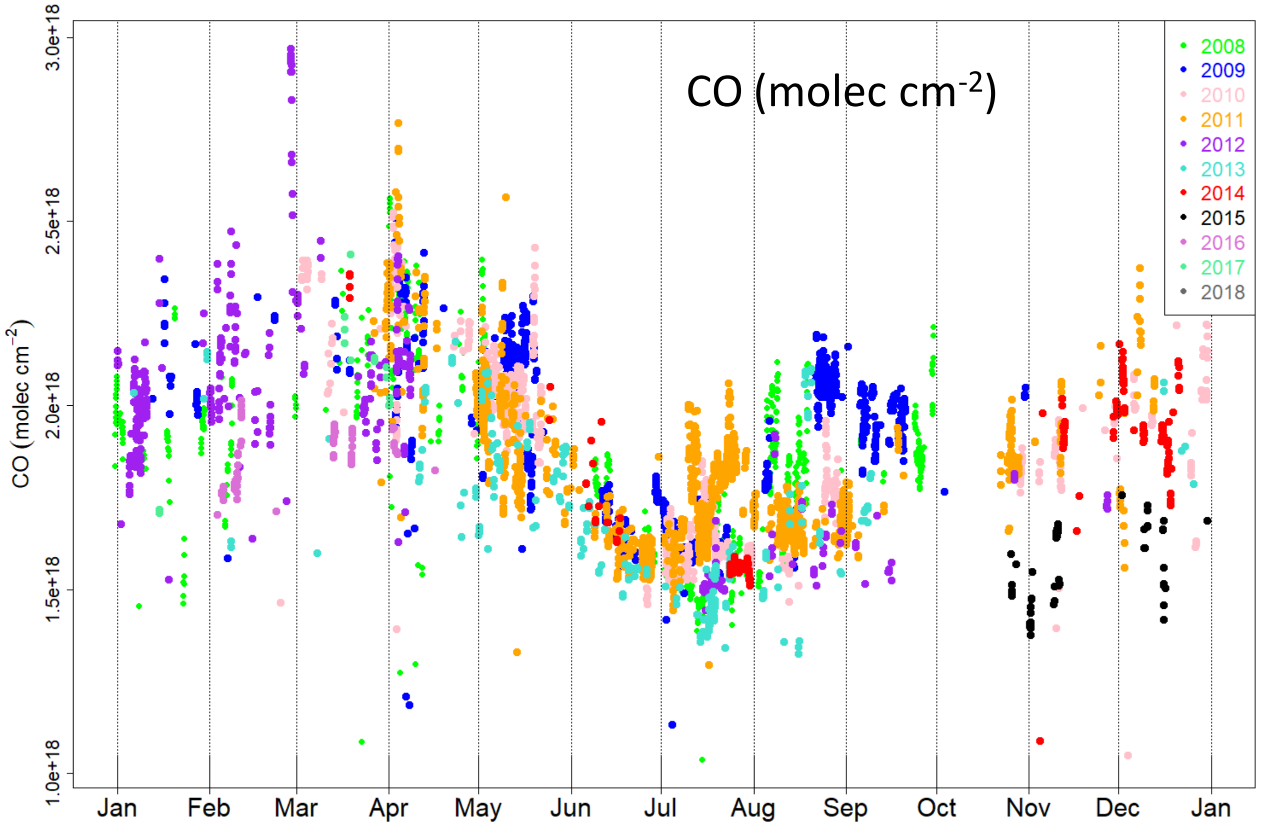
CO

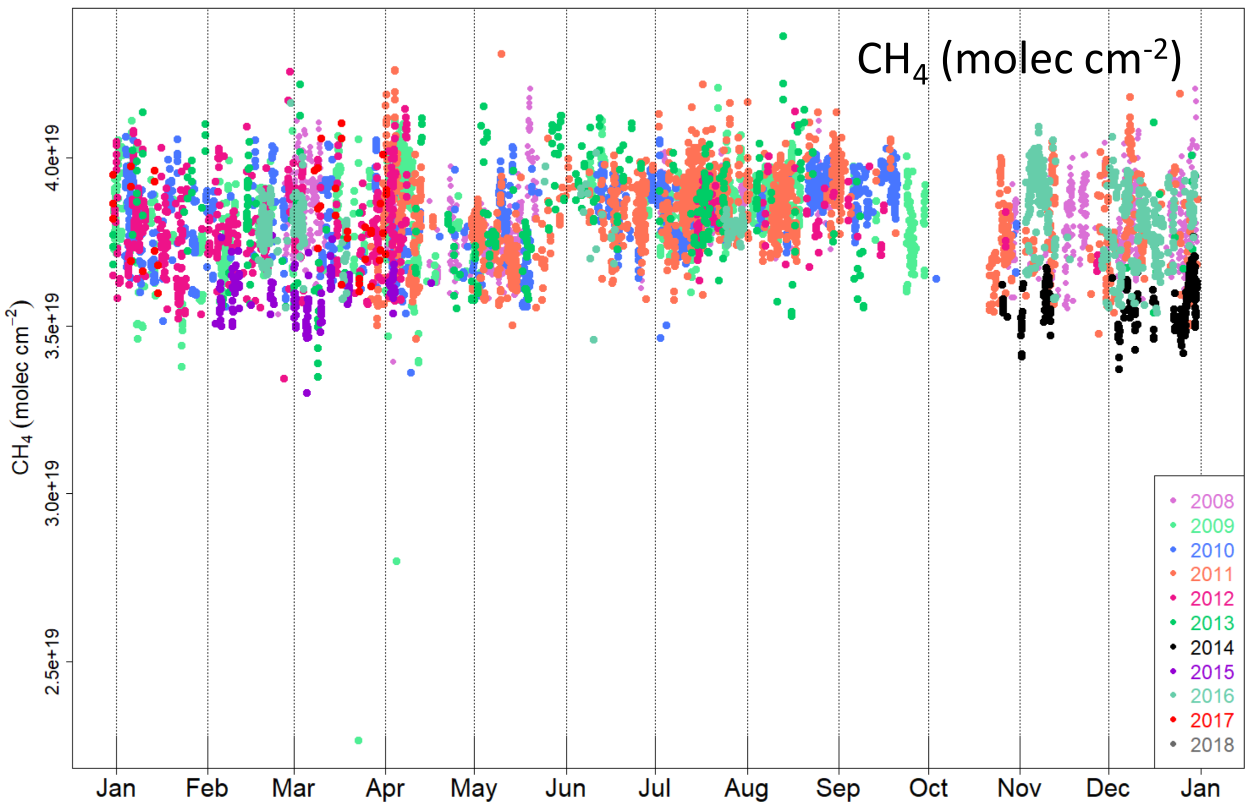


CH4



Trace Gas Analysis – Seasonal Cycle

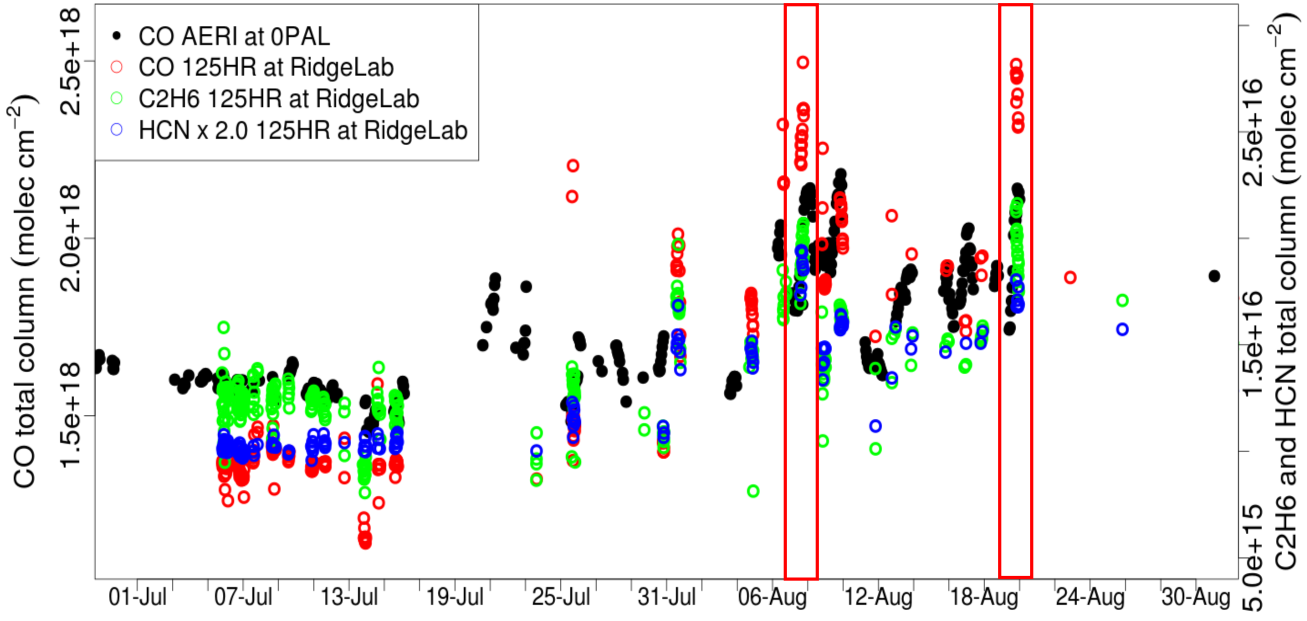


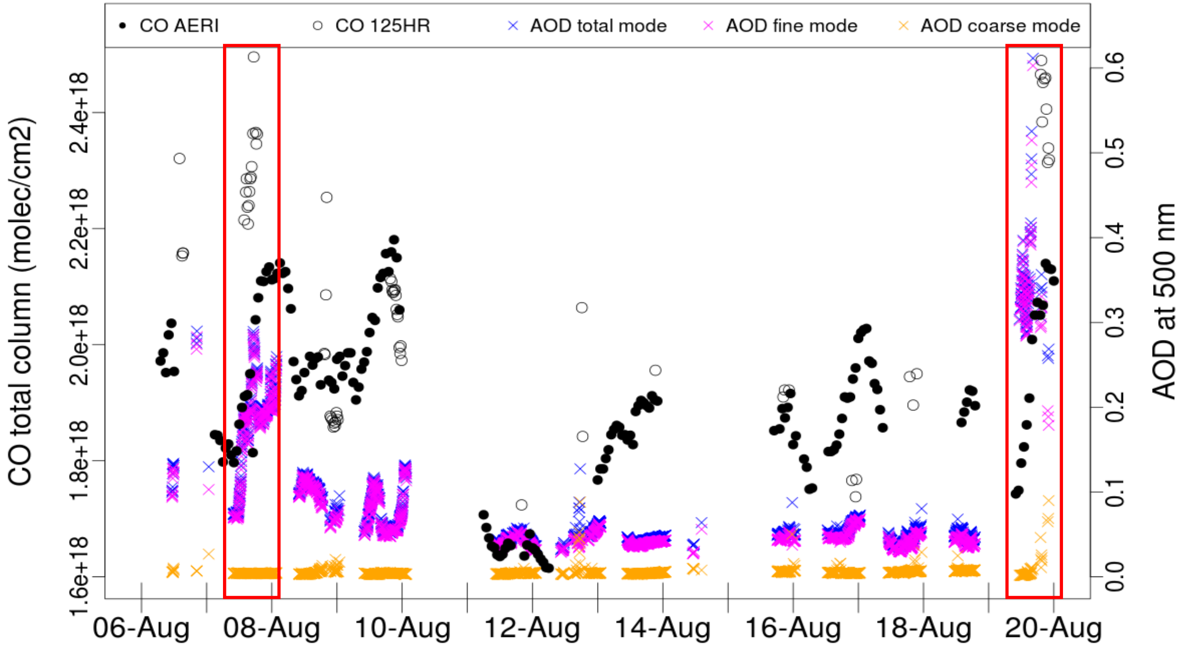


- The seasonal cycle of CO has a maximum in March and decreases from May to August primarily due to reaction with OH in summer.
- Transport of biomass burning plumes and industrial emissions from lower latitudes to the Arctic during the winter also contributes to variations in the CO total column densities while CO is accumulating in the absence of OH oxidation.
- CO enhancement in August and September is probably due to biomass burning events.

Trace Gas Analysis – CO and Biomass Burning Events in 2014

- Looking at biomass burning tracers such as CO from the AERI and 125HR FTIR, as well as ethane and HCN from the 125HR, two major biomass burning events have been identified: August 7 and August 19.
- Simultaneous enhancements of these three main gas indicate fire events.
- Aerosol optical depth (AOD) at 500 nm shows the same enhancement.
- Fine-mode AOD enhancements suggest smoke plumes over Eureka.

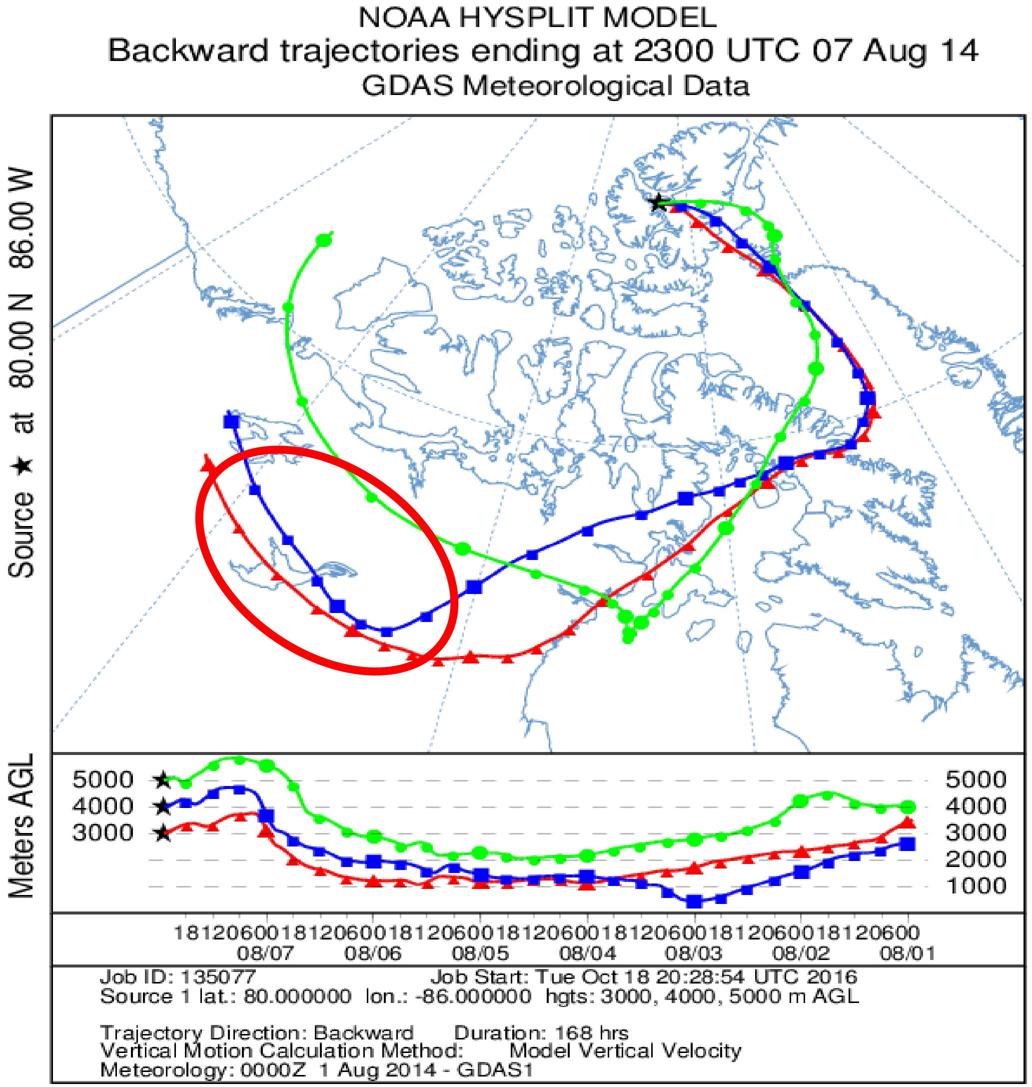




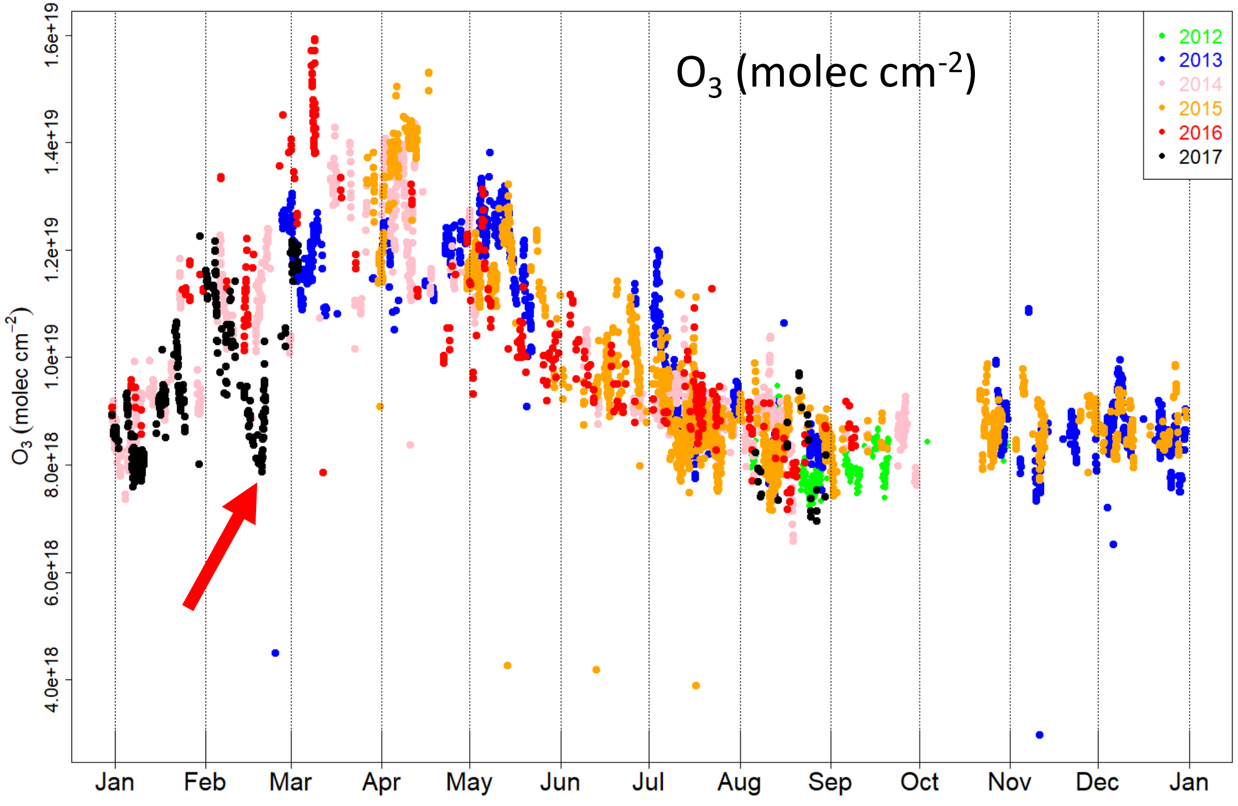
Trace Gas Retrievals – CO and Biomass Burning Events in 2014

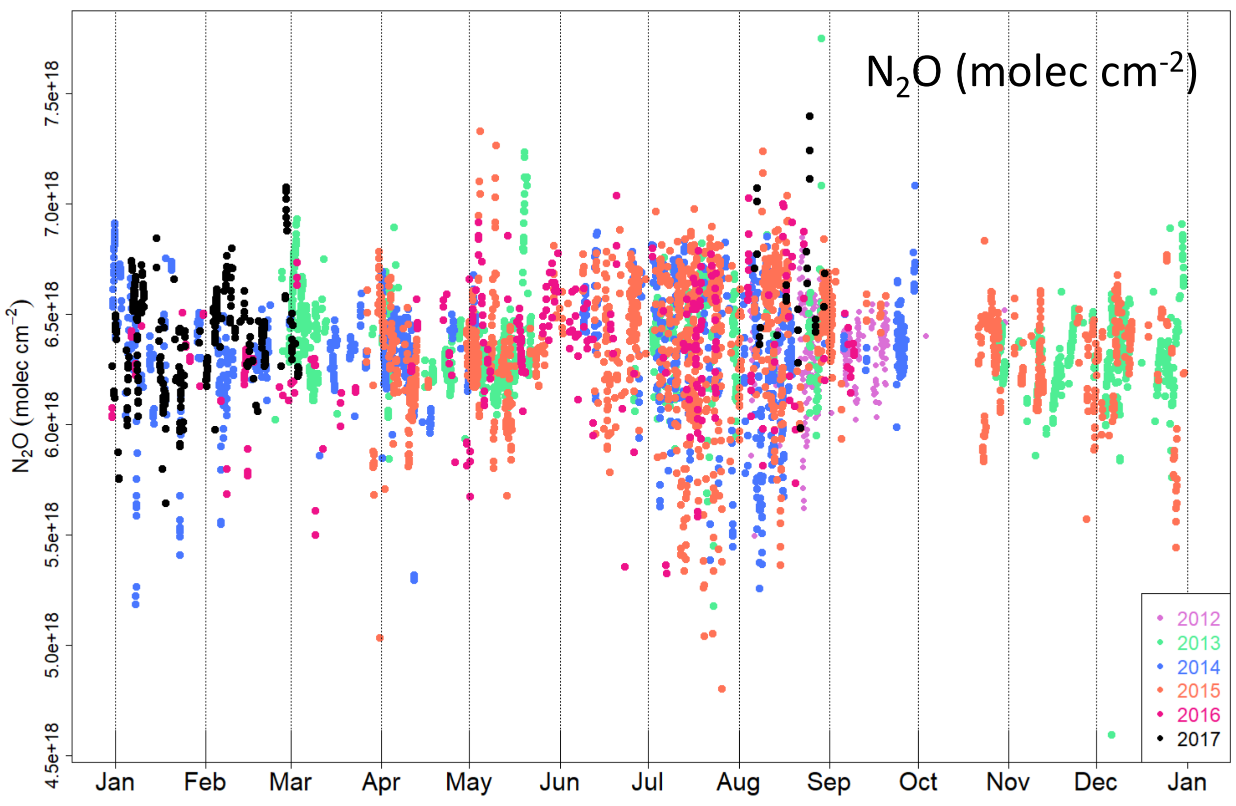
Major biomass burning events have been identified in August 2014 with back-trajectories.

August 07, 2014



Trace Gas Analysis – Seasonal Cycle





- Ozone has a strong seasonal cycle with a maximum in spring and a minimum in late summer and fall due to a combination of transport and photochemistry
- Stratospheric ozone loss occurred in February and March 2017
  - February data are during the polar night, before the solar-pointing 125HR FTIR is operational.

E-AERI Trace Gas Research – Future Work

- Examine diurnal and seasonal cycles of CO, CH_4, N_2O, and O_3 during the ten years, with emphasis on measurements during polar night.

- Perform case study of E-AERI trace gas measurements detected during biomass burning events.

- Investigate ozone depletion events and ozone enhancement events.

- Comparison between the trace gas results with SFIT2, SFIT4, and updated SFIT4 (Mathias Palm) retrieval algorithms.

E-AERI Cloud Research – Introduction

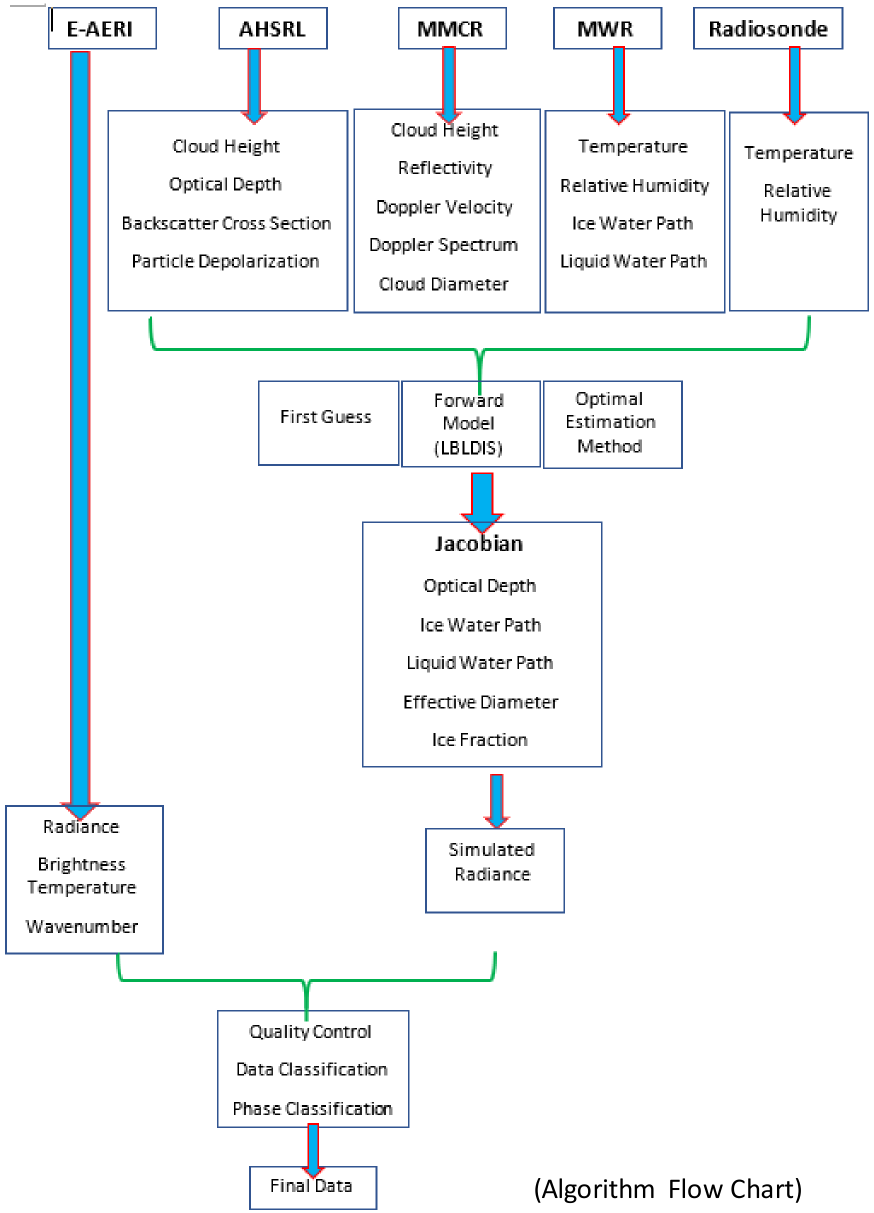
- Clouds play an important role in energy balance of the Earth because clouds both scatter and absorb solar and infrared radiation.

- The amount of scattering and absorption depends on the thermodynamic phase, size, shape, and density of the cloud particles. Microphysical properties are critical component in cloud modeling.

- While there are numerous satellite measurements of radiative fluxes, they do not directly measure surface radiative fluxes, making ground-based measurements critical for determining the effect of clouds on surface fluxes.

- Few ground-based measurements of cloud microphysics exist for the Arctic because measurements are difficult to obtain. The E-AERI, together with ground-based remote sensors including lidars, radar, and microwave radiometers, can provide information about Arctic clouds properties and radiative balance.

E-AERI - Cloud Microphysical Properties



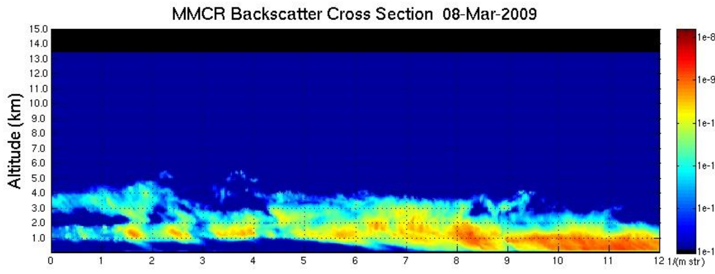
(Algorithm Flow Chart)

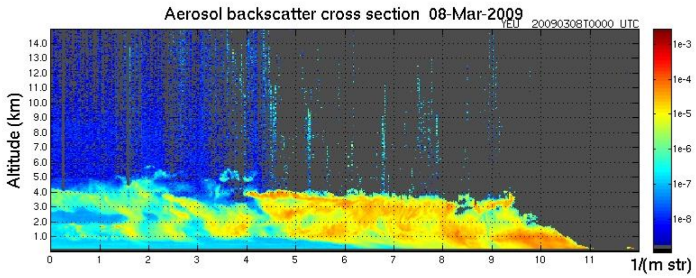
- Retrievals use measurements from the E-AERI, Arctic High Spectral Resolution Lidar (AHSRL), CANDAC Rayleigh-Mie-Raman Lidar (CRL), Millimeter Cloud Radar (MMCR), Microwave Radiometer (MWR), and radiosondes.

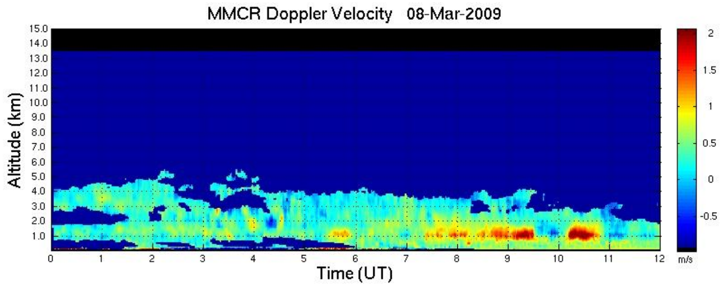
- Needs input information of surface temperature, RH, cloud mask.

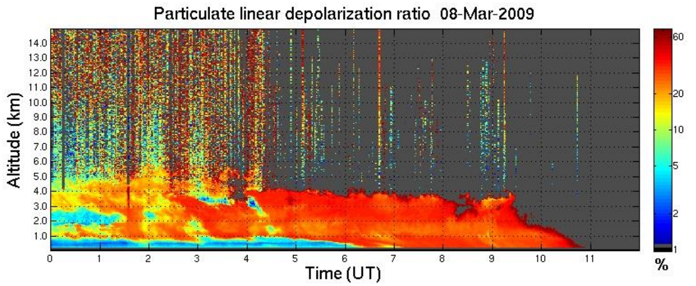
- Using the Line-by-Line Radiative Transfer Model (LBLRTM) & the combined LBLRTM and Discrete Ordinate Radiative Transfer Model (LBLDIS), and the Cloud Atmospheric Retrieval Algorithm (CLARA) to retrieve the Arctic clouds **optical depth, effective radius, ice / water path.**

Status of Data Analysis – Case Study of Cloud Event : March 8, 2009

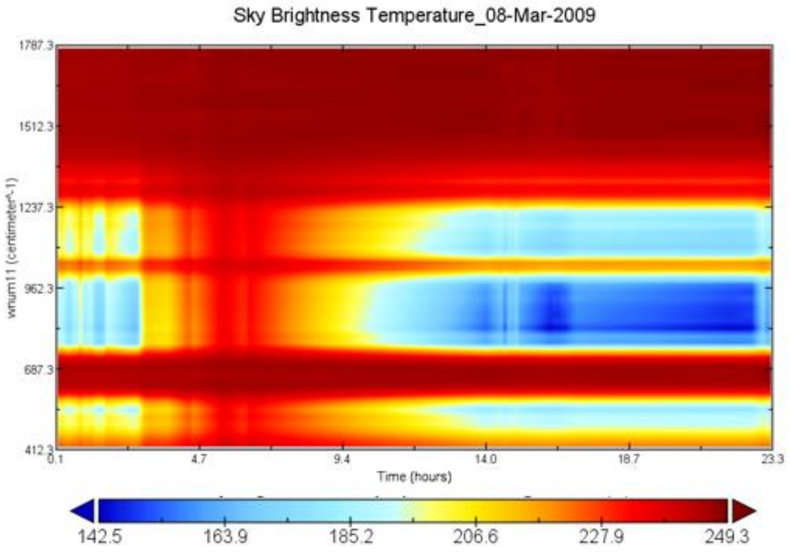




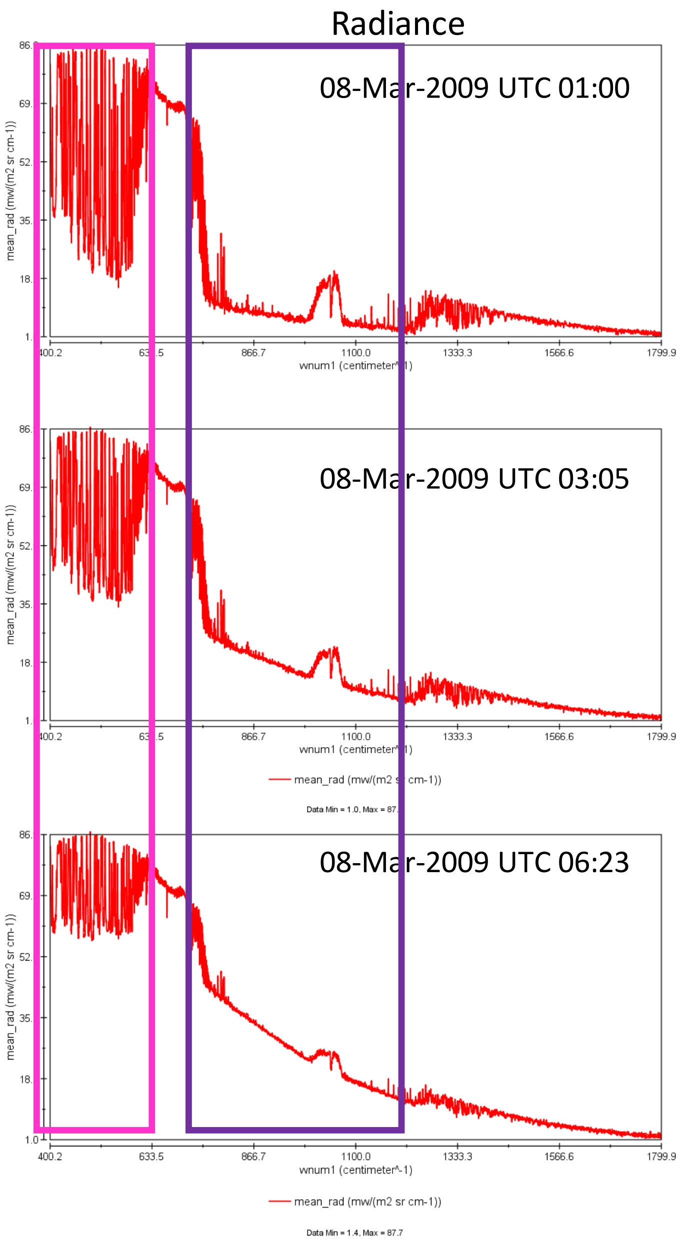




http://hsrl.ssec.wisc.edu/by_site/2/2009/03/08/am/#AHSRL



E-AERI radiance increases after 02:00 UTC in the 400-600 cm^{-1} and 750-1200 cm^{-1} regions due to emission by cloud particles, correlating with the MMCR's detection of a low-altitude cloud that first appeared above Eureka around 02:00 UTC. The brightness T correlates with increased cloud cover above Eureka. The averaged radiance over 750-1200 cm^{-1} increases from 7.4 to 23.6 $mW/(m^2\ sr\ cm^{-1})$.



E-AERI Cloud Research – Future Work

- ❖ Simulate clear-day/cloudy-day radiances using LBLDIS.
- ❖ Retrieve IWP/LWP using EAERI spectrum data.
- ❖ Use CLARA (with Penny Rowe) to run case studies for chosen months and years (MMCR and AHSRL data can provide cloud information), and assess whether this algorithm works well for the E-AERI data.
- ❖ Apply the analysis to the full E-AERI dataset, to examine the trends, monthly distributions, and frequency of occurrence of Arctic clouds and their microphysical properties.
- ❖ Compare E-AERI results with other instruments, such as the Far Infrared Radiometer (FIRR).

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Thanks for your attention!