MW Activities in Canada

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NDACC Microwave Radiometry Workshop
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Overview

- Introduction to SPÉIR instrument and status of its development
- Proposed location for instrument: Eureka, Nunavut
- Observation system simulation experiments for SPÉIR

Where the SPÉIR Story Starts...

- In setting up my research group at University of Toronto, proposed to look improving atmospheric measurement capabilities in Canada
  - Using millimeter-wave radiometry and infrared Fourier transform spectrometry
  - Interests coming from my PhD and postdoctoral work in high resolution microwave spectroscopy and my more recent work with the Atmospheric Chemistry Experiment (ACE) satellite mission

- Obtained funding to develop a millimeter-wave radiometer to make continuous ClO measurements over the Canadian Arctic

SPÉIR Specifications

- Receiver range: 260 – 280 GHz
- Target species: O_3, ClO, HNO_3, N_2O
- Detector: superconducting-insulating-superconducting mixer operating at 4.2 K (using ALMA band 6 SIS; noise T ~60 K)
- 1 GHz bandwidth / 1 MHz resolution (Fast Fourier Transform Spectrometer)
- Ultra-Gaussian horn antennas
- Calibration targets: Ambient and LN_2 cones with rotatable wire grid (for reference beam meas.)

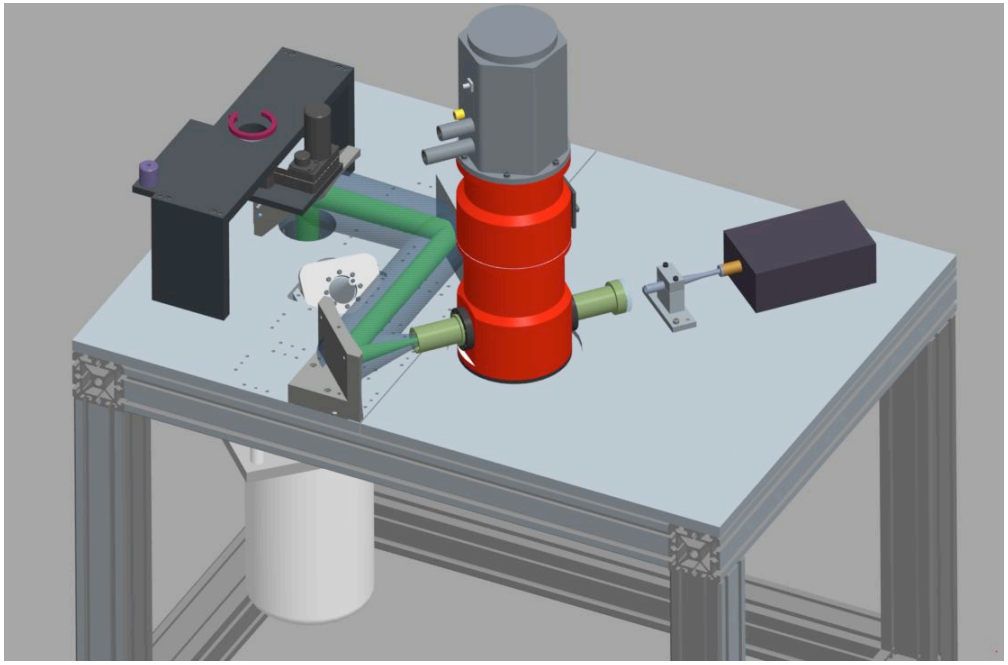
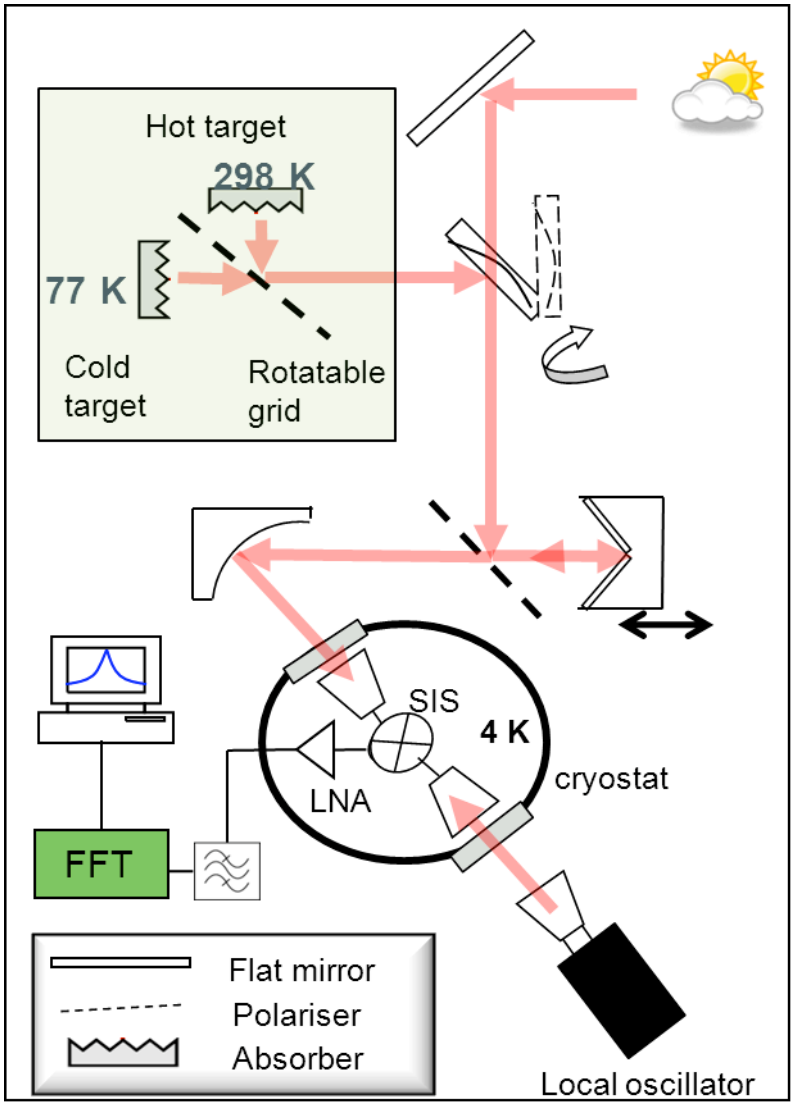
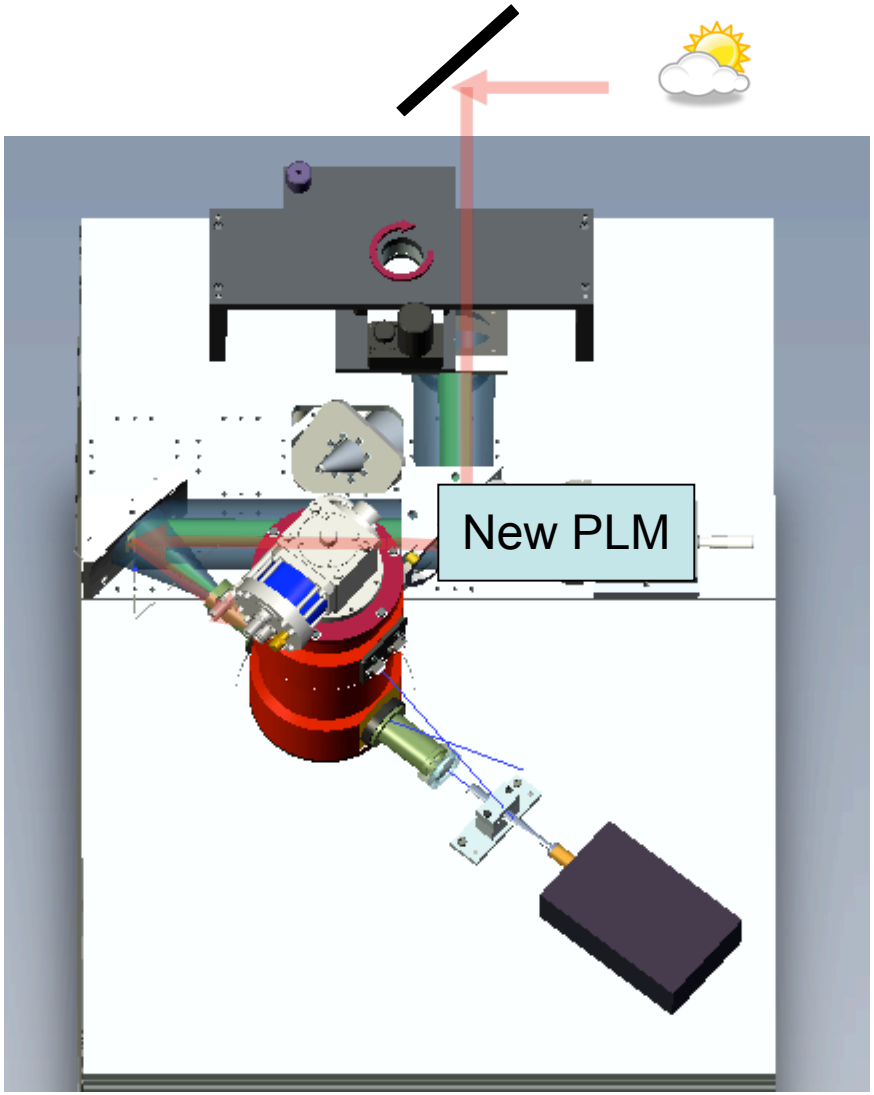


Diagram: Thomas Keating Instruments

Optical Setup for SPÉIR





Diagrams: Niall Ryan and Thomas Keating Instruments

Antenna Mirror Configuration

- Antenna mirror will be mounted outside of laboratory with beam going through wall hatch
- 1º beamwidth on sky
- 180 º range of motion for Tipping curve measurement
- Safety range for mirror to prevent snow accumulation

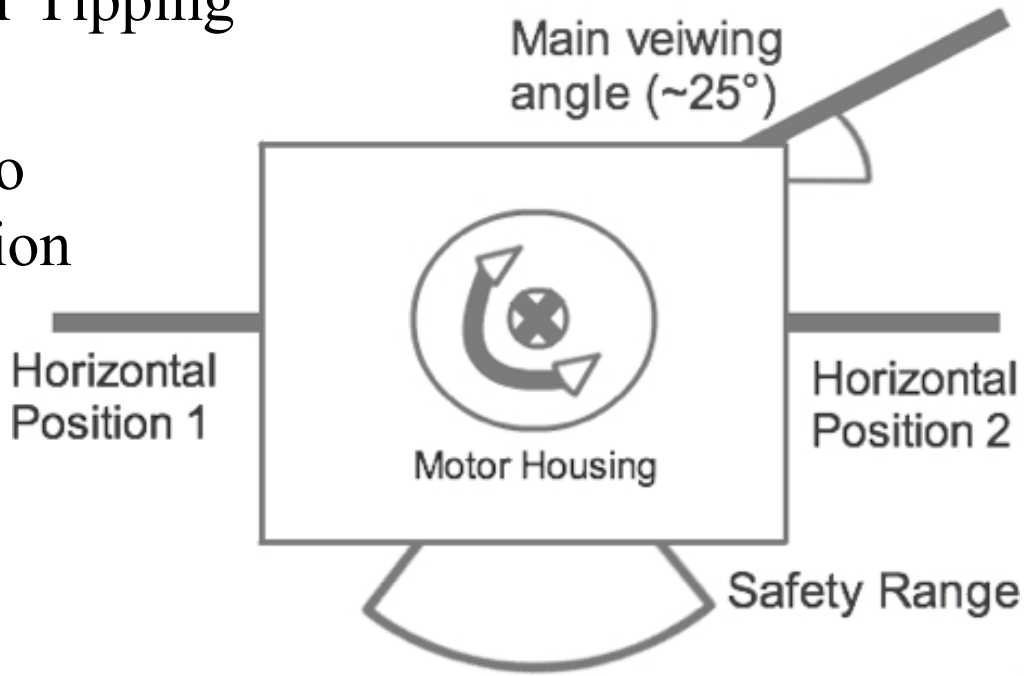


Diagram: Boris Pavlovic

Status of Instrument

- Design work almost completed with Uni. Bern and Thomas Keating Instruments
- Reviewing TK optical design this week (and we welcome input from everyone!)
- With design can proceed with manufacturing with industrial partners and interfacing/programming work continues at UoT

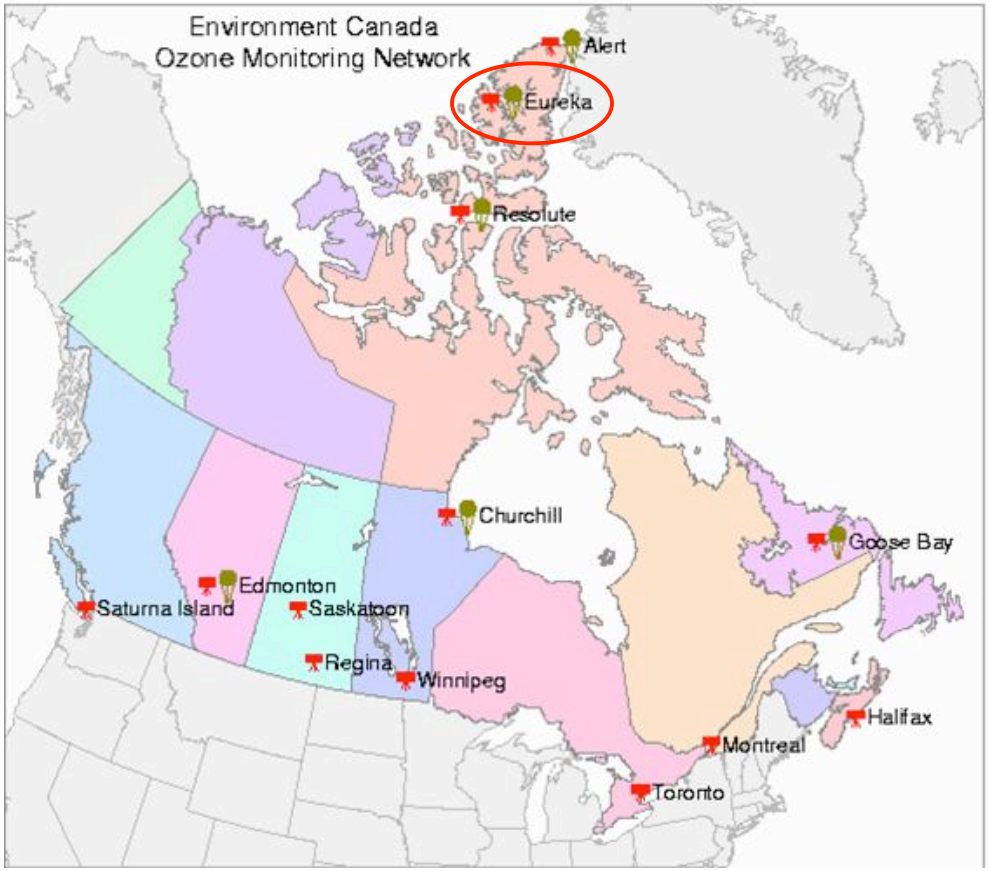
Tentative (optimistic) schedule:

- Instrument ready for testing in one year
- Deployment in Eureka after testing/debugging at UoT for several months prior to shipping

PEARL at Eureka

Polar Environment Atmospheric Research Laboratory (PEARL)

- Formerly Environment Canada's Arctic Stratospheric Ozone (AStrO) Observatory
- Operated by the Canadian Network for Detection of Atmospheric Change (CANDAC) since Aug. 2005
- ~25 experiments at 3 facilities to characterize the atmosphere from 0-100 km



- On Ellesmere Island, Nunavut (80ºN, 86ºW)
  - 15 km from Env. Canada's Eureka Weather Station
  - 1100 km from North Pole

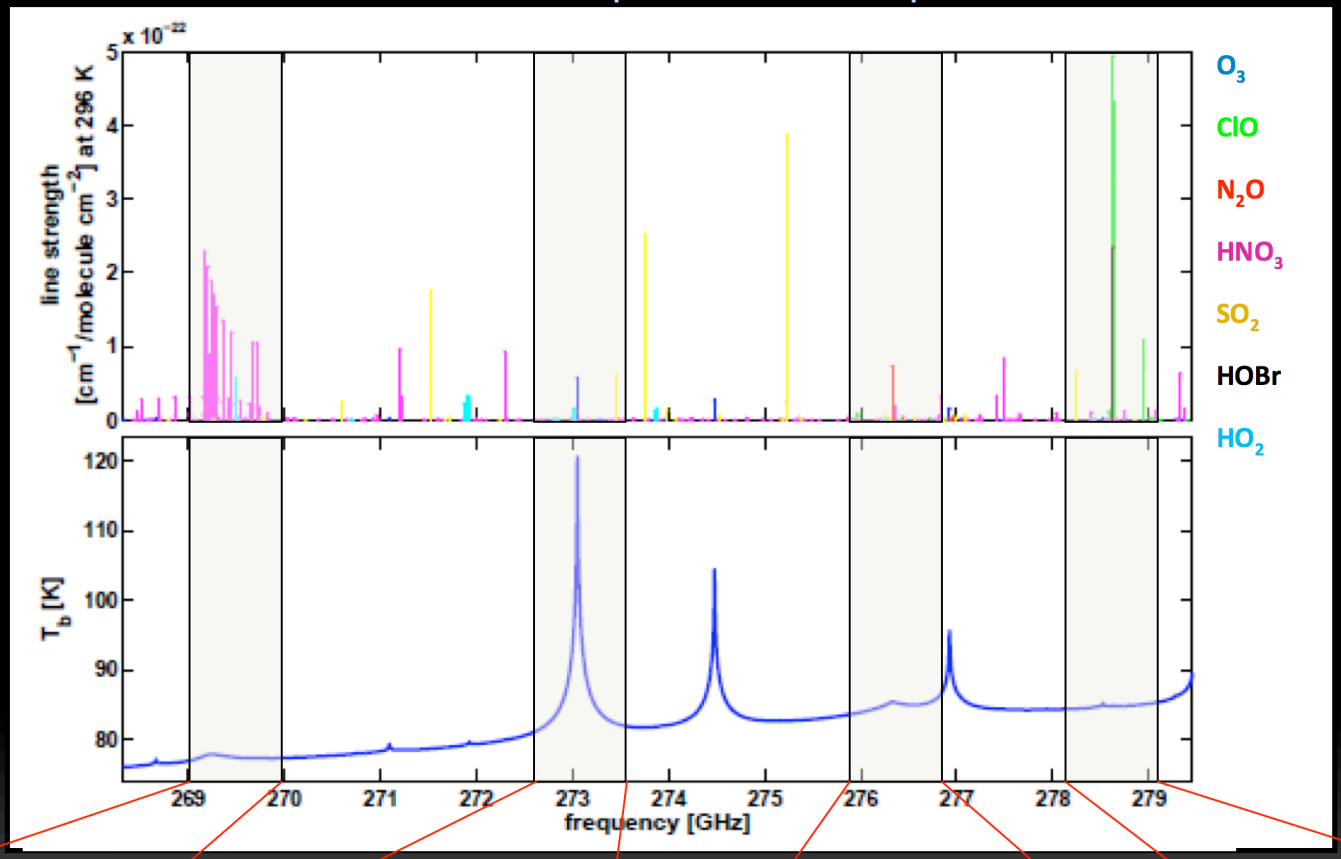
Ridge Laboratory - one of three PEARL sites in Eureka, Nunavut

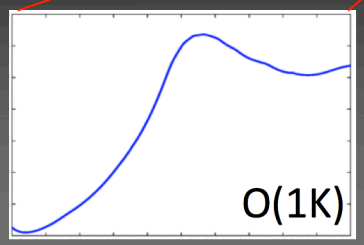
Photos courtesy of Pierre Fogal.

Species and Spectral lines

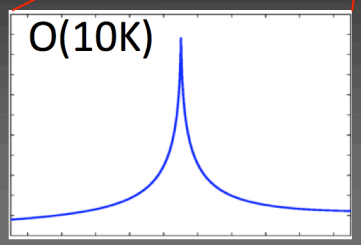
- Forward modelling is done using ARTS. Gas concentration profiles are Eureka climatologies. Radiosondes are used for atmospheric states (zPT).

lower plot is simulated spectrum at Eureka in March

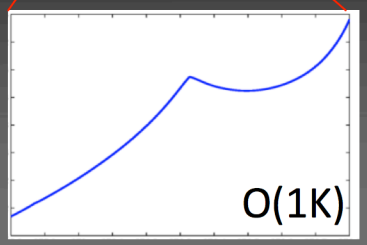




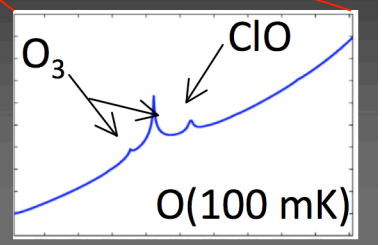
HNO_3 @ 269.2 GHz



O_3 @ 273 GHz



N_2O @ 276.3 GHz



ClO @ 278.6 GHz

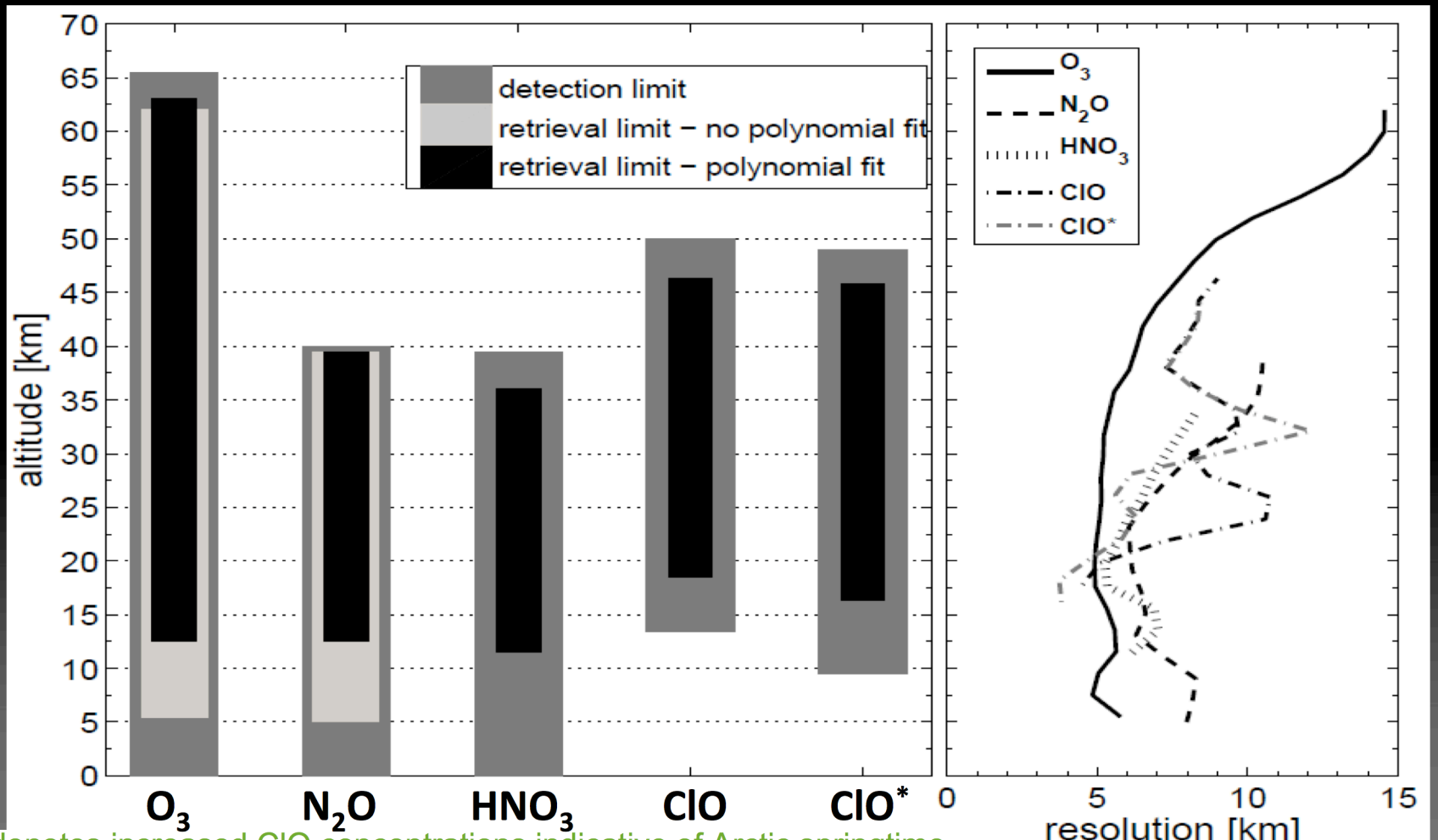
Altitude limits

The detection limits for each gas are a function of the instrument/atmosphere.

Detectable at an altitude if the gas concentration causes a signal larger than the noise of the instrument

The retrieval limits for each gas are a function of both the instrument/atmosphere and the inversion.

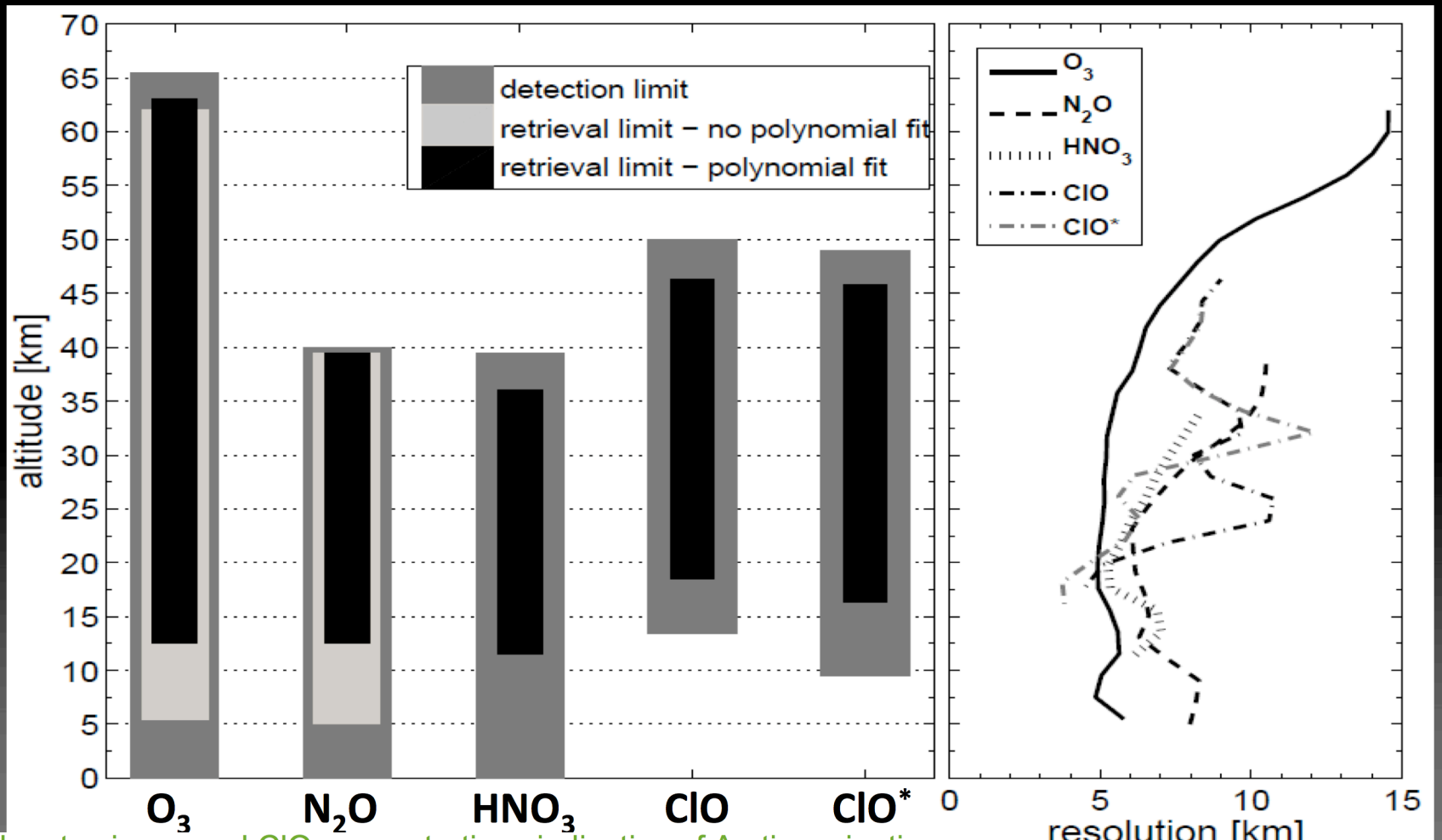
Retrievable at an altitude if over 80% of the information in the retrieval comes from the measurement



ClO* denotes increased ClO concentrations indicative of Arctic springtime

Altitude limits – main points

- Retrievable altitude limits range from ~6 - 62 km for O_3, to ~12 - 36 km for HNO_3.
- O_3, N_2O, and HNO_3 are detectable down to 610 m (ground level at PEARL).
- Using a fit to the baseline of the O_3 and N_2O spectra causes a loss of ~7km of low altitude information.
- Enhanced ClO concentrations in Arctic springtime means a gain in low altitude information but a loss of some high altitude information.



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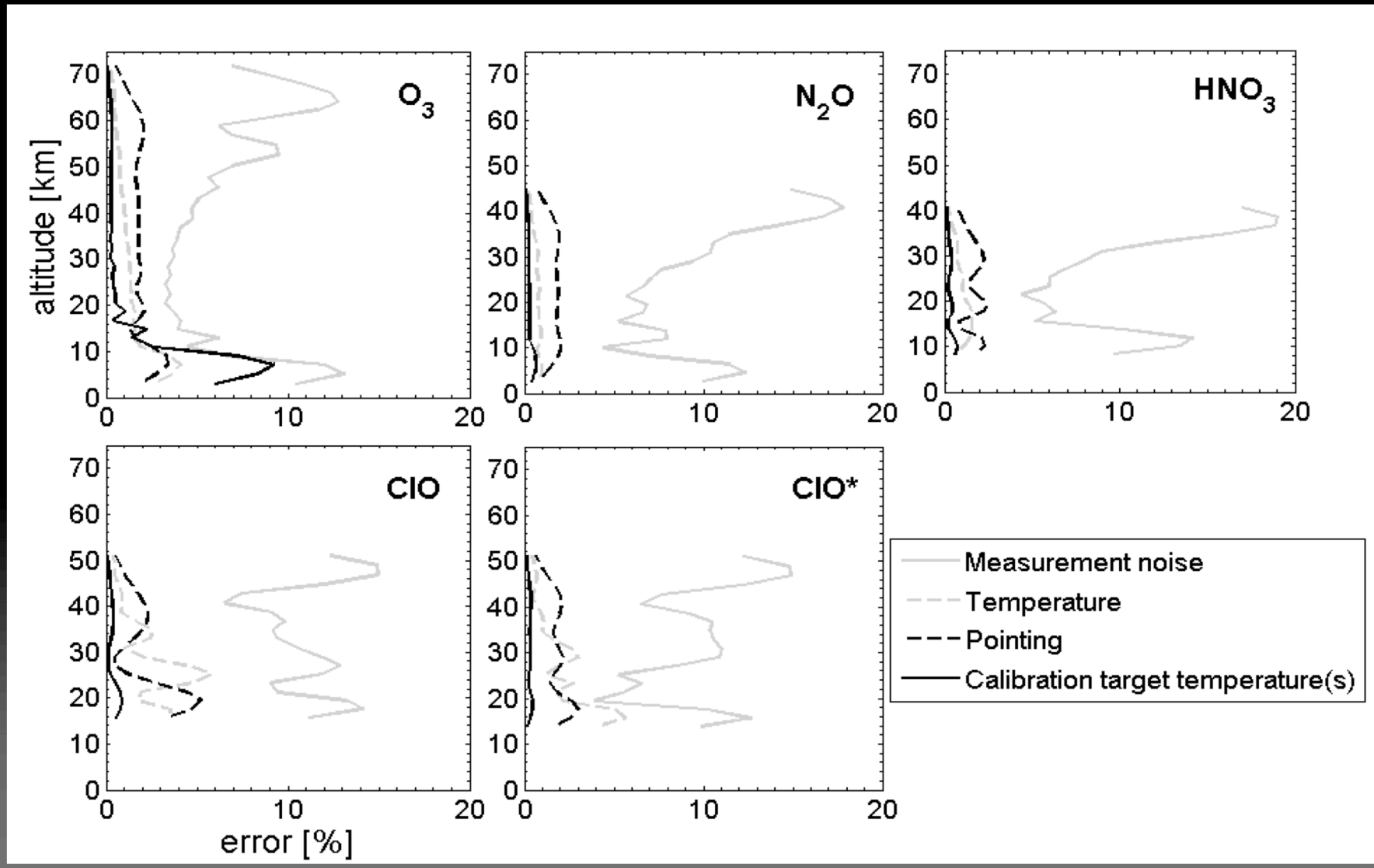
Sources of error in the retrieved concentration profiles

- Uncertainties are set to 2 K for the atmospheric temperature profiles, 0.5° for the pointing accuracy of SPÉIR, and 0.5 K for the physical temperature readings of the blackbody reference loads.



OEM Estimates vs. Repeated Simulations

Are the statistics from Optimal Estimation comparable to those from inversions?

- Simulated 500 different spectra for each species by allowing the concentration profiles to vary within their climatologies and creating synthetic measurements of these atmospheres.
- By looking at the difference between the true (simulated) profiles and retrieved profiles you can assess the performance of the inversion setup.

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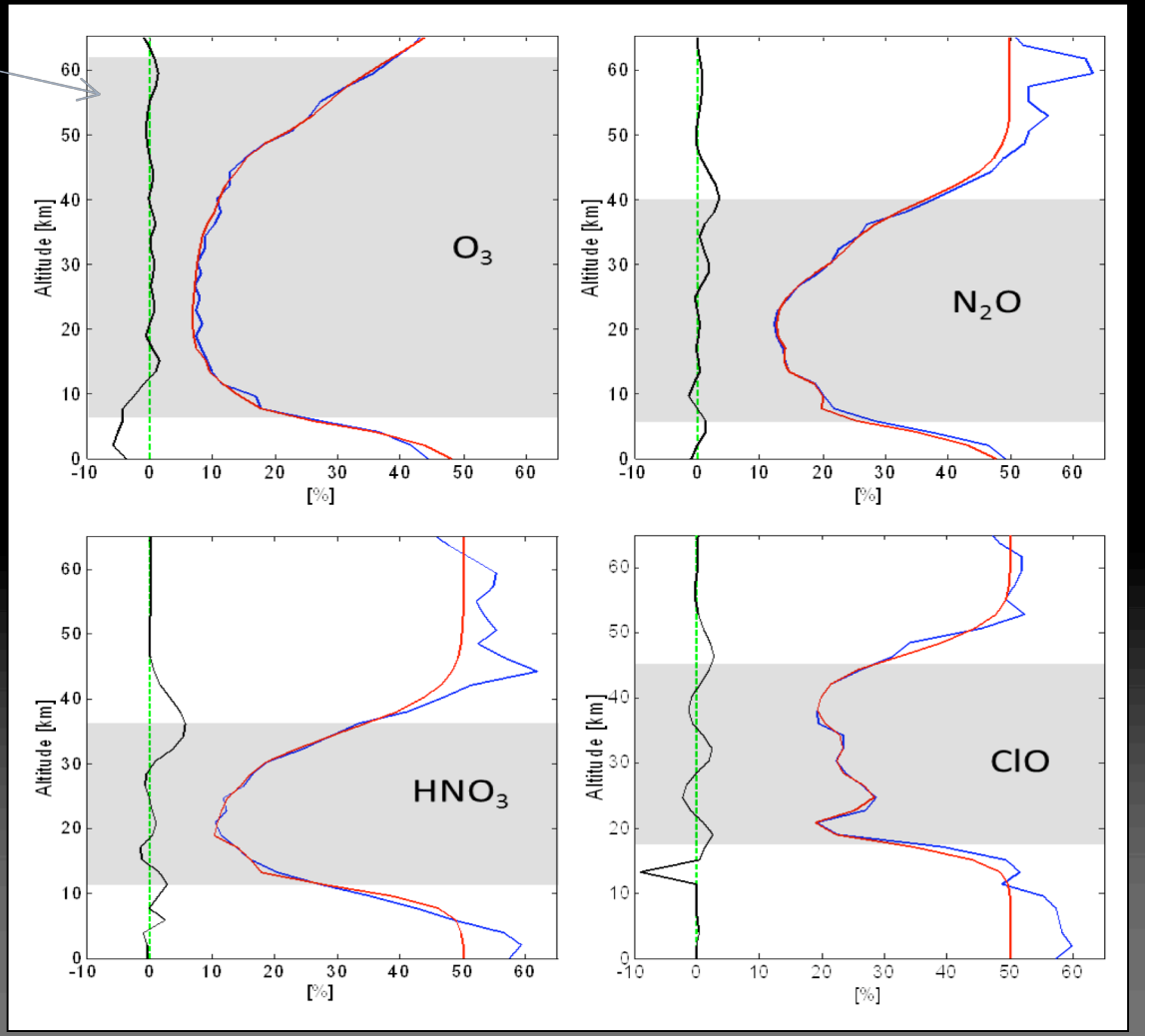
retrievable altitude ranges in grey

- the error from 500 simulated retrievals. *sdev[retrieved – true]*
- total retrieval error as estimated with OEM
- bias from 500 simulated retrievals. *mean[retrieved – true]*
- optimal bias from OEM *(0%)*



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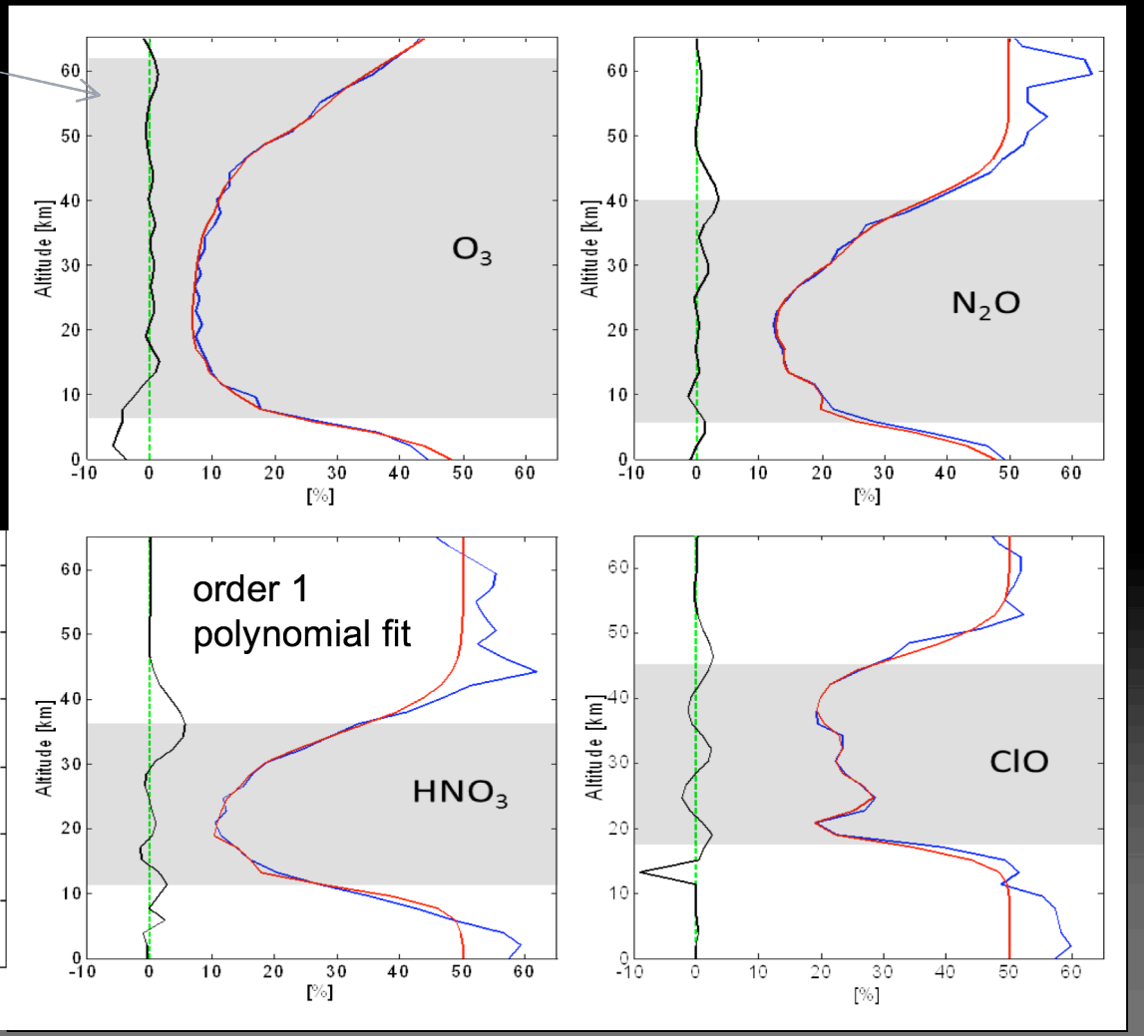

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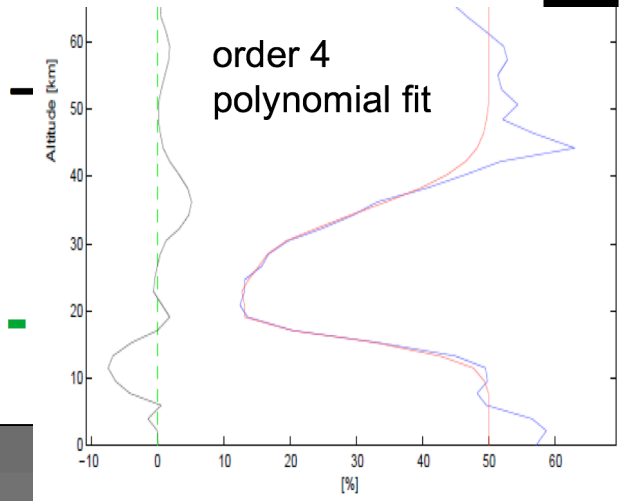

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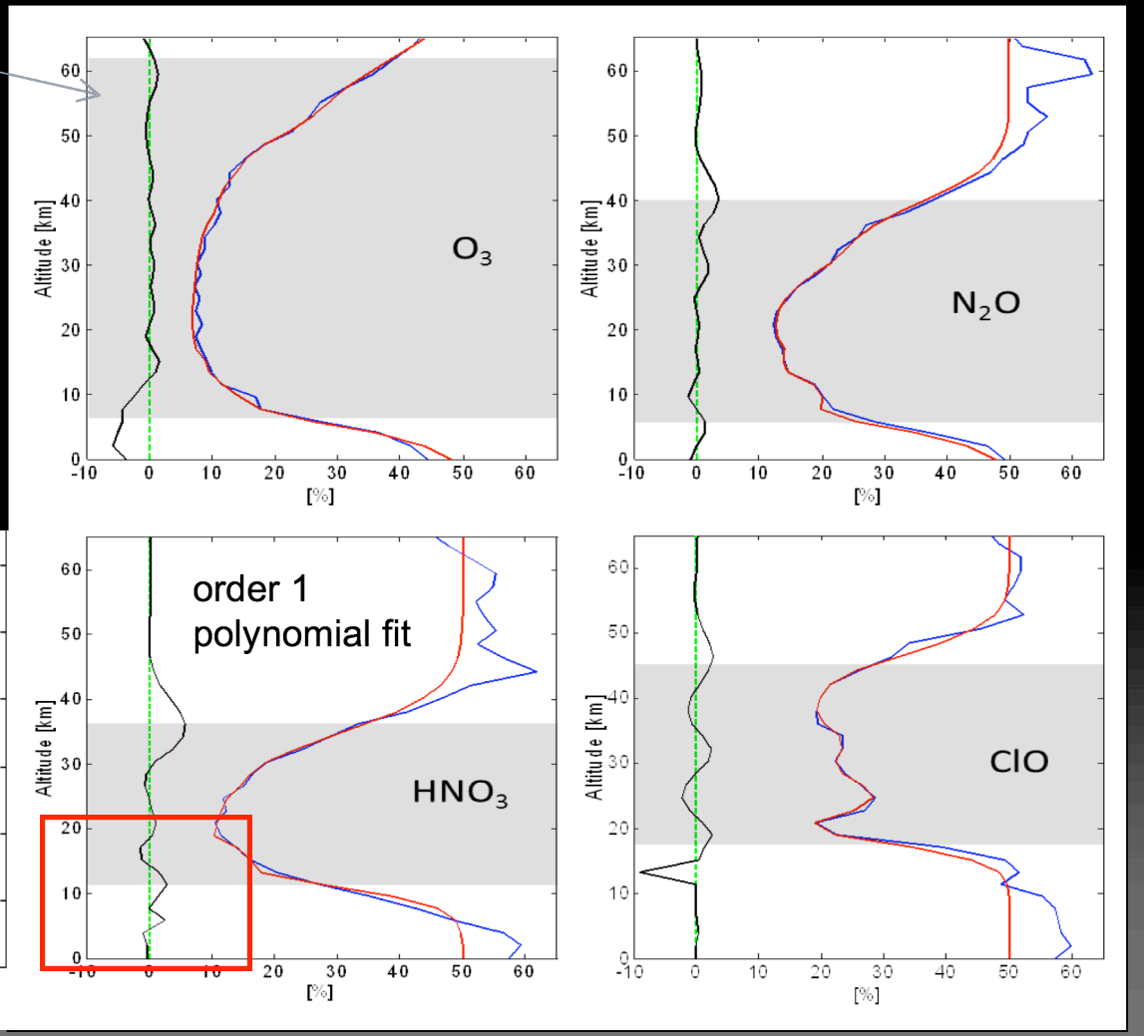

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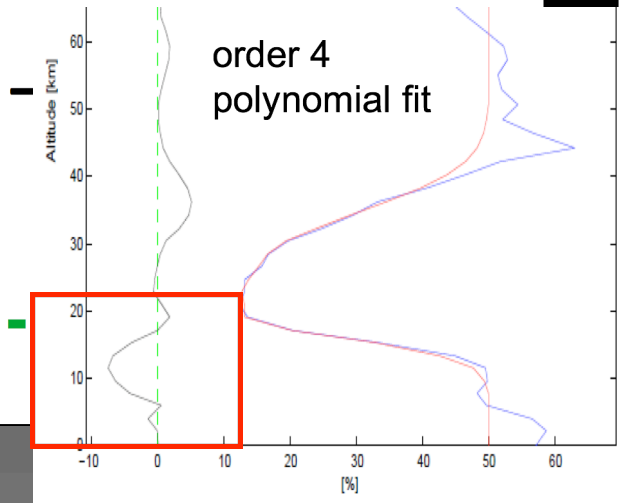


Summary

- New 270 GHz radiometer in development for deployment in Canadian high Arctic at PEARL in Eureka, Nunavut
- Reviewed design and progress to date
- Presented OSSE study of instrument performance

- Looking for people to join the team in Toronto!

Acknowledgments

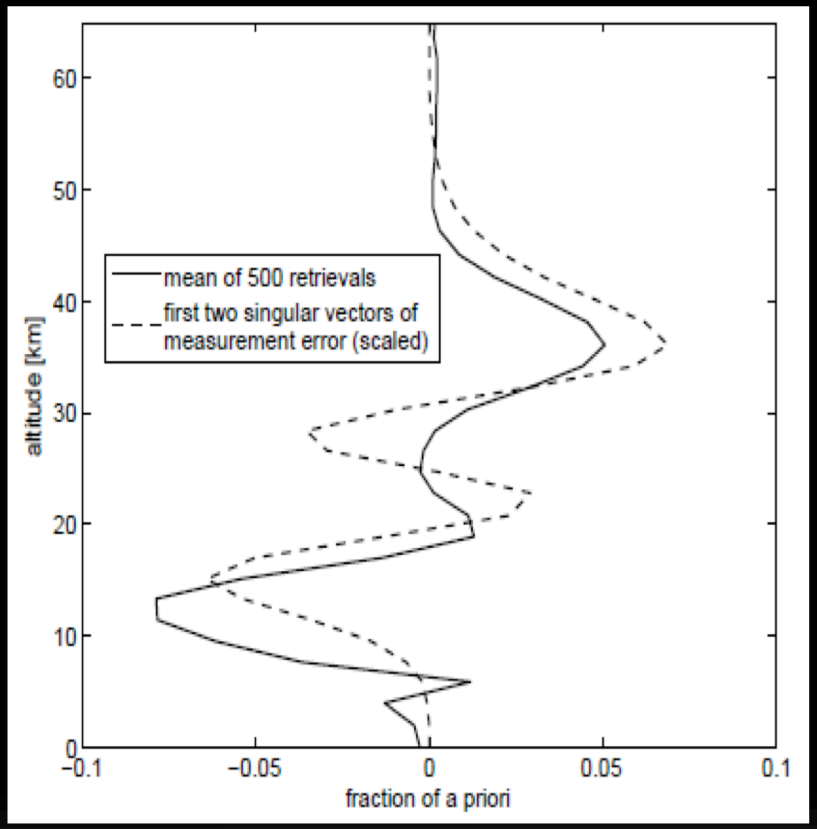
Funding support:

- PEARL/CANDAC: CFCAS, CFI, EC, MRI, MSC, NSERC, NSIRT, OIT, PCSP, SEARCH
- Instrument development: CFI, ORF, UofT, Connaught Fund, CREATE, CGCS

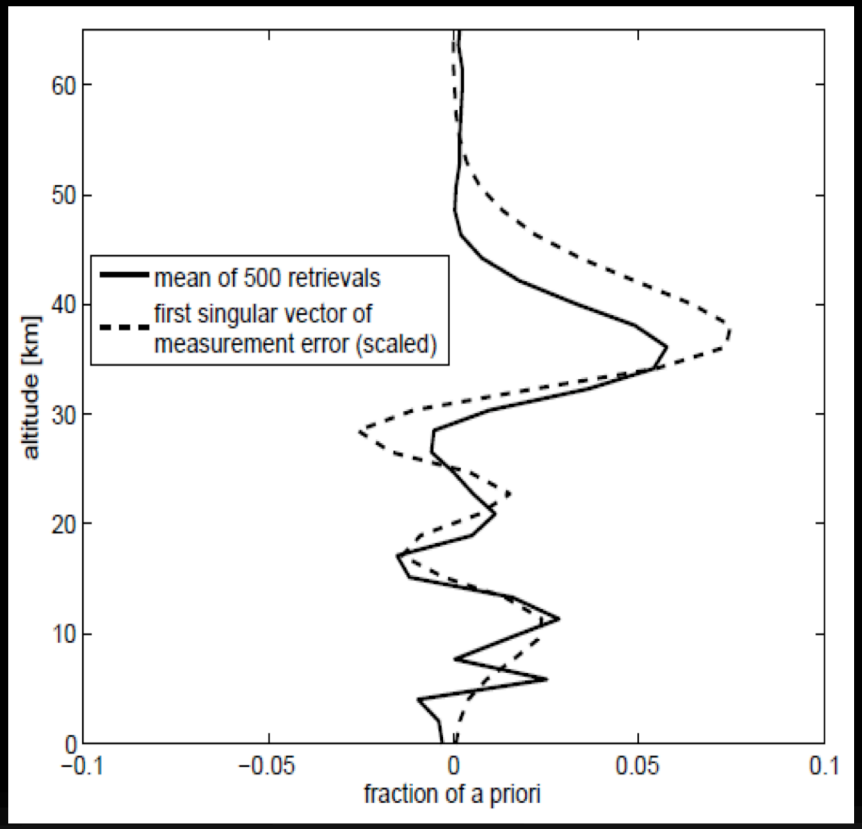
Acknowledgments:

- Axel Murk, Nik Kaempfer, and the Uni Bern Microwave and Terahertz Optics groups
- Richard Wylde and Stuart Froud of Thomas Keating Instruments
- Keeyoon Sung and Rodica Lindenmaier for their work on the Eureka gas concentration climatologies
- The Eureka weather station staff for the radiosonde data
- The ARTS/Qpack development team

Singular value decomposition of the measurement noise matrix vs. the mean of 500 inversions

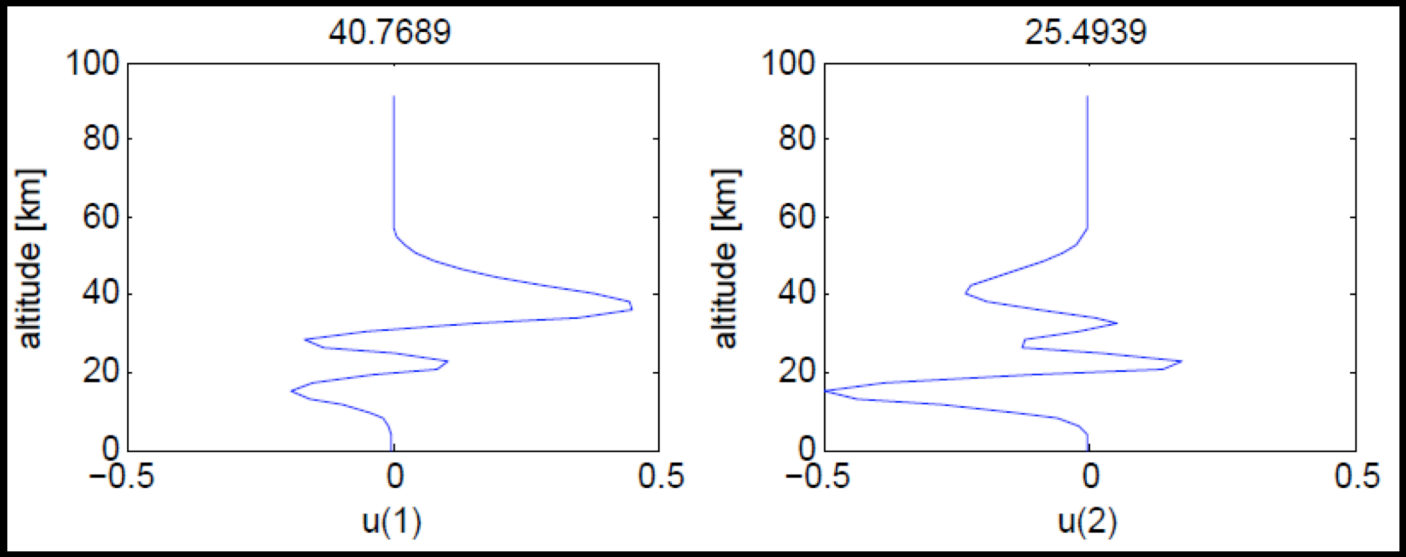


Inversion with baseline polynomial fit order 4



Inversion with baseline polynomial fit order 1

First two singular vectors the of gain matrix for HNO_3, in state space



Corresponding singular vectors of the gain matrix in measurement space