

# A new radiometer in the Canadian Arctic

Niall Ryan  
Kaley Walker

University of Toronto  
Department of Physics

ARTS Workshop June 2010

# Outline

---

- PEARL and CANDAC
- Science motivation
- Measurement and retrieval simulations for a new radiometer in Eureka, Nunavut



# The PEARL at Eureka

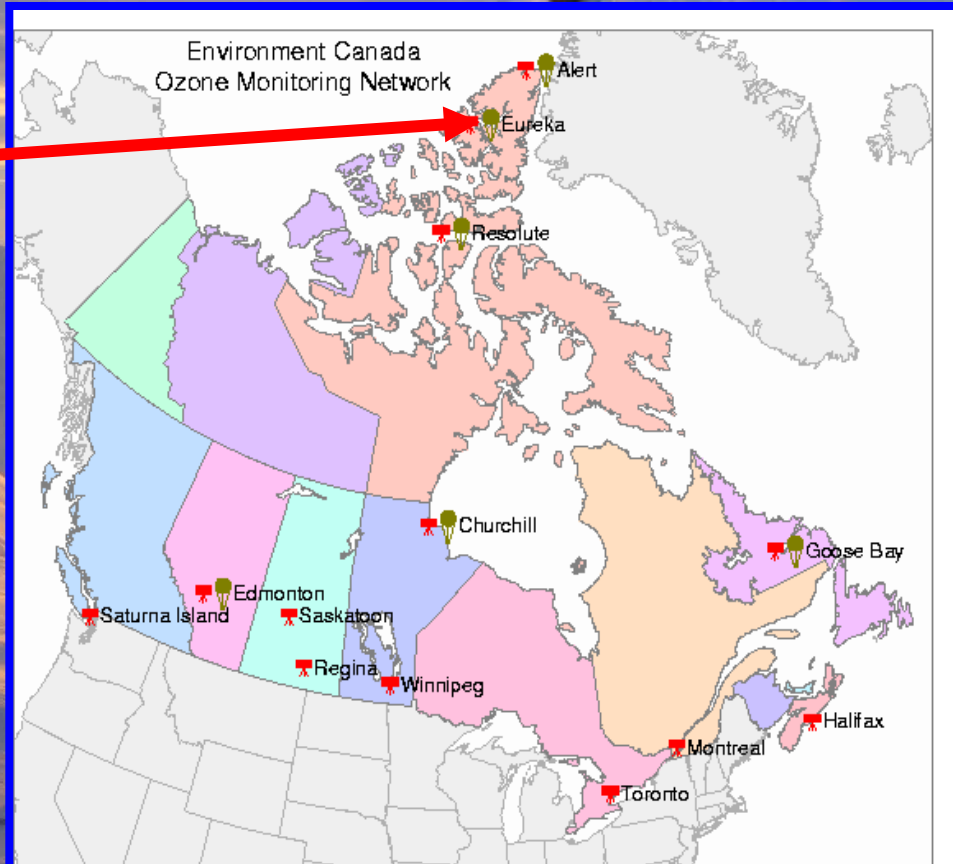


## Polar Environment Atmospheric Research Laboratory

80.05N 86.43W



Formerly the MSC's  
Arctic Stratospheric  
Ozone Observatory



# PEARL Objectives

- To measure the atmosphere in the range 0-100km as comprehensively as possible
  - air quality, stratospheric ozone, climate change
- Deploy research-grade equipment
- Develop new instrumentation and observing strategies
- Provide a Canadian research presence at this location (1,100 km from the North Pole)





# CANDAC: Canadian Network for the Detection of Atmospheric Change

A collaboration of Canadian university and government scientists

## Research Themes:

- Arctic Troposphere Transport and Air Quality (ATTAQ)
- The Arctic Radiative Environment: Impacts of Clouds, Aerosols and Diamond Dust (ARE)
- Waves and Coupling Processes (WACP)
- **Arctic Middle Atmospheric Chemistry (AMAC)**

# PEARL



ØPAL



SAFIRE



*Paul Loewen, 2006*

# PEARL Instrument Complement

## PEARL

- Stratospheric Ozone Lidar
- DA8 FTS/ 125HR FTS
- UV-Vis Spectrometer
- Michelson Wind Interferometer (ERWIN)
- Spectral Imaging Interferometer (SATI)
- All Sky Imager
- Aerosol Mass Spectrometer (AMS)
- Photometer
- Brewer Spectrophotometer

Green = currently installed

Blue = "guest instrument"

## ØPAL

- Millimeter Cloud Radar
- High Spectral Resolution Lidar
- Meteor Radar
- Eureka Atmospheric Emitted Radiance Interferometer (E-AERI)
- Microwave radiometer (water vapour)
- Tropospheric Ozone Lidar
- Rayleigh/Mie/Raman Lidar
- Photometer

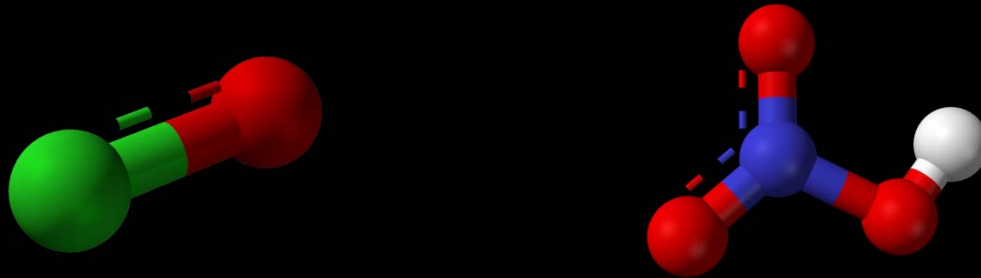
## SAFIRE

- VHF radar
- BSRN
- Flux Tower

# Observable species and Ozone Destruction

---

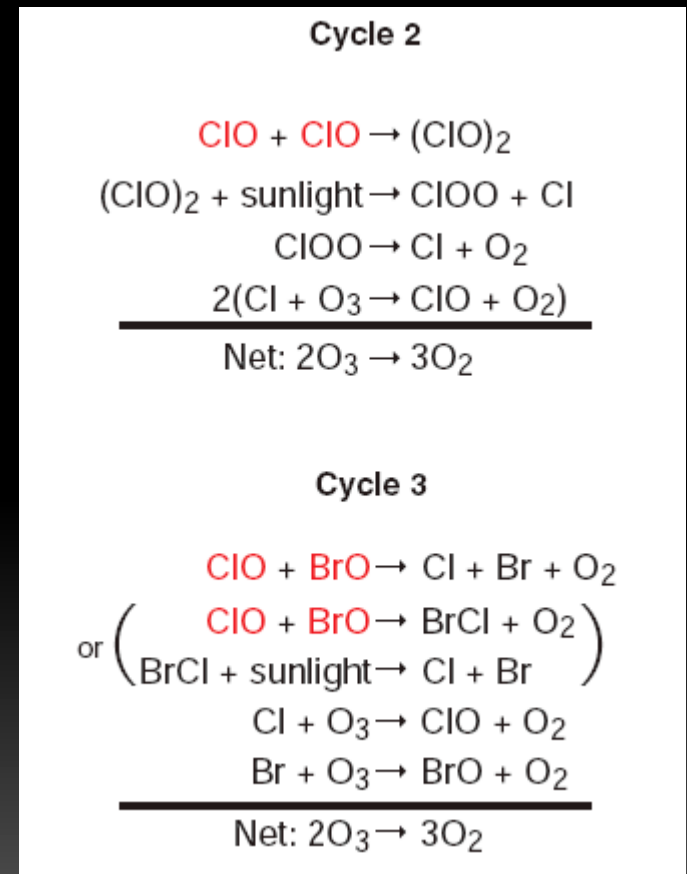
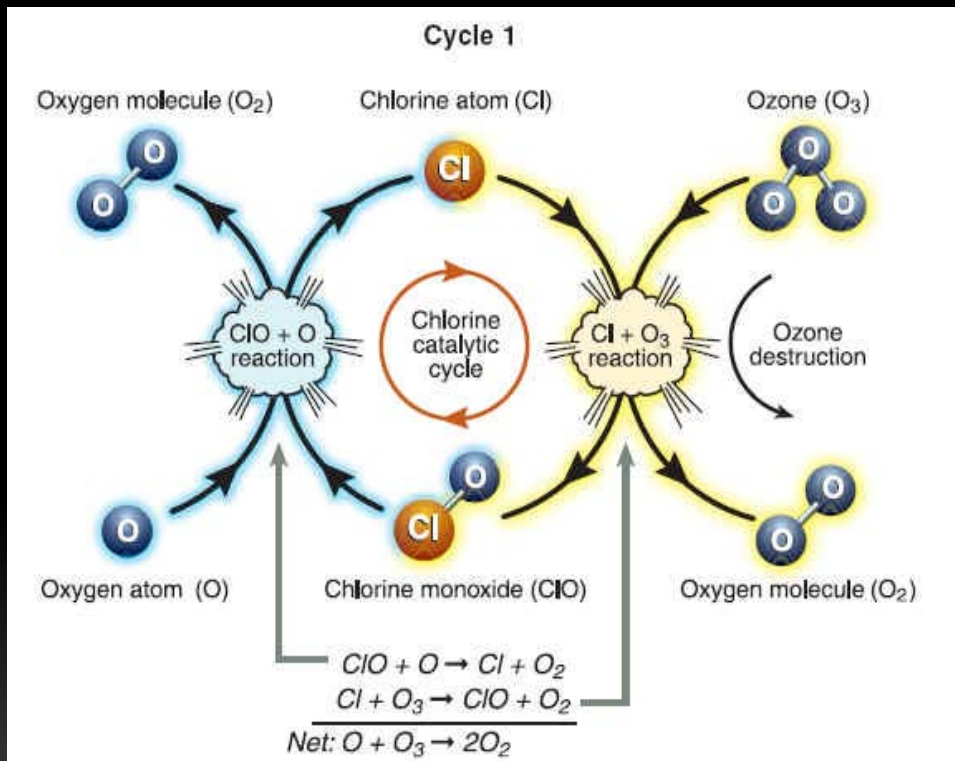
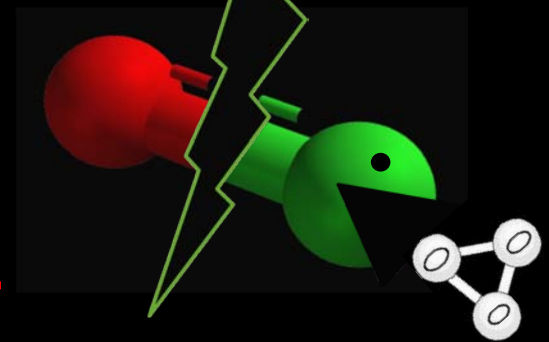
- Both chlorine and nitrogen oxide radicals form ozone destructive, catalytic cycles in the stratosphere.



- ClO is involved in all of the reaction sequences in which chlorine, originally released by CFCs, breaks down stratospheric ozone.
- HNO<sub>3</sub> is a reservoir species for NO<sub>x</sub>.
  - The stratosphere contains sufficiently high concentrations of HNO<sub>3</sub> that solid HNO<sub>3</sub>-H<sub>2</sub>O phases may form at temperatures higher than the frost point of water contributing to PSC formation (e.g. HNO<sub>3</sub>•3H<sub>2</sub>O, NAT)

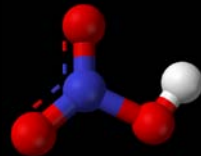


# Ozone Destruction ( Cl )

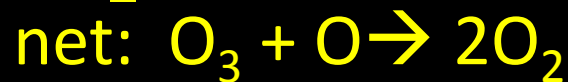
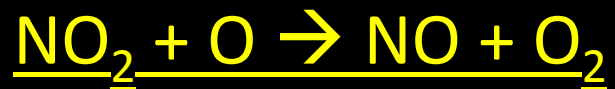


# Ozone Destruction ( $\text{NO}_x$ & $\text{HNO}_3$ )

---



- $\text{NO}_x$  forms destructive catalytic cycle with  $\text{O}_3$ .

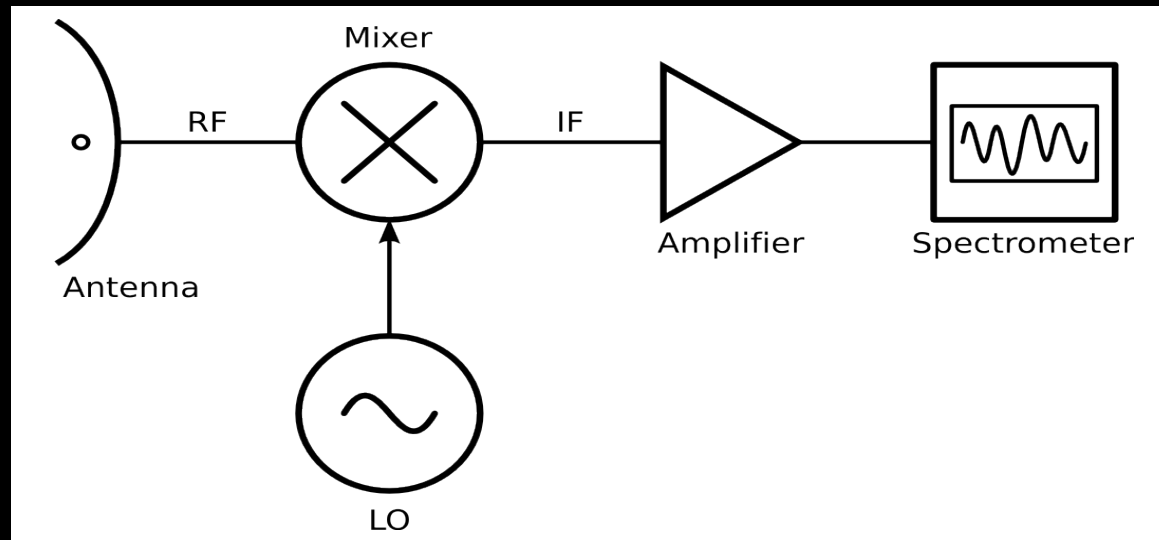


- Termination of cycle by reaction with  $\cdot\text{OH}$ .



- $\text{HNO}_3$  is a reservoir species for  $\text{NO}_2$  and keeps in non-reactive form with a relatively long lifetime.

# The instrument design



- Signal coupled to mixer in waveguide and down-converted to IF with heterodyne technique.
  - Super cooled **SIS mixer** (superconductor-insulator-superconductor) gives very low system noise.
- IF output is amplified and then processed by an *acousto-optical spectrometer*.
  - detector yields an output voltage proportional to the input power at the receiver .
- **LO** gives a bandwidth of 1 GHz and with 1024 channels get a resolution of  $\sim 1$  MHz ( $3 \times 10^{-5} \text{ cm}^{-1}$ ).

# Polar atmosphere RT modelling

---

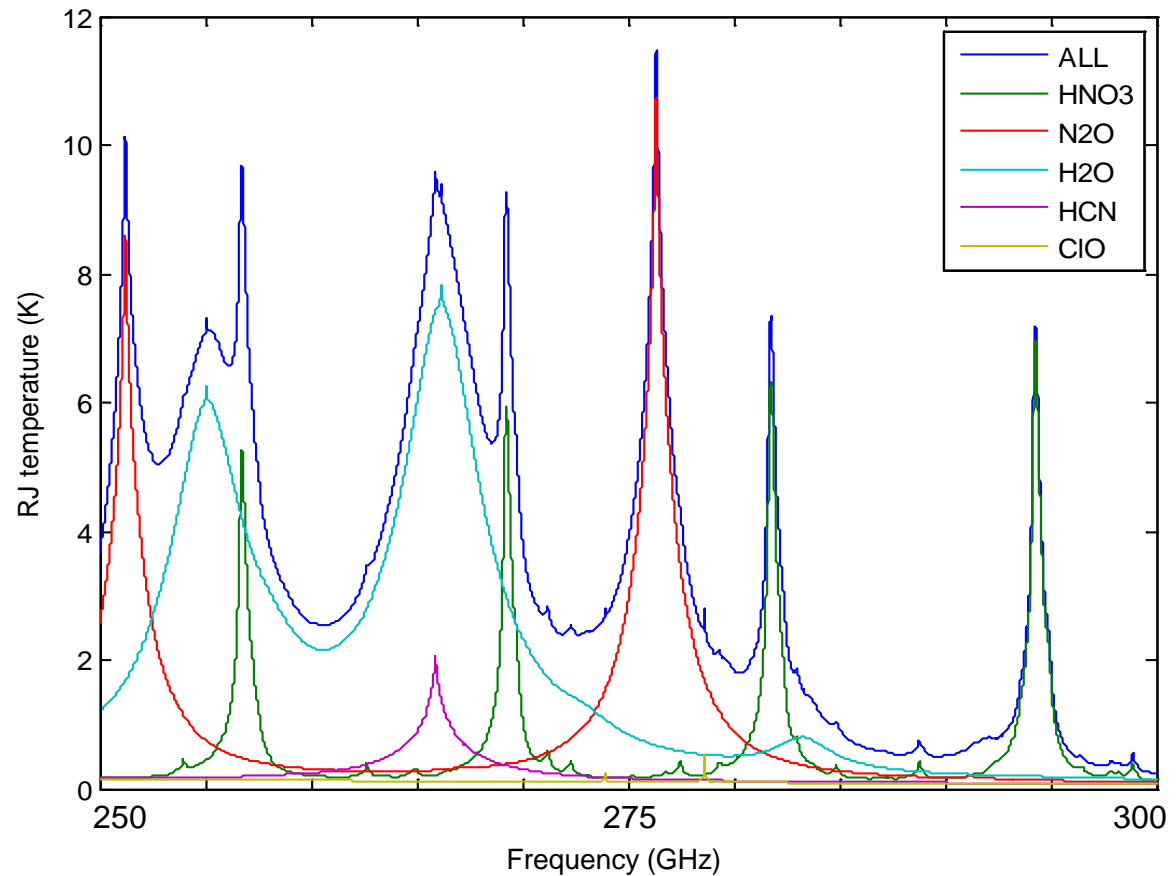
- Radiative transfer modelling carried out with the ARTS (*IEP, Bremen & Chalmers UT, Gothenburg*).
- Eureka climatologies for VMRs
- zpTs from Eureka radiosondes.
- Used to simulate actual expected output from the MMW Radiometer operating at PEARL.



# Polar atmosphere RT modelling

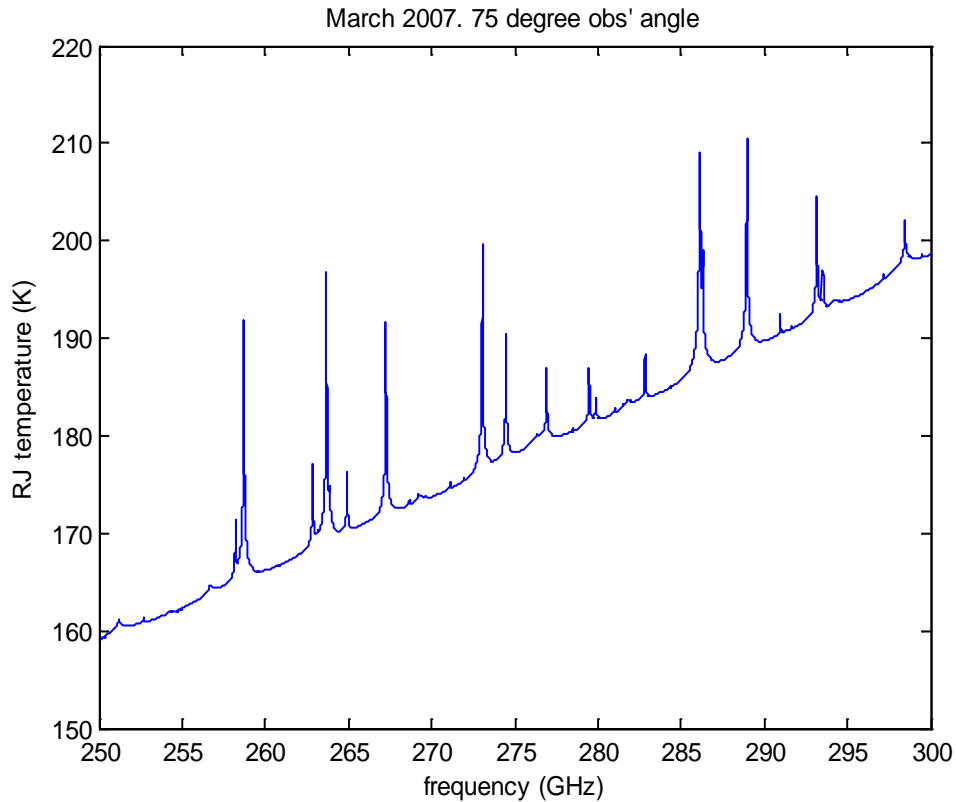
---

- Runs with atmosphere containing only one gas profile.



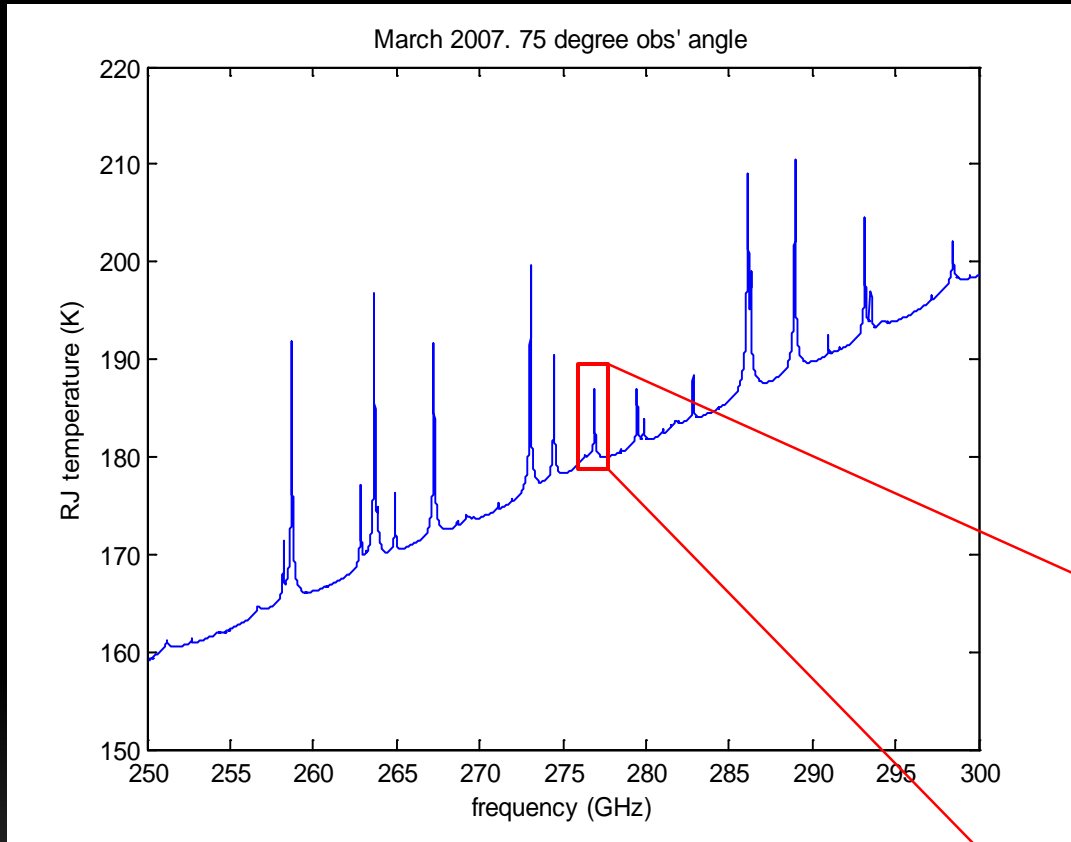
# Polar atmosphere RT modelling

---

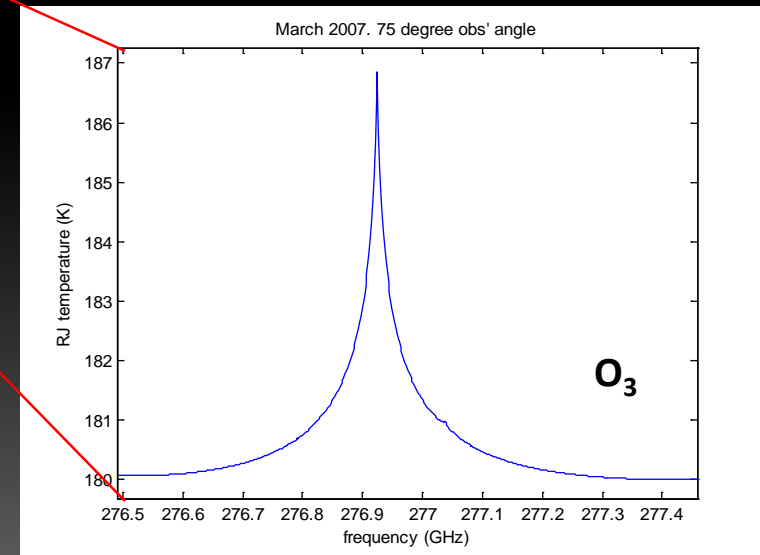


- Between 250 and 300 GHz at 2 MHz resolution with all contributing species.

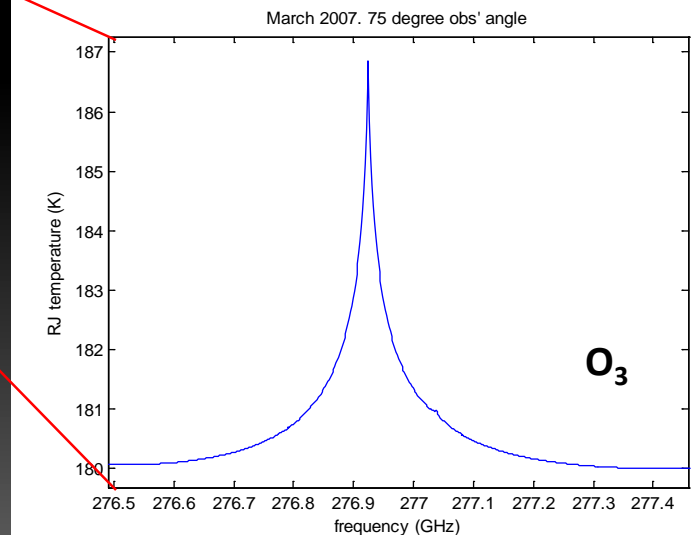
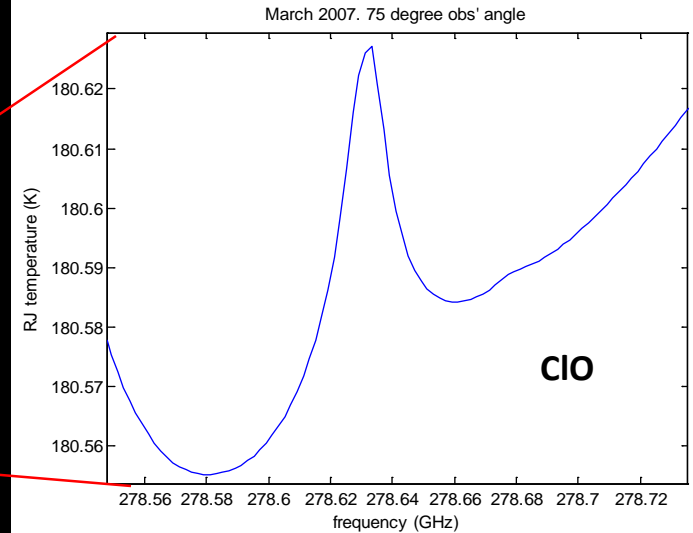
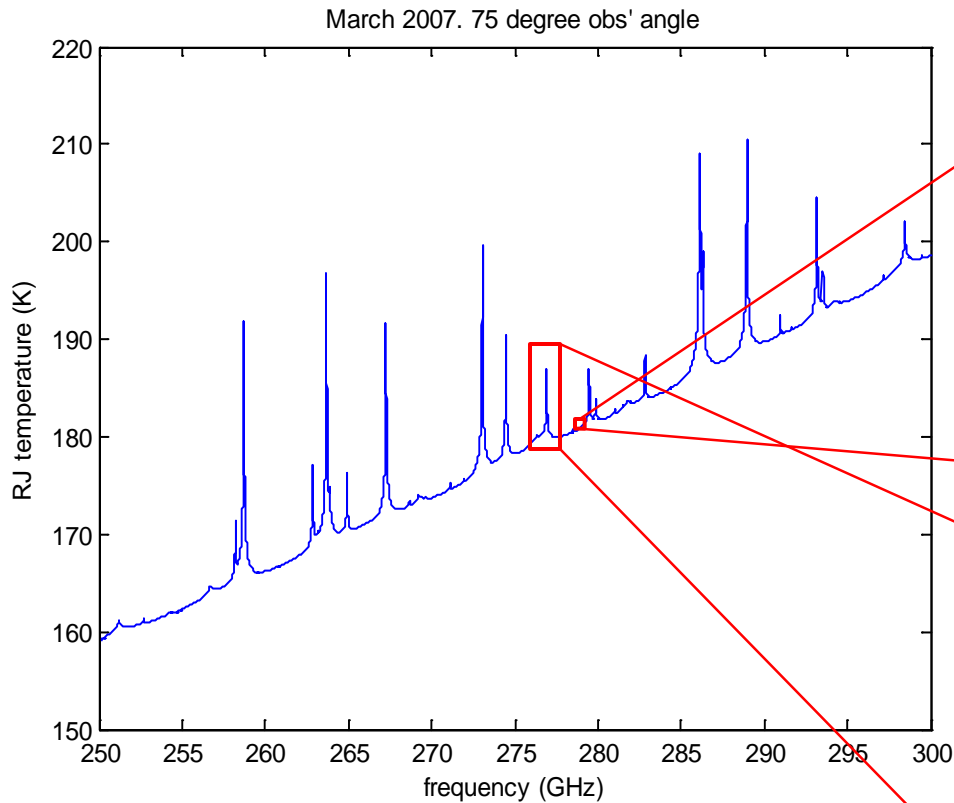
# Polar atmosphere RT modelling



- Between 250 and 300 GHz at 2 MHz resolution with all contributing species.



# Polar atmosphere RT modelling



- Between 250 and 300 GHz at 2 MHz resolution with all contributing species.

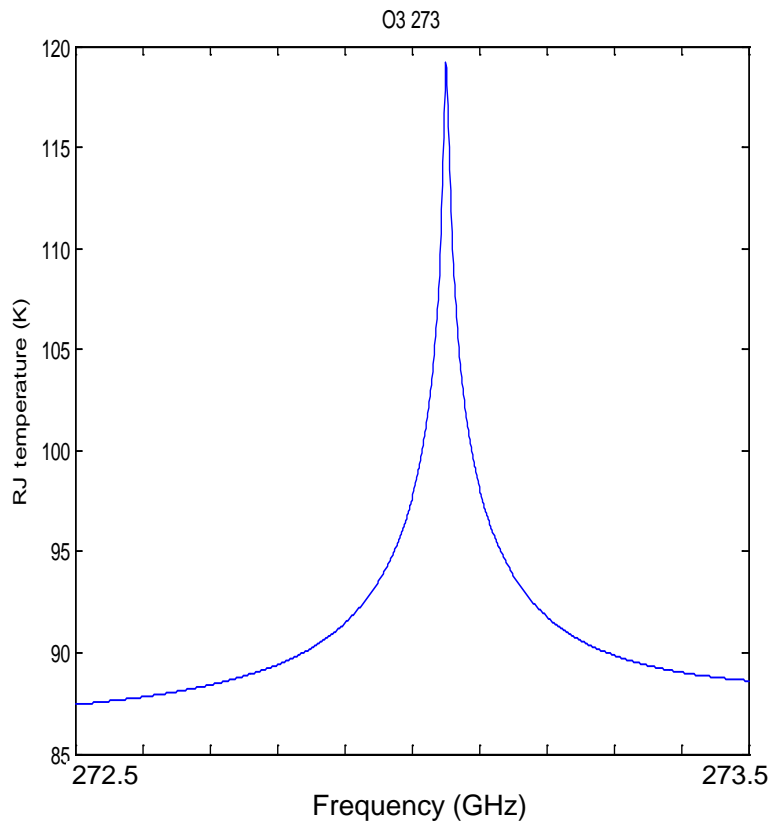


# Simulating Retrievals

---

Simulate a measurement...

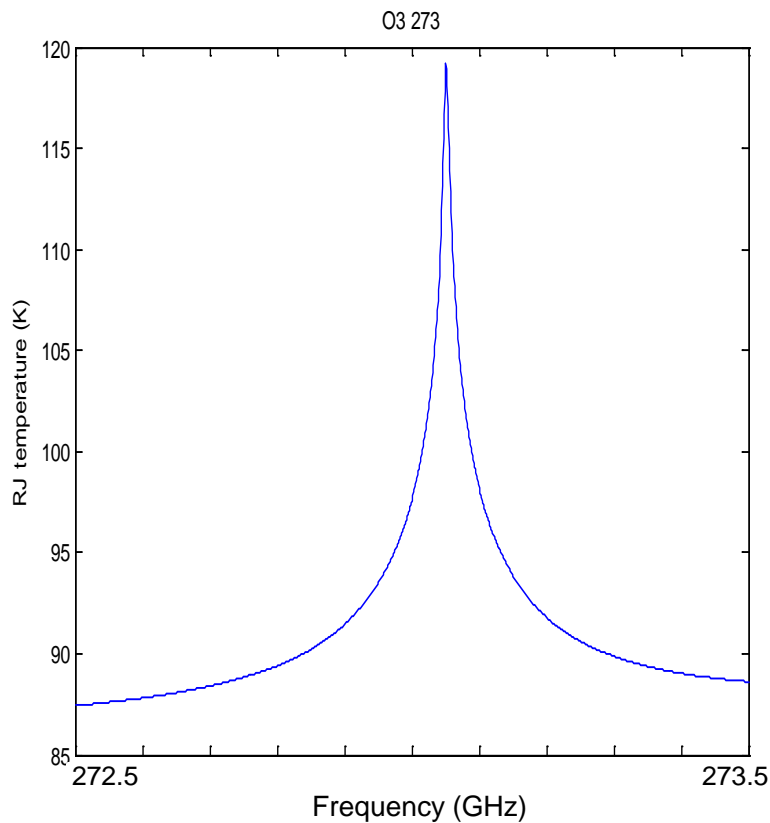
Add instrument noise...



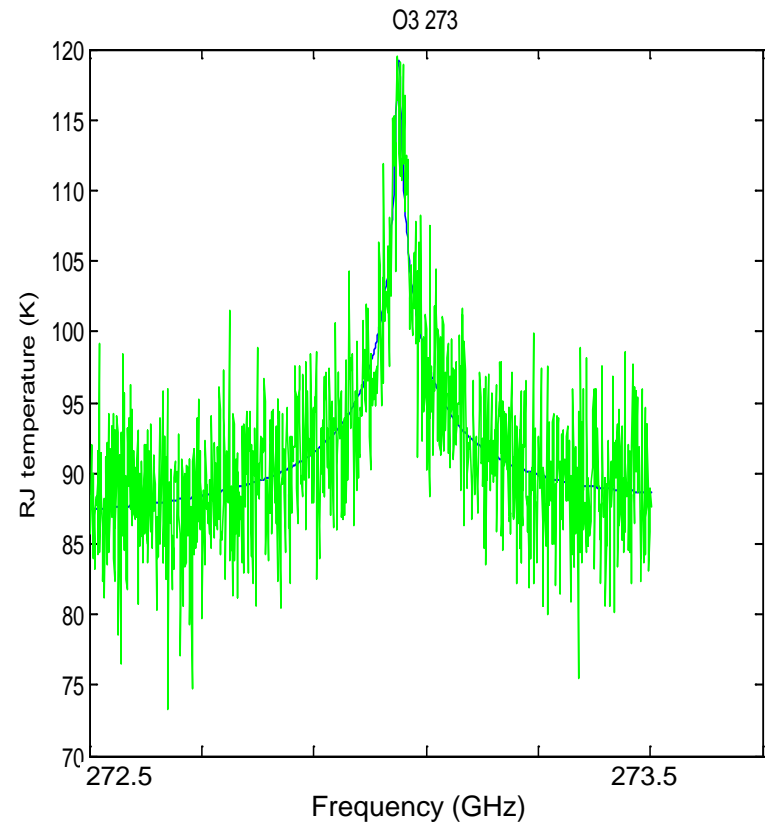
# Simulating Retrievals

---

Simulate a measurement...



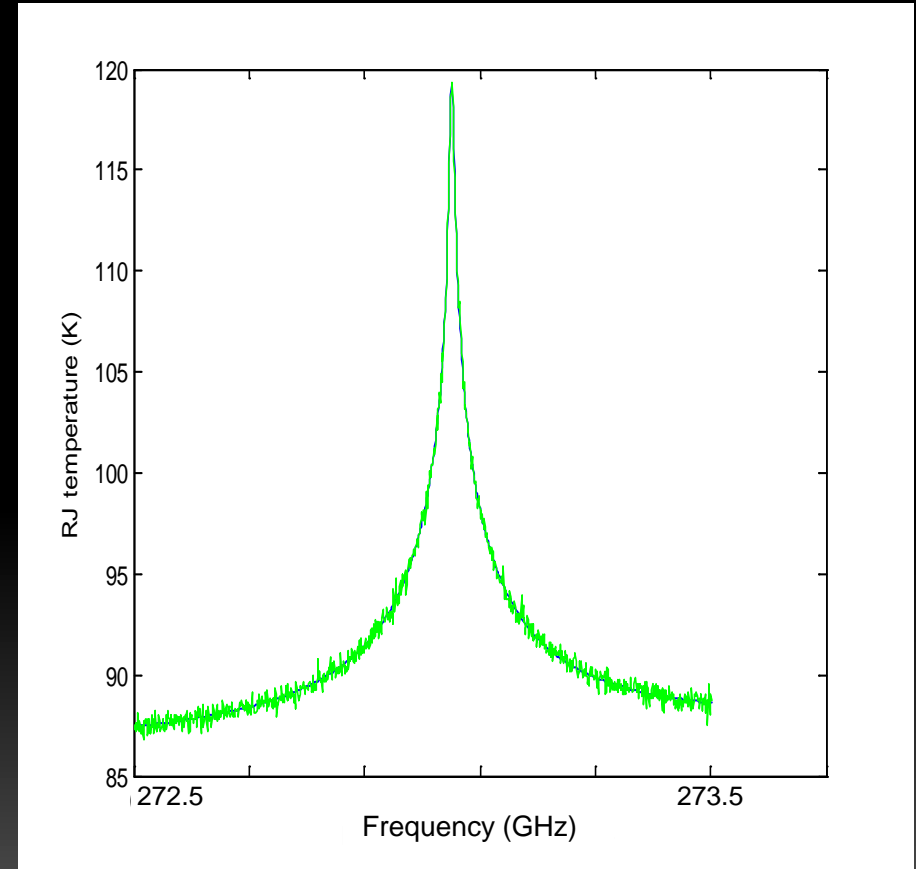
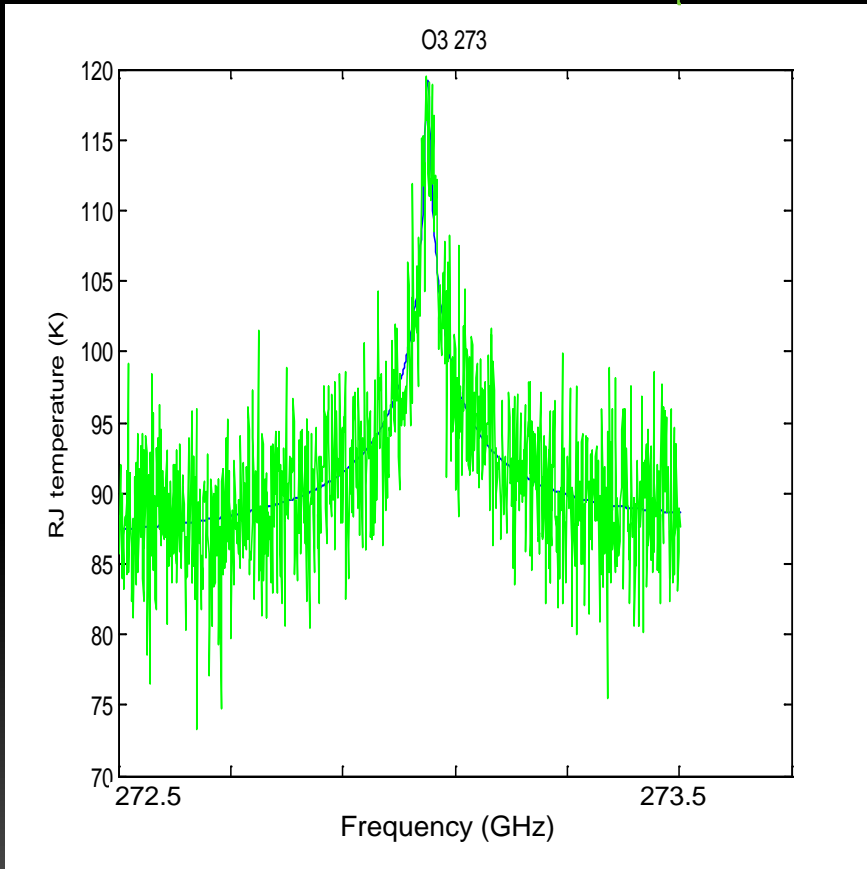
Add instrument noise...



# Simulating Retrievals

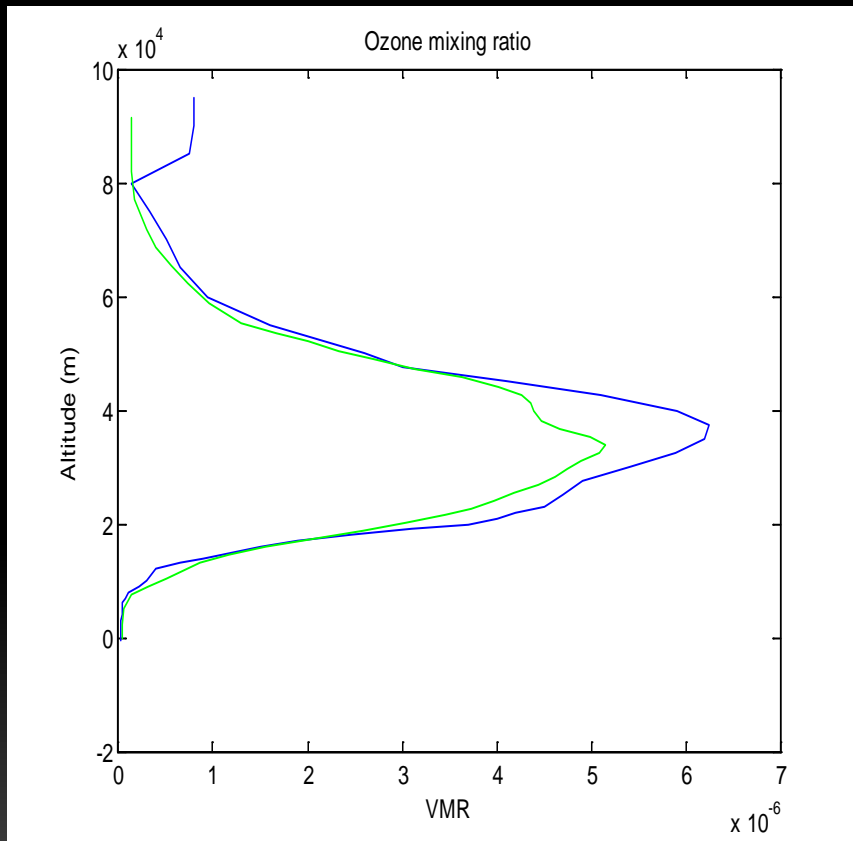
---

Average over many measurements

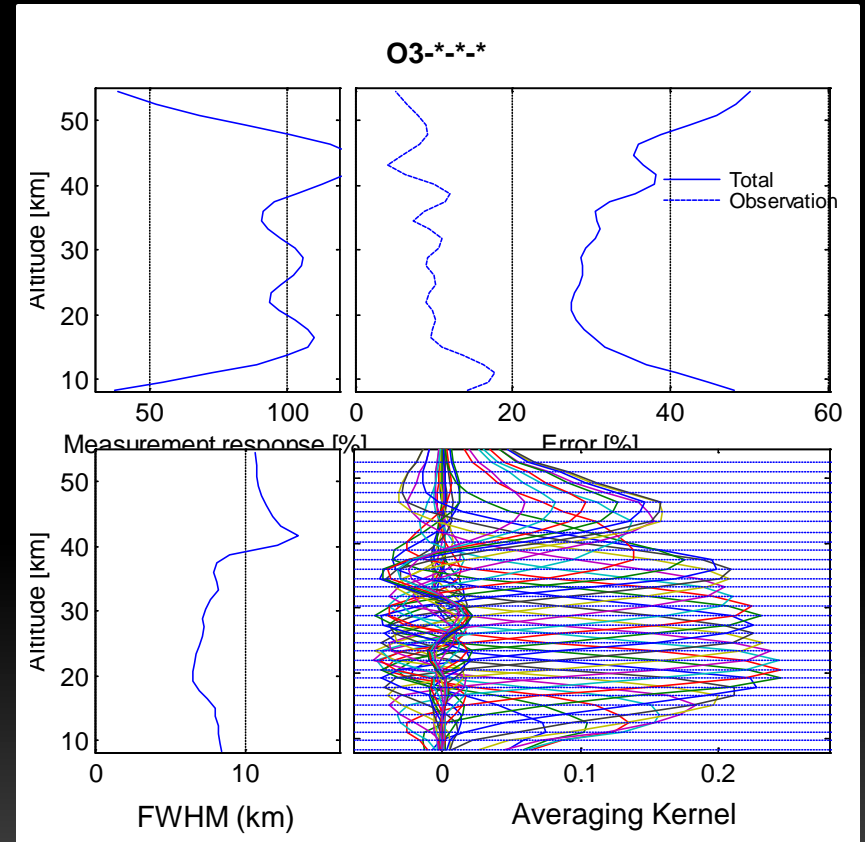
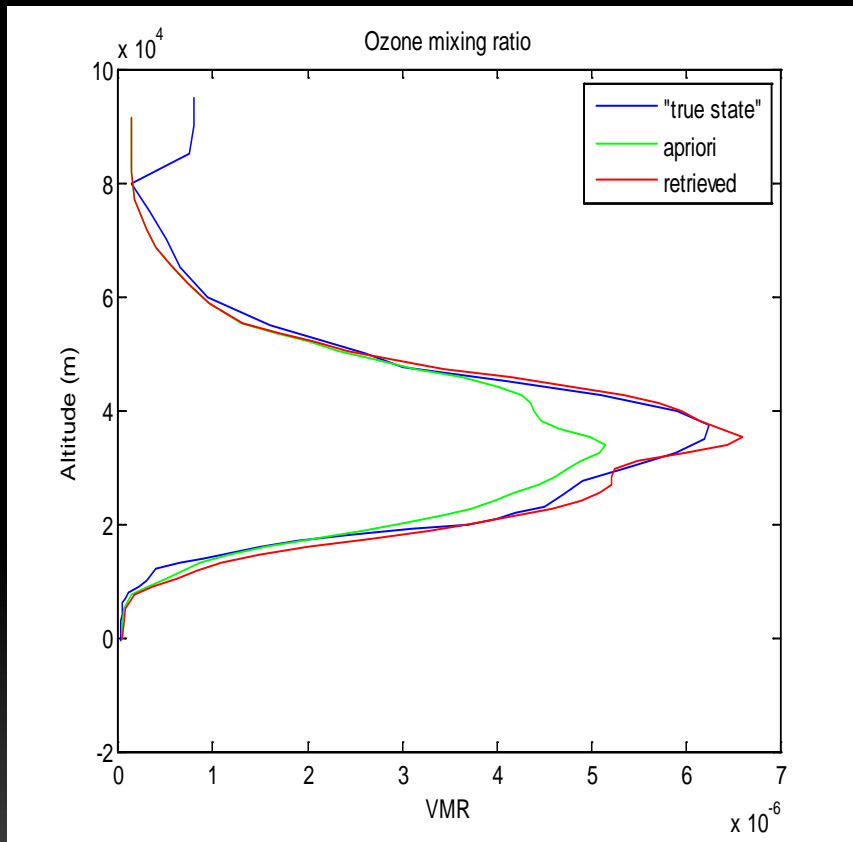


# Simulating Retrievals

---



# Simulating Retrievals



# To Summarise..

---

- New radiometer is under development and to be deployed at PEARL in Eureka, Nunavut.
- Will make year round observations of crucial ozone related species.
- RT calculations performed with ARTS to simulate measurements made at Eureka.
- Retrieval scheme to be completed using Qpack in parallel with instrument construction.

# Acknowledgements

---

- We gratefully acknowledge support from the following groups:
  - PEARL/CANDAC: AIF/NSIRT, CFCAS, CFI, CSA, EC, GOC-IPY, INAC, MRI/MEDT, MSC. NSERC, OIT, PSCP. SEARCH
  - Instrument funding: CFI, ORF, UofT
- Special thanks to:
  - The Eureka weather station staff for the radiosonde data.
  - ARTS/Qpack development team.
  - R. Batchelor, F. Kolonjari , R. Lindenmaier, A. Jones , C. Adams, and K. Sung.
- Logistical and operational support at Eureka is provided by:
  - CANDAC/PEARL Principal Investigator James R. Drummond
  - PEARL site manager Pierre Fogal
  - The CANDAC operators
  - EC Weather station

---

# Thanks

Any ideas for a name?