POLAR SCIENCE
FOR PLANET EARTH

NO, O_3, and CO observations using the BAS microwave radiometer at Troll station and Halley, Antarctica

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BAS microwave radiometer

Outline of talk

1. Science objectives & instrument description.
2. NO observation & data inversion.
3. Antarctic deployments.
4. Future developments.

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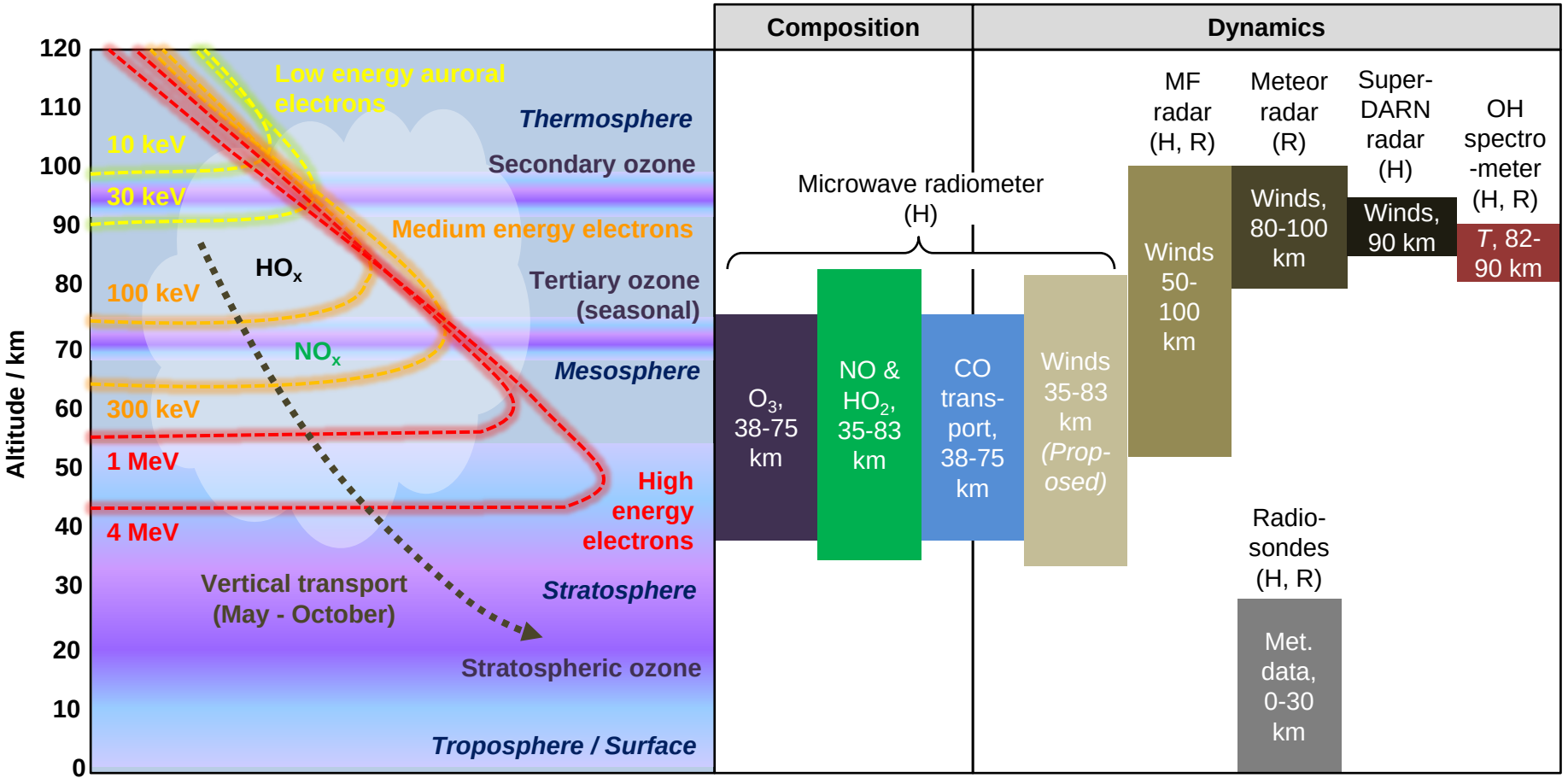
1. Science objectives



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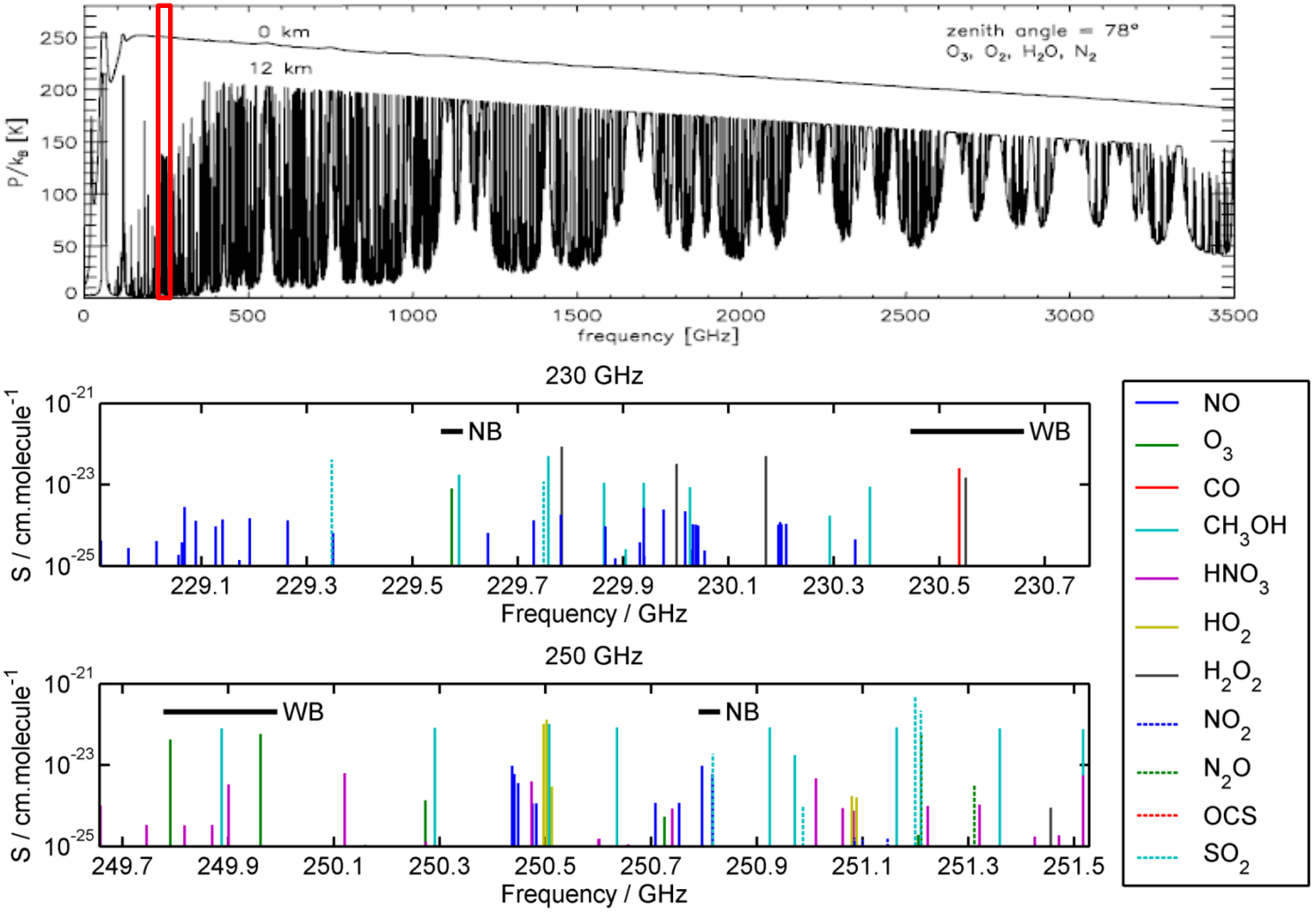
1. Atmospheric spectra: 230 GHz / 250 GHz



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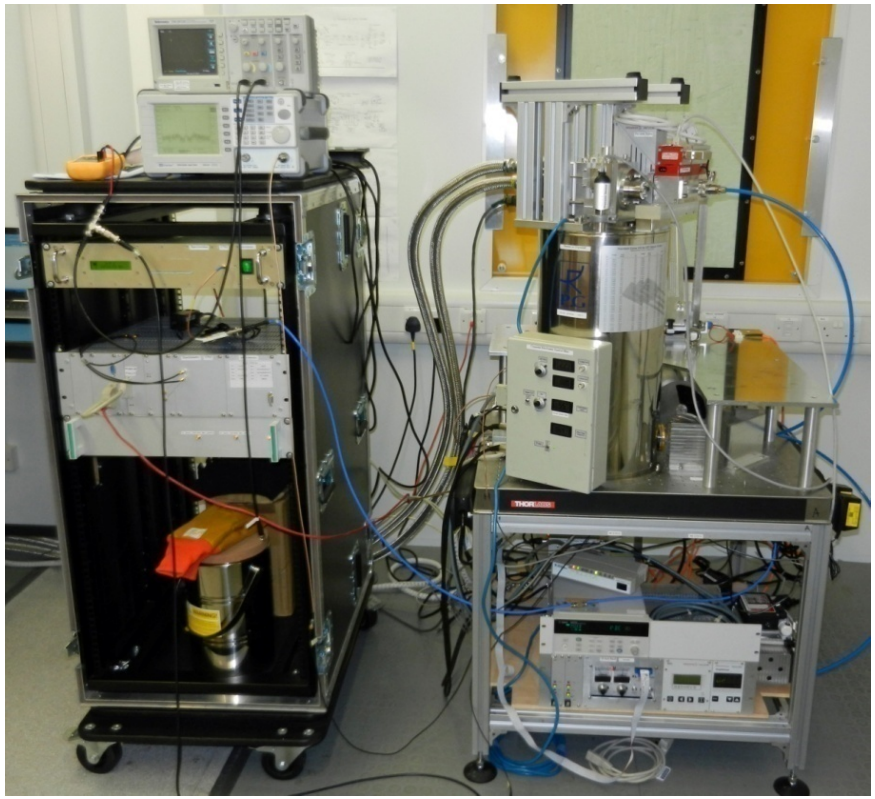
1. Instrument - Key features

- Ground-based, passive, continuous measurements (polar winter/diurnal variability).
- Heterodyne detection using SIS mixer @ 4 K for high sensitivity/time resolution.
- Chirp transform spectrometers for high frequency resolution.
- Simultaneous profiles of NO, O_3, and CO from 35 km to 85 km (up to 8 km vertical resolution) for all conditions.



A microwave radiometer for the remote sensing of nitric oxide and ozone in the middle atmosphere, Espy et al, Proc. SPIE 6362, 63620P-3 (2006).

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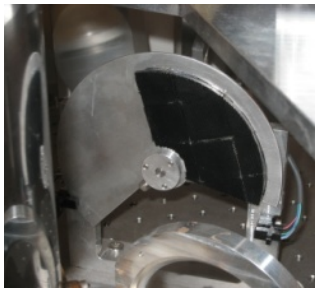
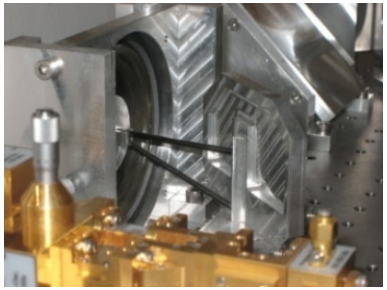
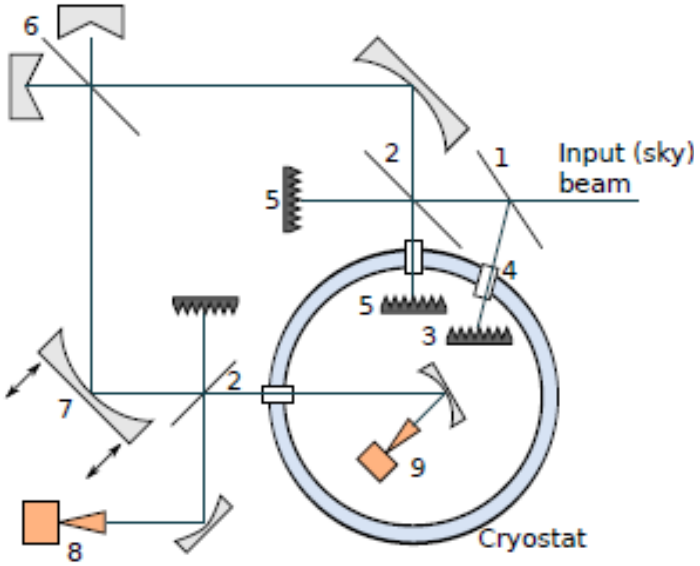
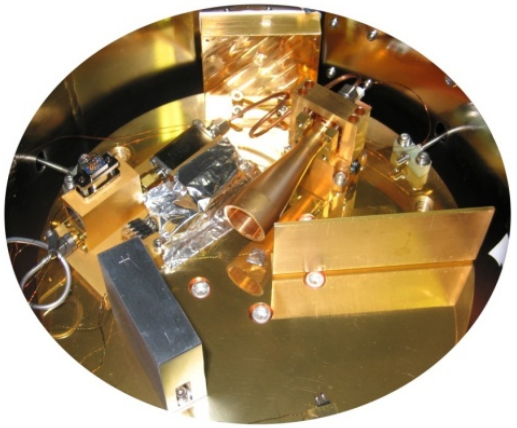
1. Instrument - Optical layout

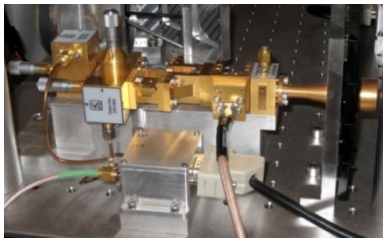


1. Hot-cold-sky chopper
2. Polarising grid (beam-splitter)
3. Cold load @ 60 K
4. Anti-reflection windows
5. Beam dump
6. Martin-Puplett sideband filter
7. Phase modulator
8. Local oscillators (225 GHz & 255 GHz)
9. SIS mixer @ 4 K









Mesospheric CO above Troll station, Antarctica observed by a ground-based microwave radiometer, Straub et al., Earth Syst. Sci. Data (in press, 2013).

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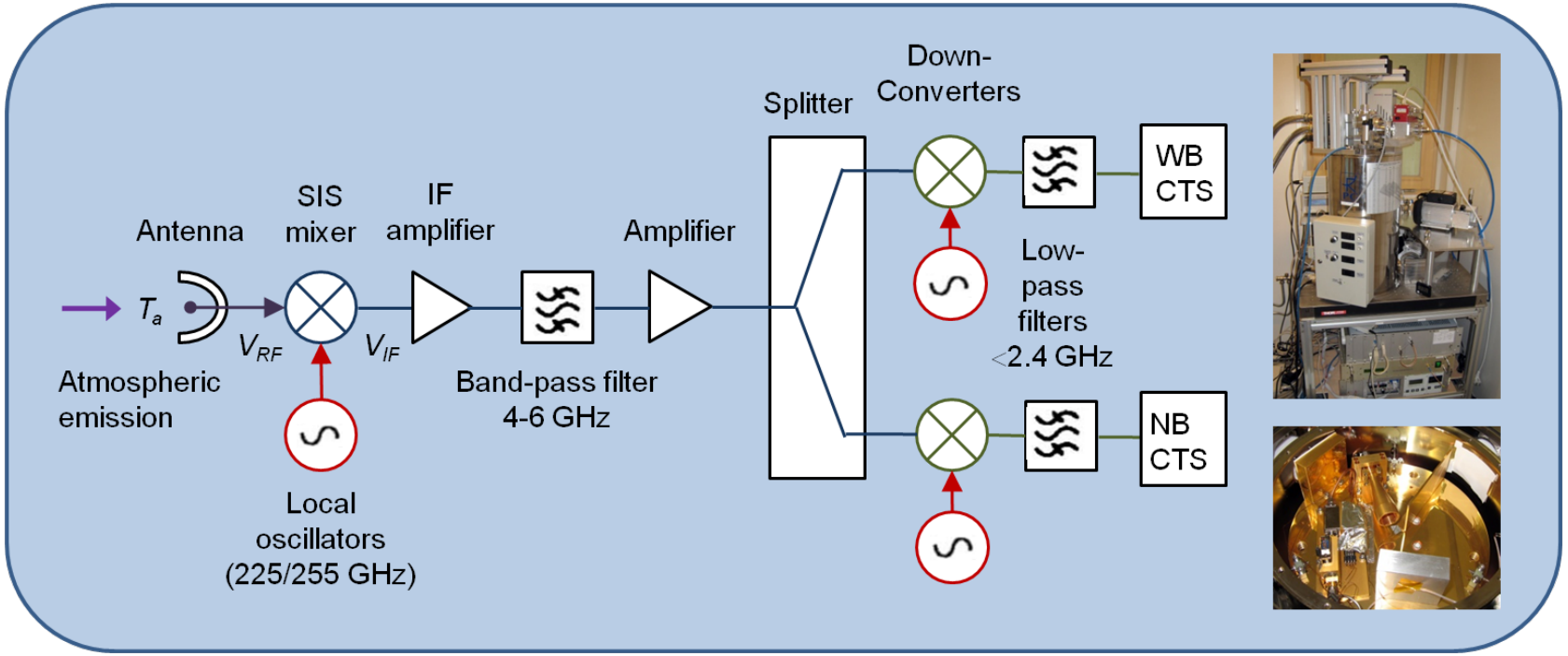
1. Instrument - mm-wave–IF–RF signal chain



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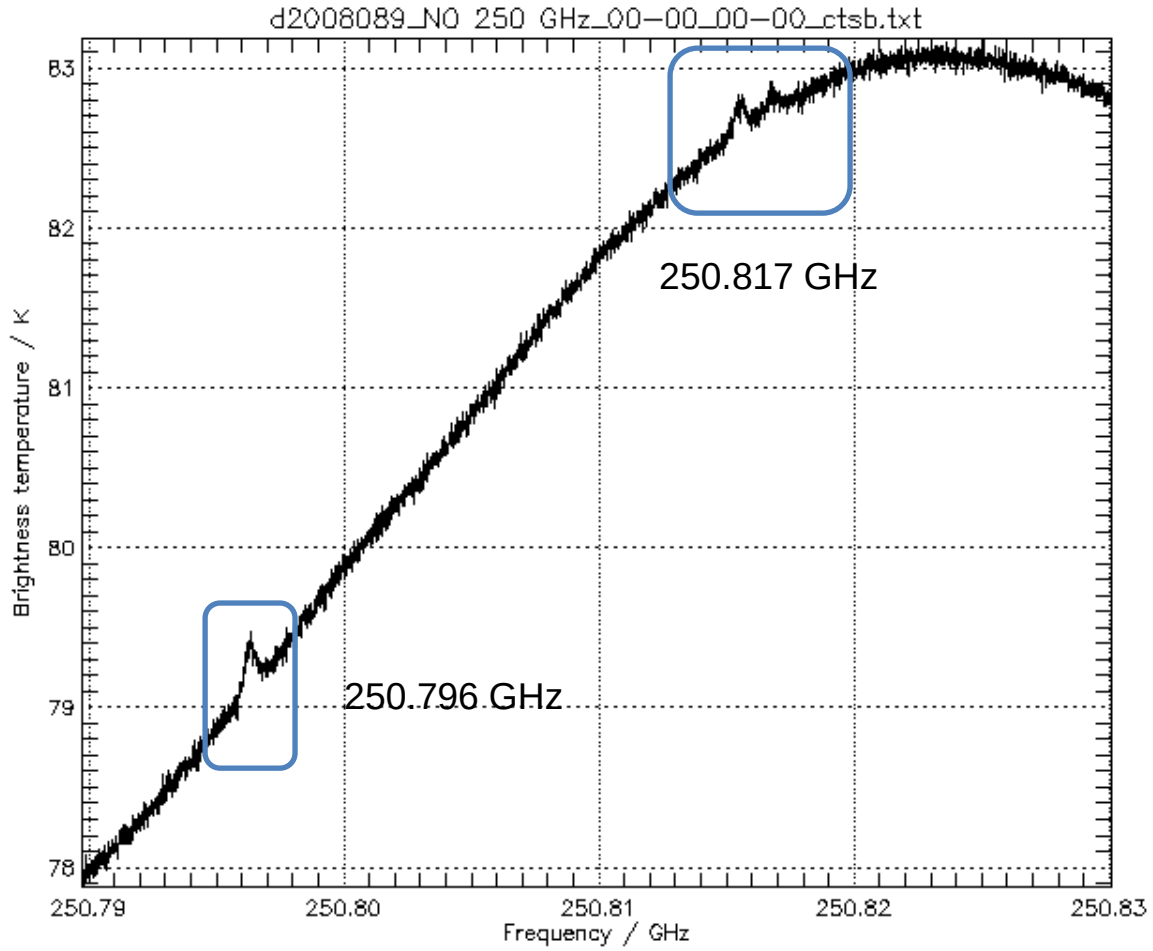
2. NO observations - 250 GHz spectrum



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2. Data inversion

Parameter	NO	Ozone
Code	MOLIERE v5 (Microwave Observation Line Estimation and Retrieval): forward model/inversion.	
Radiative transfer	Line-by-line and continua absorption/emission from HITRAN 2008 database.	
	125 levels, 0-125 km, 1 km interval.	
A priori atmospheric profiles	Neumayer ozonesonde & SIC model (2006) monthly average pressure/temperature & VMR's: NO, O_3, and H_2O. SOPRANO 80n VMR's for other species.	
Inversion method	Linear inversion using optimal estimation.	
Adjusted parameters	NO profile, H_2O profile, frequency shift; baseline – slope + sine wave amplitude, oscillation period, & phase.	O_3 profile, H_2O profile, frequency shift; baseline – slope.
Instrument model	Measurement error covariance: Observed ΔT; Antenna response; Spectrometer channel response (sinc function).	

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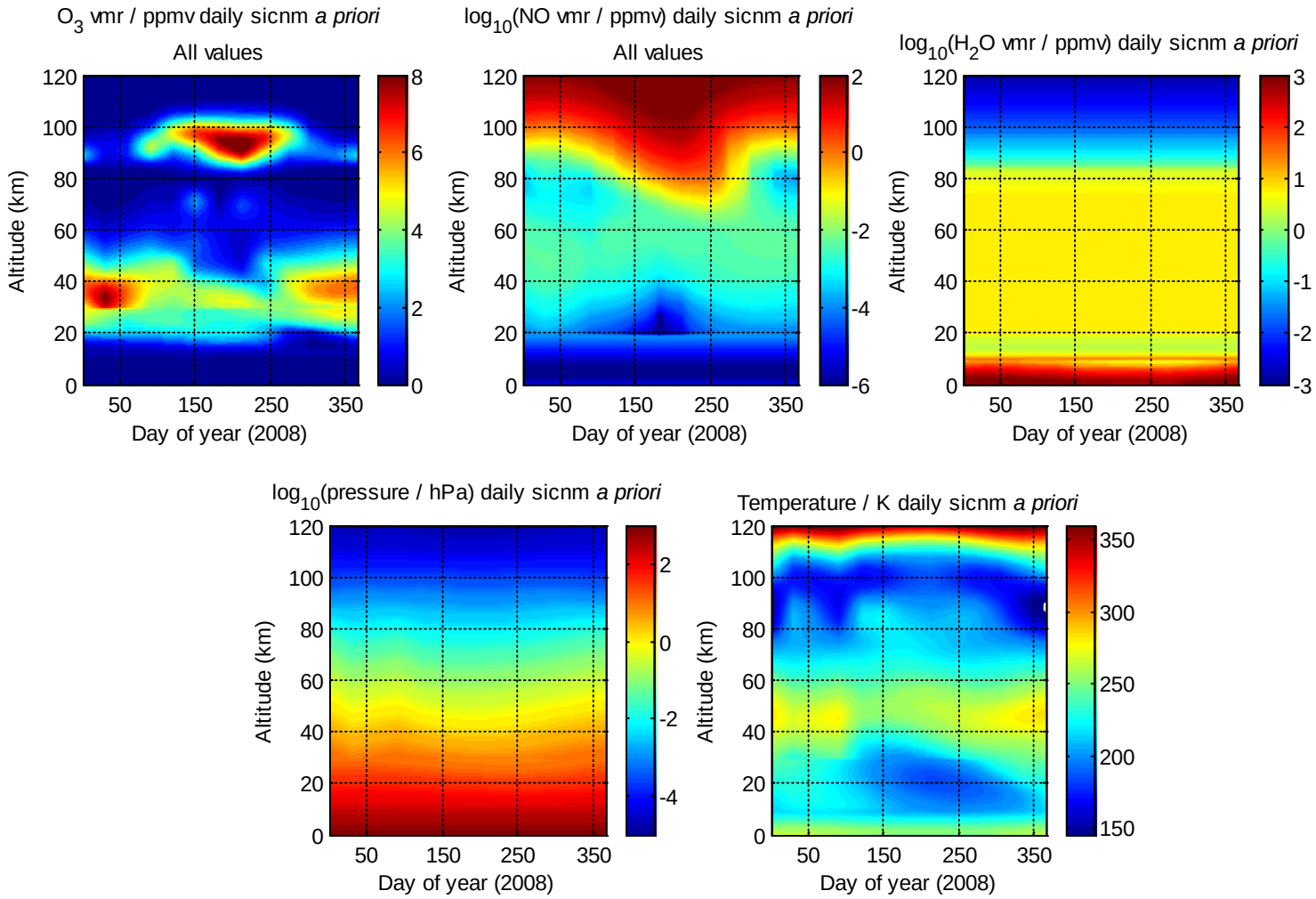
2. Data inversion – *a priori* data



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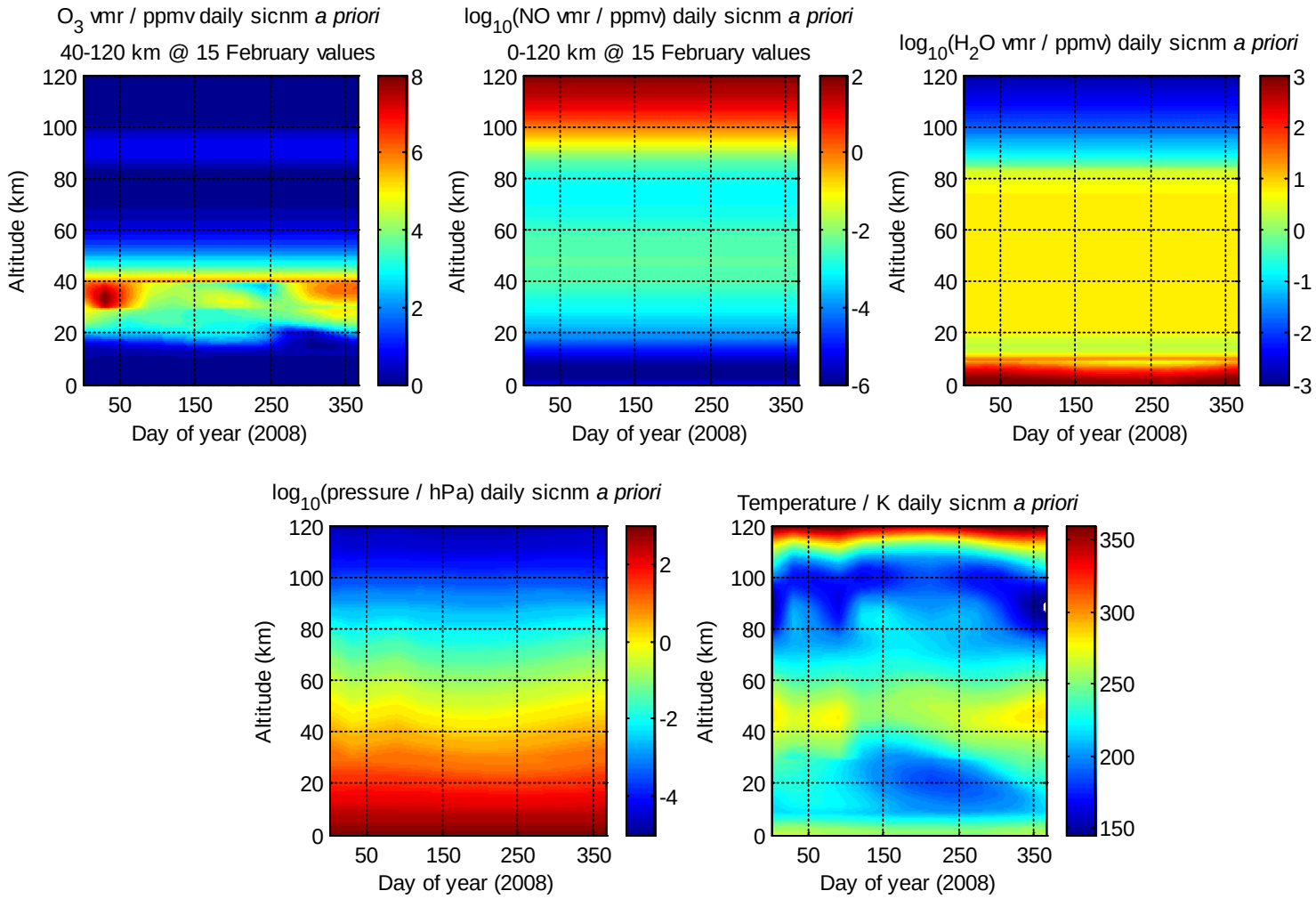

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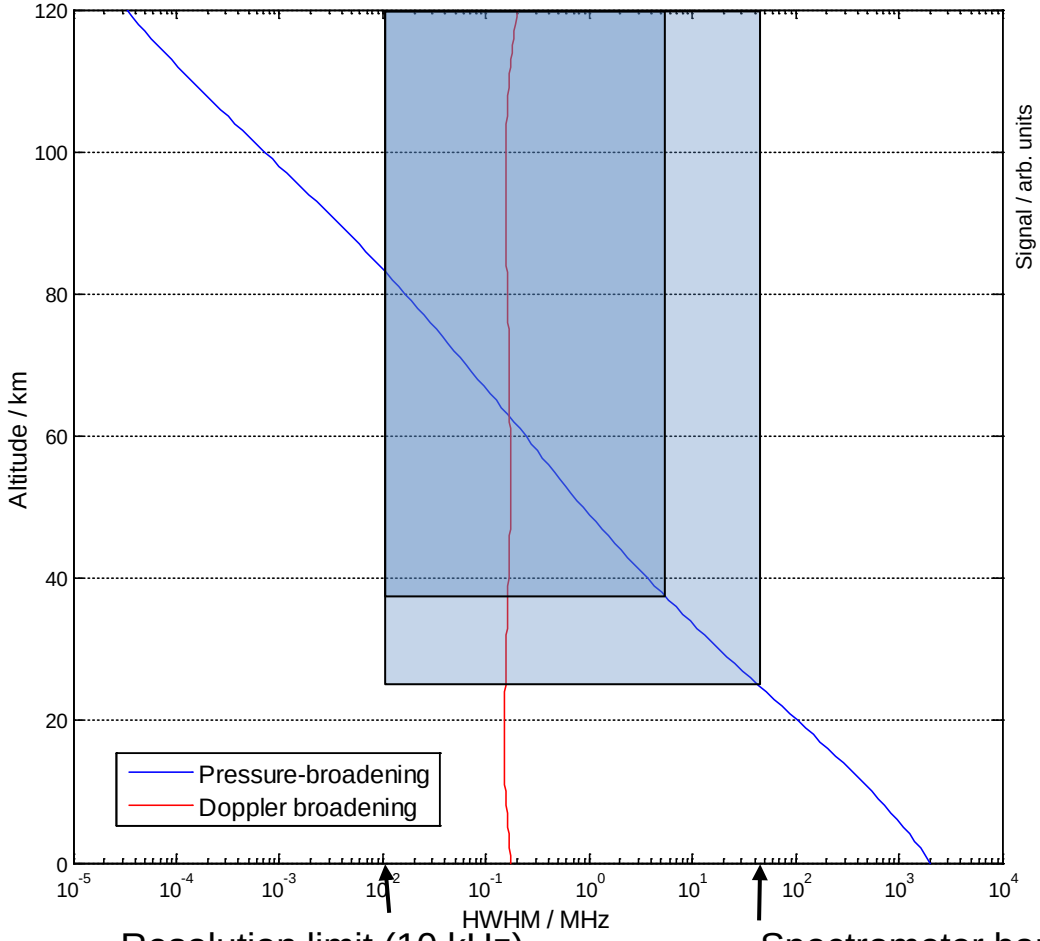
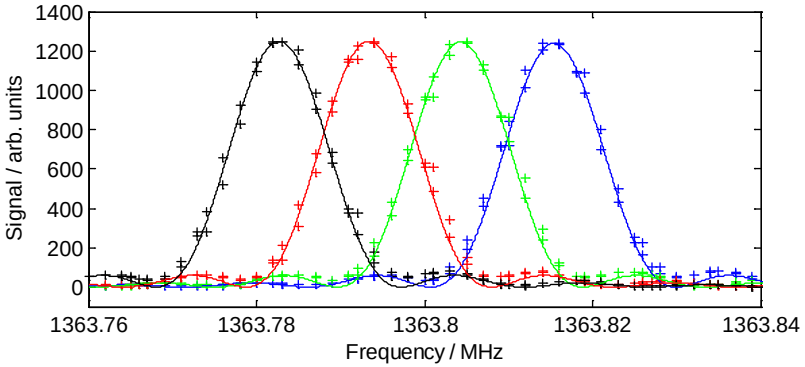
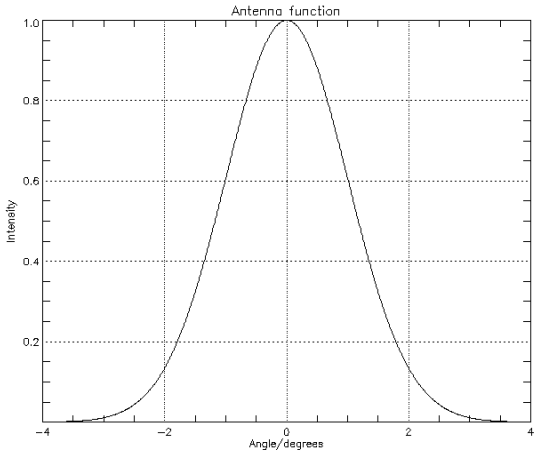
2. Data inversion – NO vertical profiling







Resolution limit (10 kHz)

Spectrometer bandwidth limit (40 MHz)

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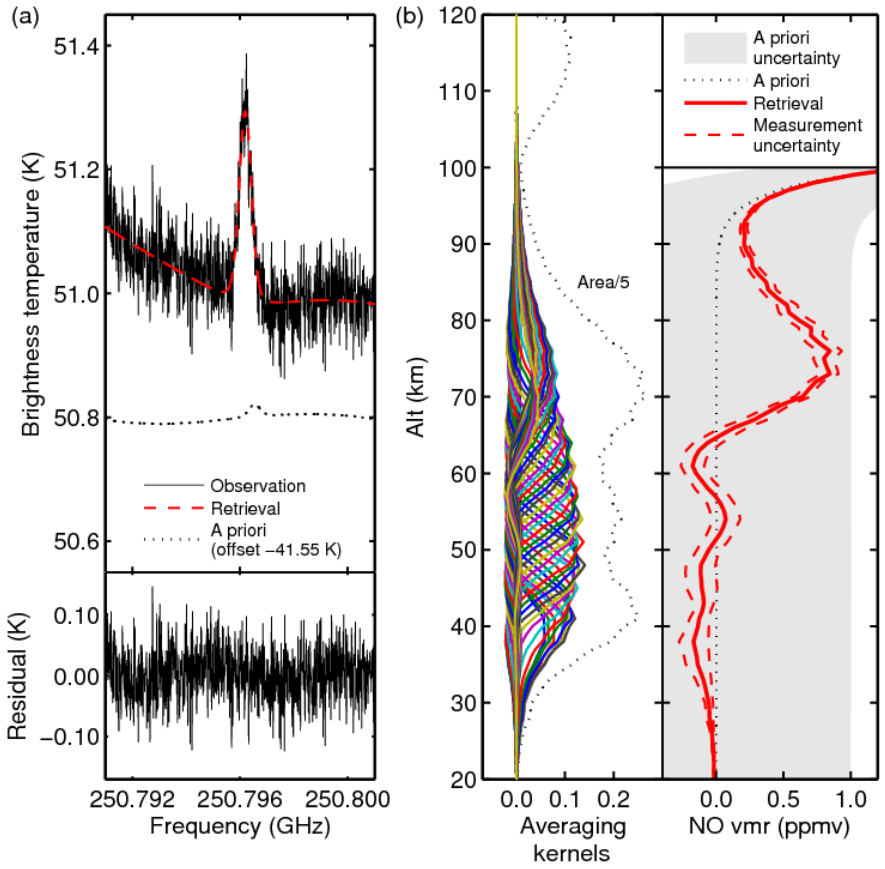
2. Data inversion – example NO retrieval



Newnham et al., Direct observations of nitric oxide produced by energetic electron precipitation into the Antarctic middle atmosphere, Geophys. Res. Lett., 38, L20104, doi:10.1029/2011GL048666.

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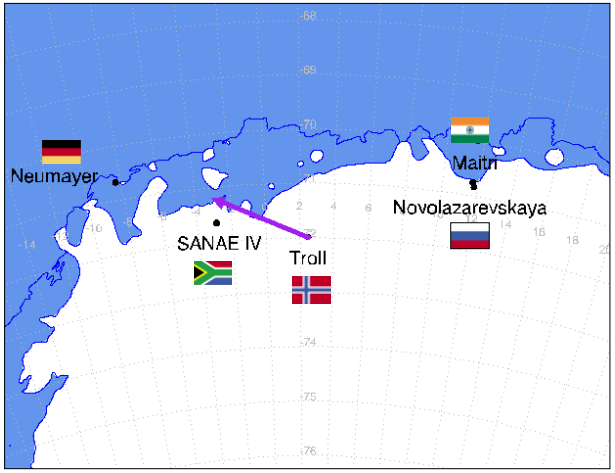
3. Antarctic deployments

- Troll station, Antarctica (72.0°S, 2.5°E)
  - 2/2008-1/2010.
  - Deployed in collaboration with NPI.
  - Dry location (polar desert).
  - Relevant co-located instrumentation?



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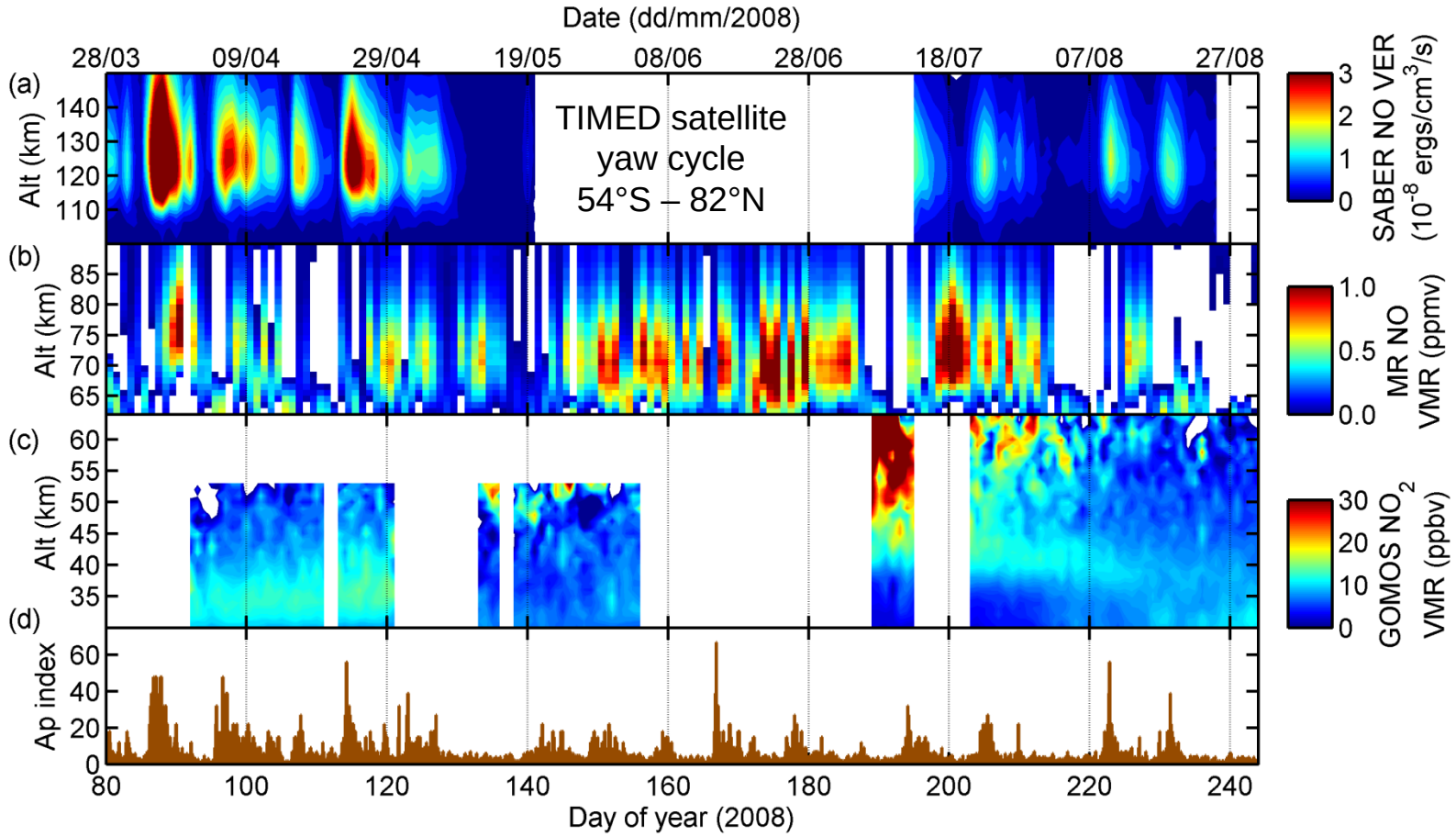
3. Antarctic deployments



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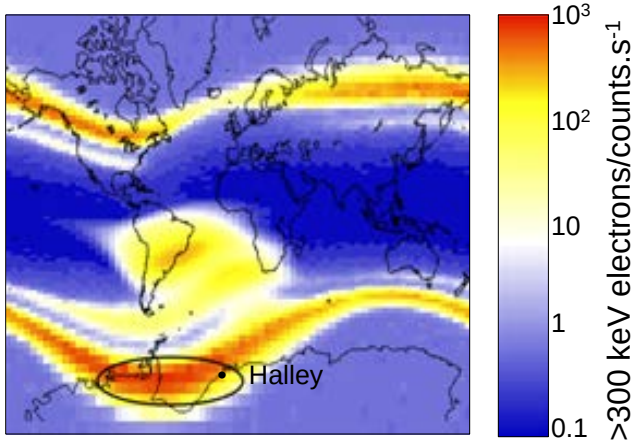
3. Antarctic deployments

- Halley VI station, Antarctica (76°S, 27°W)
  - Observations 1/2013 – 2/2015.
  - Scientific collaborations with Leeds, Lancaster, FMI/SGO, NCAR, University of Otago, and Met Office.
  - Co-located atmospheric observations (radars, riometer, meteorology).



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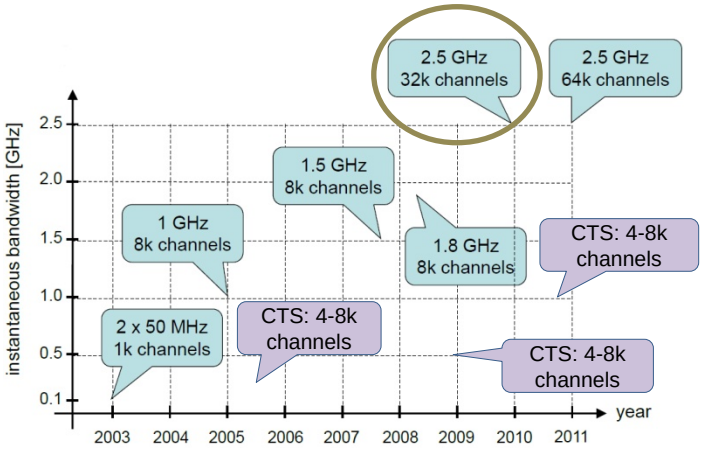
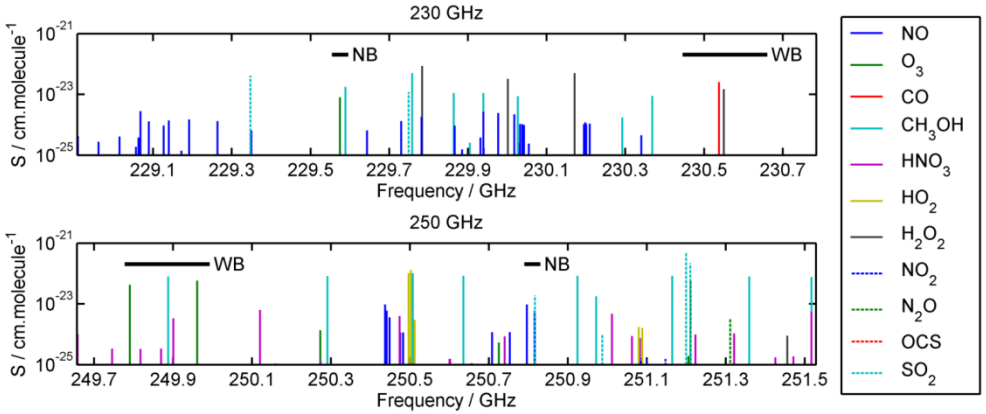
4. Future developments

- Digital FFT spectrometer upgrade
  - 300 MHz bandwidth / 10 kHz resolution for NO, O_3, and CO ⇒ Improve altitude coverage.
  - 2.5 GHz bandwidth / 80 kHz resolution ⇒ Measure new atmospheric species.
  - Doppler shifts ⇒ meridional / zonal winds.





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Acknowledgements

- Radiometer hardware & deployment
  - David Maxfield, Mark Clilverd, & Paul Breen (BAS).
  - Atle Markusson, Asbjørn Djupdal, & Tore Dahl (NPI Troll station).
- Data inversion
  - Joachim Urban (Chalmers University).
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  - UK's Natural Environment Research Council.

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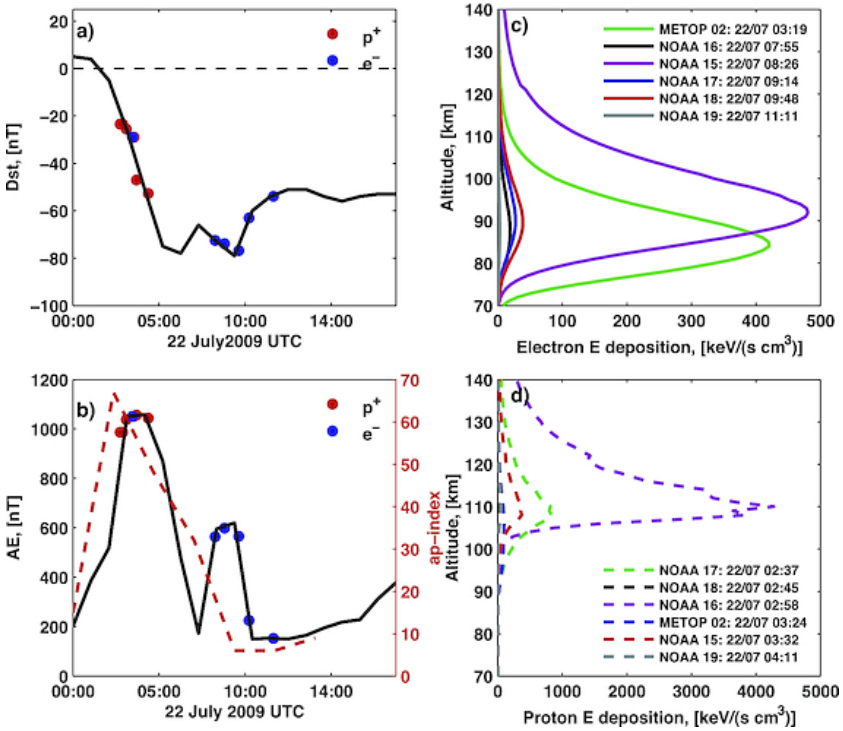
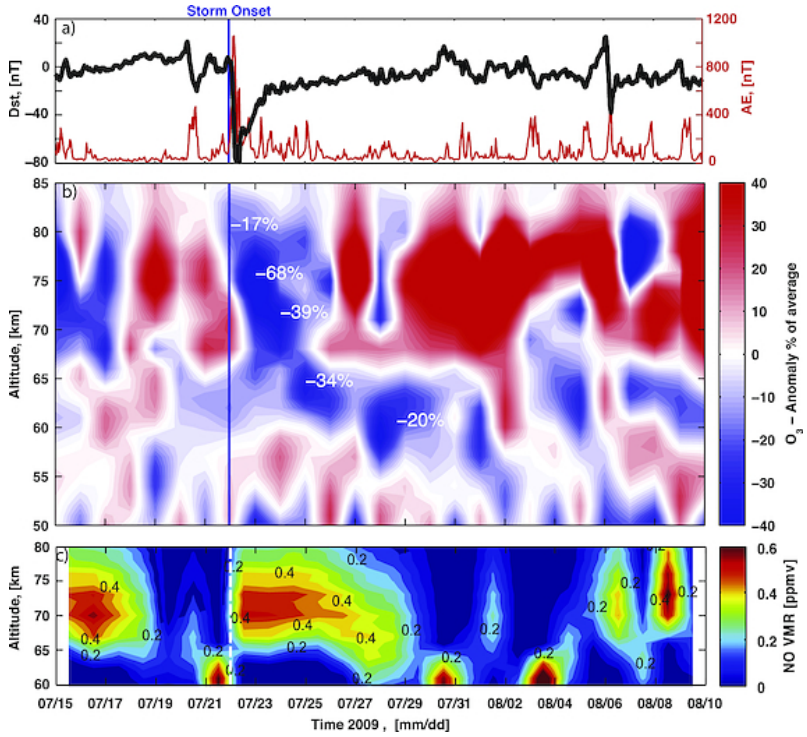
3. Antarctic deployments





Daae, M., P. Espy, H. Nesse Tyssøy, D. Newnham, J. Stadsnes, and F. Søraas (2012),
The effect of energetic electron precipitation on middle mesospheric night-time ozone during and after a moderate geomagnetic storm, Geophys. Res. Lett., 39, L21811, doi:10.1029/2012GL053787.