POLAR SCIENCE FOR PLANET EARTH

Simulation study for Ku-band microwave radiometry of the polar atmosphere

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NERC Technologies
Proof-of-Concept grant
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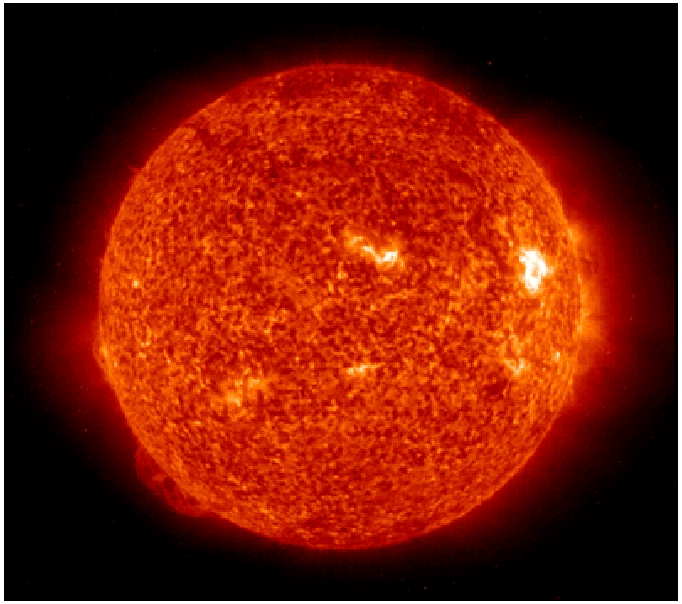
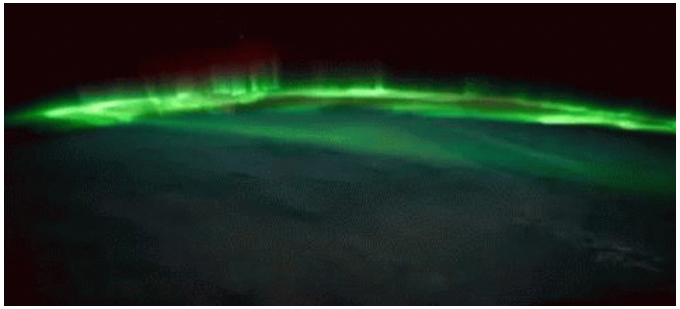
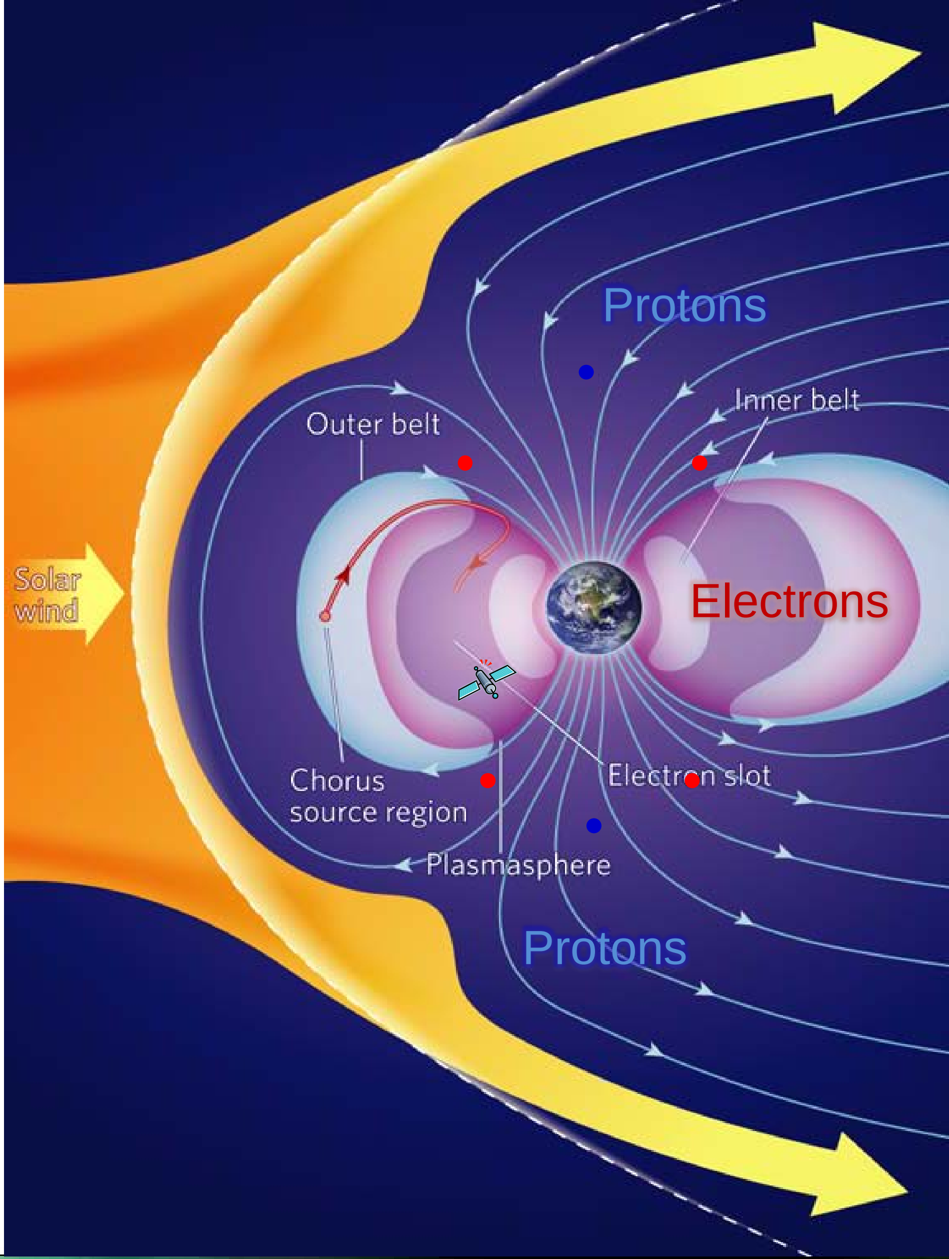
BAS – Space Weather & Atmosphere



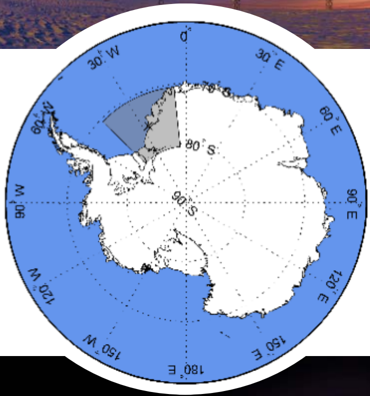


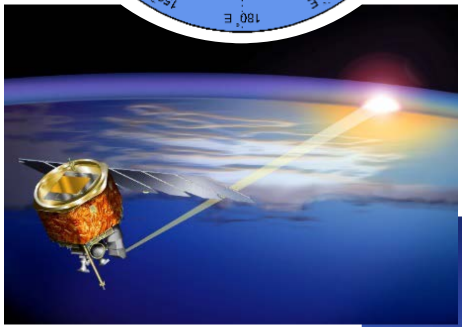


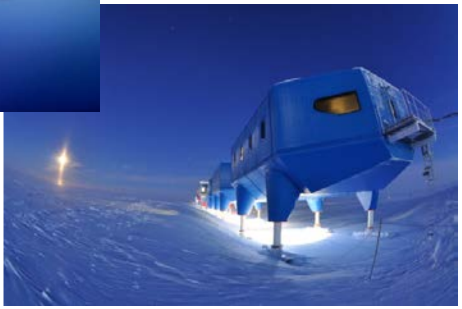
BAS – Space Weather & Atmosphere

Science & Innovation

- Science priorities
  - – Space radiation environment.
  - – Atmospheric heating.
  - – Space-atmosphere coupling.
  - – Solar effects on climate.
- Technologies / expertise
  - – Instruments: Ground-based radars, radiometers, VLF receivers, & magnetometers.
  - – Computer models: BAS radiation-belt model, atmosphere models.
  - – Data: Exploiting ground and space-based observations.



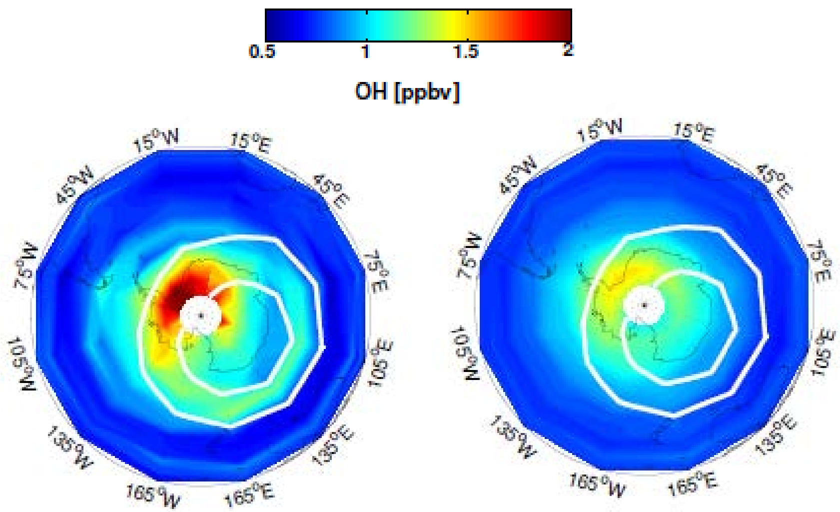




Ku-band atmospheric microwave radiometry

Space weather and the polar atmosphere

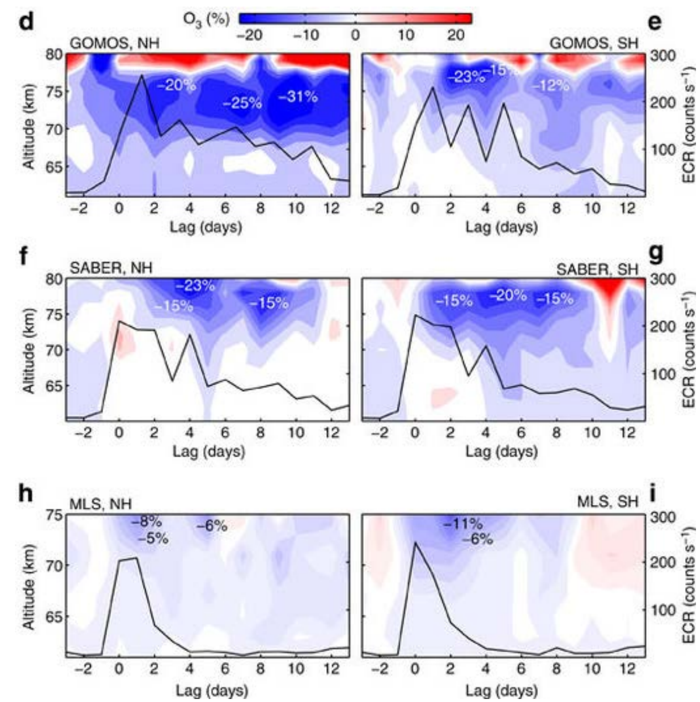
Hydroxyl (OH) at 70–78 km



High 100-300 keV electron flux

Low 100-300 keV electron flux

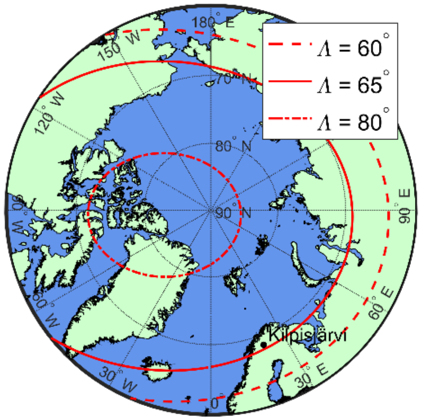
Mesospheric ozone (O_3)

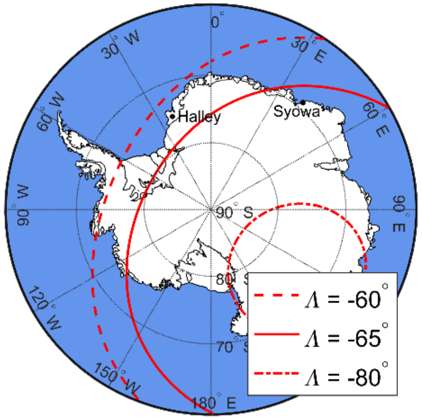


Ku-band atmospheric microwave radiometry

Space weather and the polar atmosphere

- The polar middle atmosphere responds strongly to solar variability and space weather.
- ~1250 magnetospheric substorms / year ⇨ high energetic electron flux.
- New O_3 and OH measurements are needed to verify model predictions.

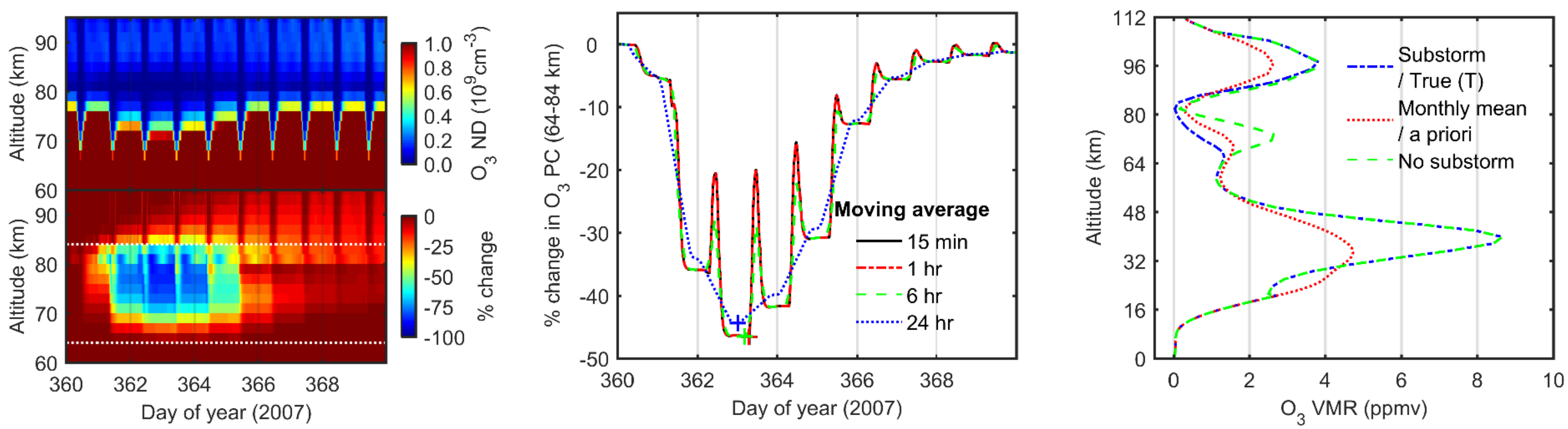




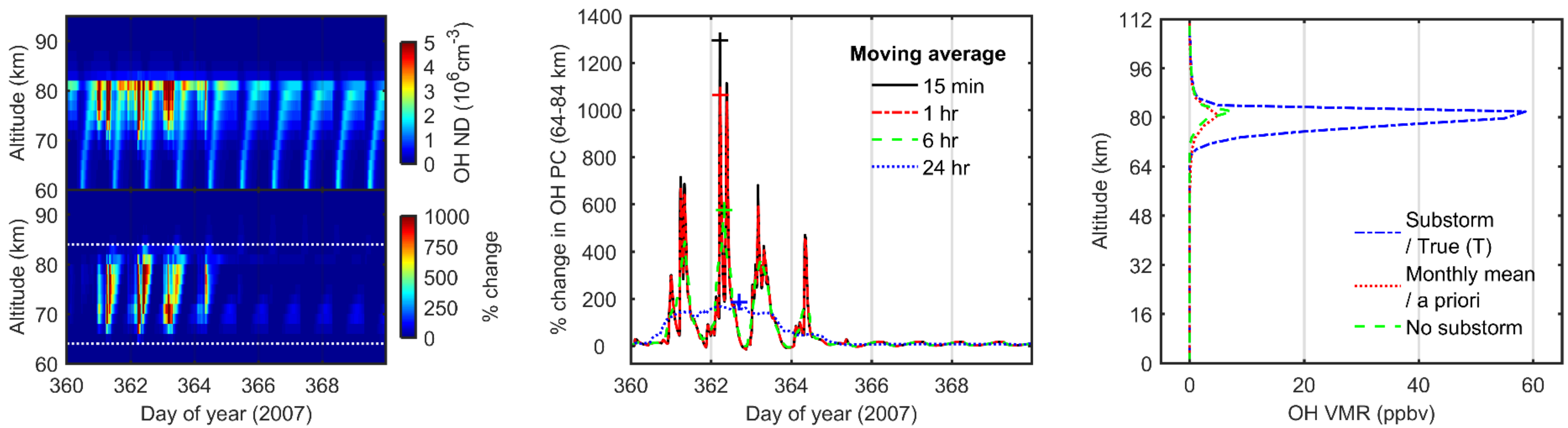
Ku-band atmospheric microwave radiometry

Atmospheric model – Sub-storms in December 2007

O_3

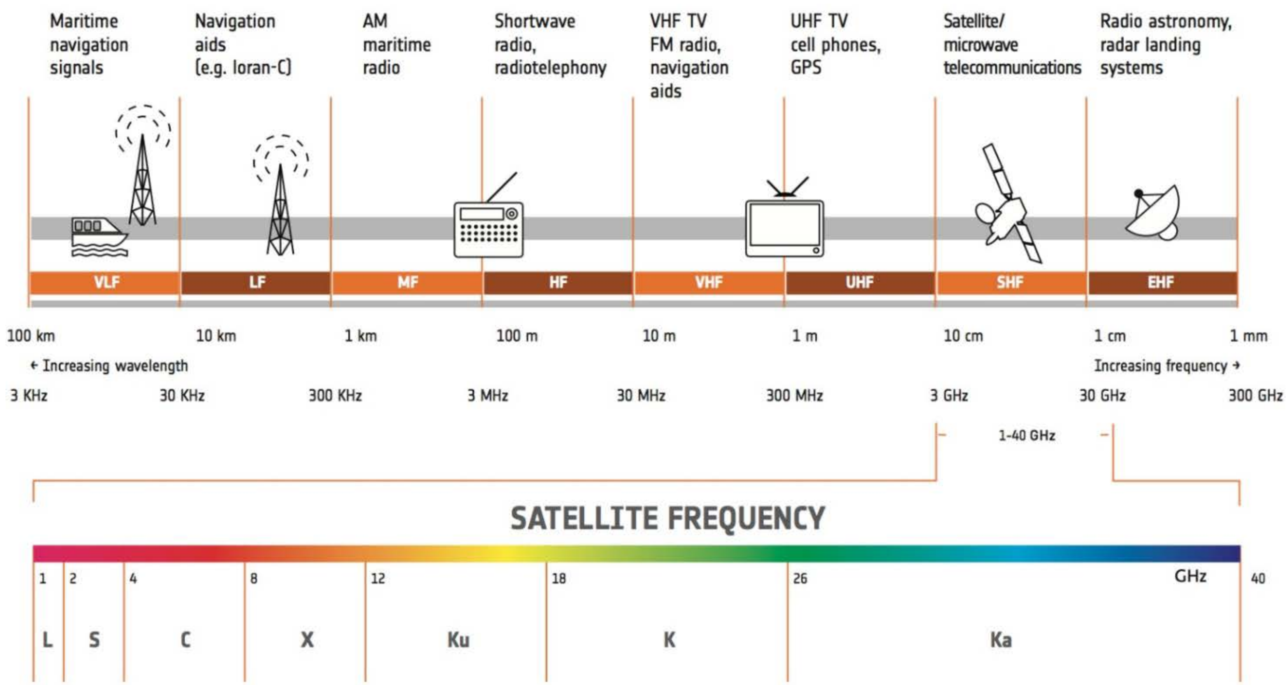


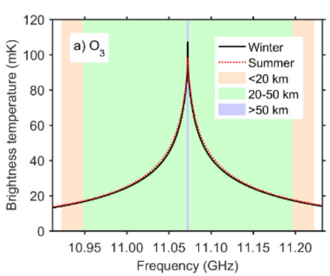
OH



Ku-band atmospheric microwave radiometry

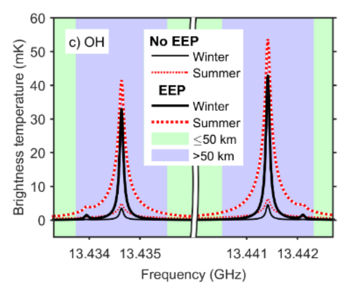
Ku-band microwave region





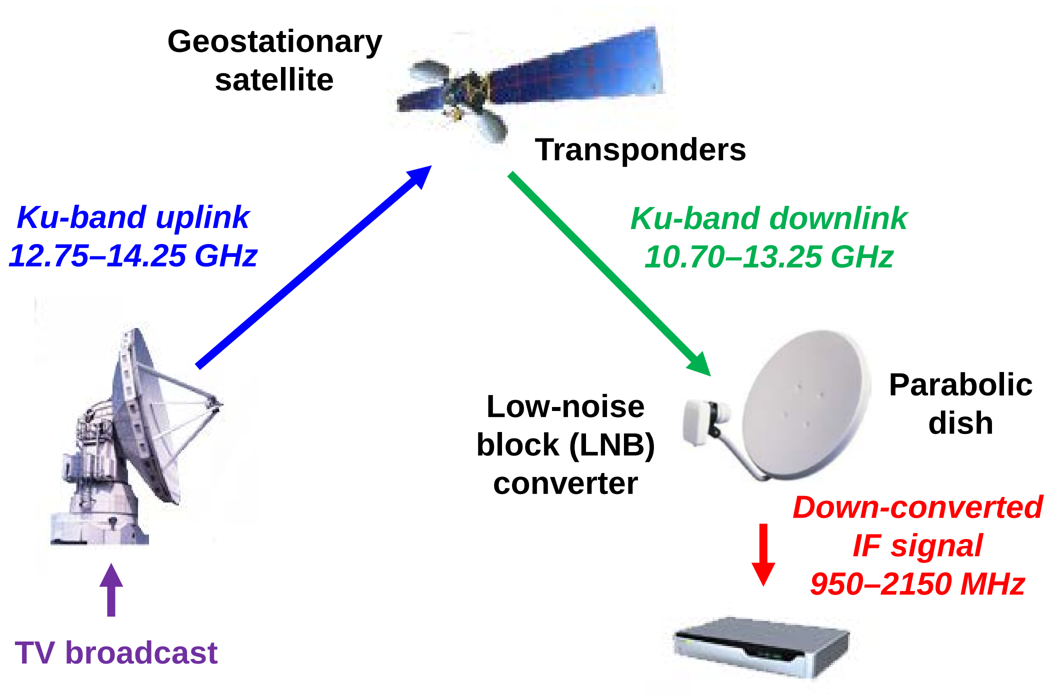
O_3
11.072 GHz

OH
13.44 GHz



Ku-band atmospheric microwave radiometry

From satellite TV to remote sensing



- Continuous atmospheric O_3 and OH profiling from the ground using satellite TV receiver technology.
- Ground-based, passive technique.
- Radiometers can be assembled from low-cost, COTS components.

Ku-band atmospheric microwave radiometry

Optimal estimation retrieval

- Measured calibrated spectrum,

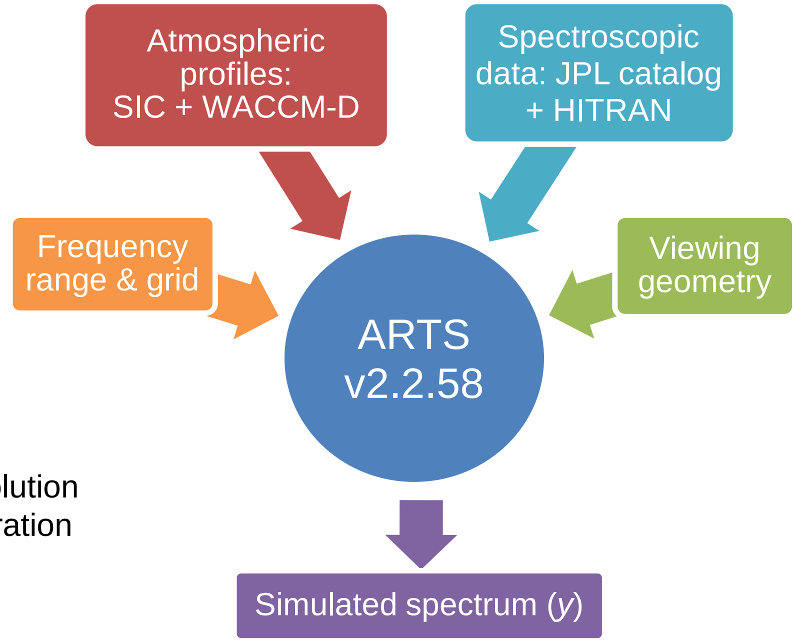
$$y = F(\boldsymbol{x}, \boldsymbol{b}) + \boldsymbol{\epsilon} \quad \begin{cases} F \text{ – Forward model} \\ x \text{ – State vectors} \\ b \text{ – additional parameters;} \\ \varepsilon \text{ – Measurement noise} \end{cases}$$

- Linearised forward model,

$$y = F(\hat{\boldsymbol{x}}_i, \boldsymbol{b}) + \mathbf{K}(\boldsymbol{x} - \hat{\boldsymbol{x}}_i) + \boldsymbol{\epsilon}$$

- Jacobian matrix, $\mathbf{K} = \left.\dfrac{\partial F}{d\boldsymbol{x}}\right|_{\hat{\boldsymbol{x}}_i, \boldsymbol{b}}$

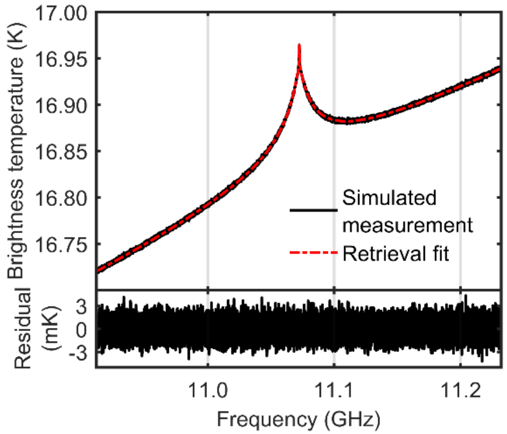
$\hat{x}_i$ - Retrieval solution after *i* th iteration

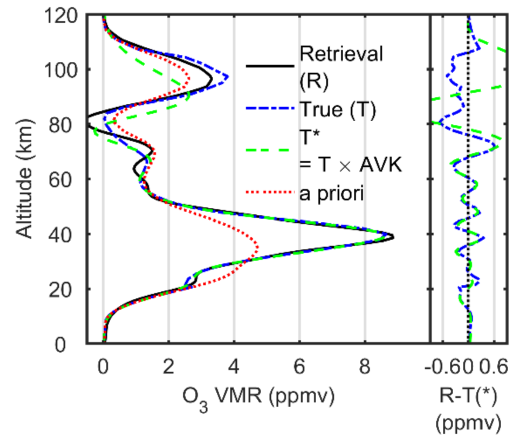


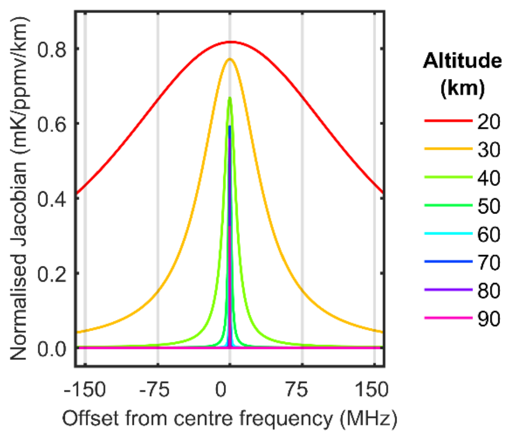
Frequency (GHz)	Target species	Retrieved interfering* and background species	Bandwidth (MHz)	*ΔT* (mK)
11.072	O_3	H_2O continuum*, OH, N_2, O_2, CO_2, HNO_3, H_2O_2, HO_2	12, 320	1–5
13.434, 13.441	OH	H_2O continuum*, O_3, N_2, O_2, CO_2, HNO_3, H_2O_2, HO_2	1, 12	1–10

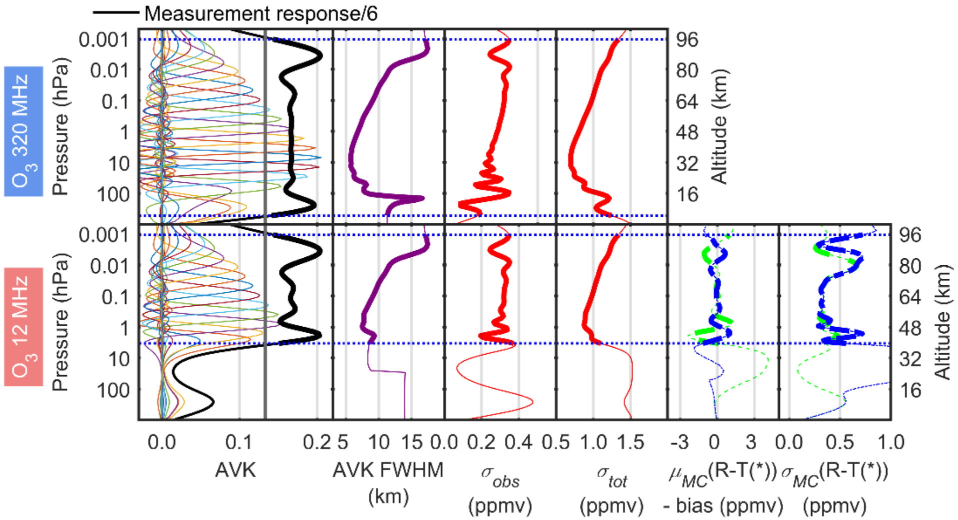
Ku-band atmospheric microwave radiometry

Simulation results - Ozone



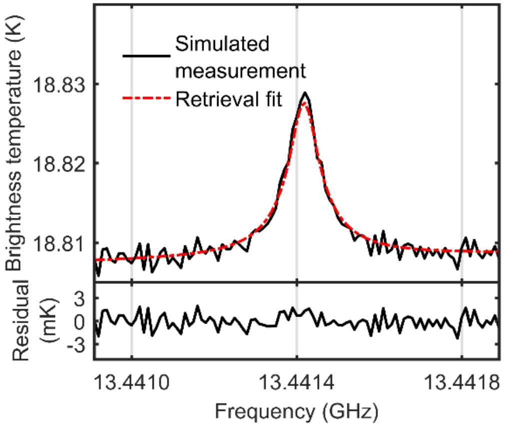


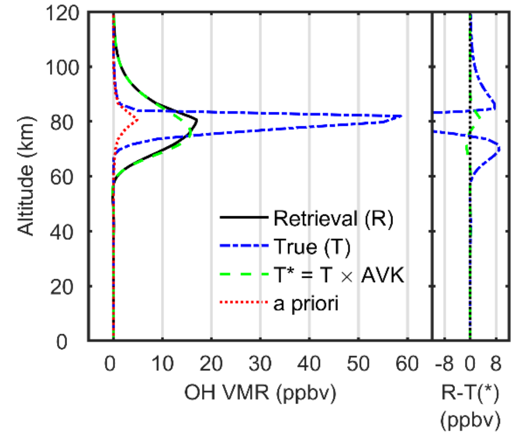


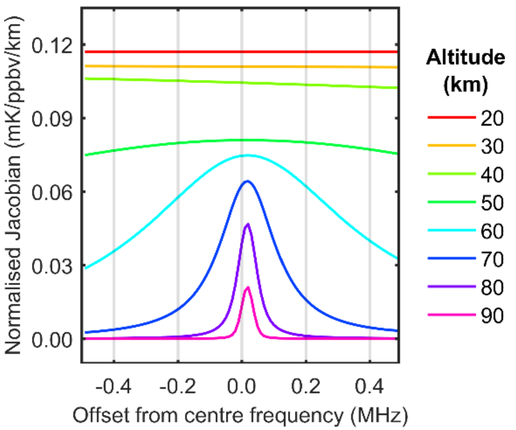


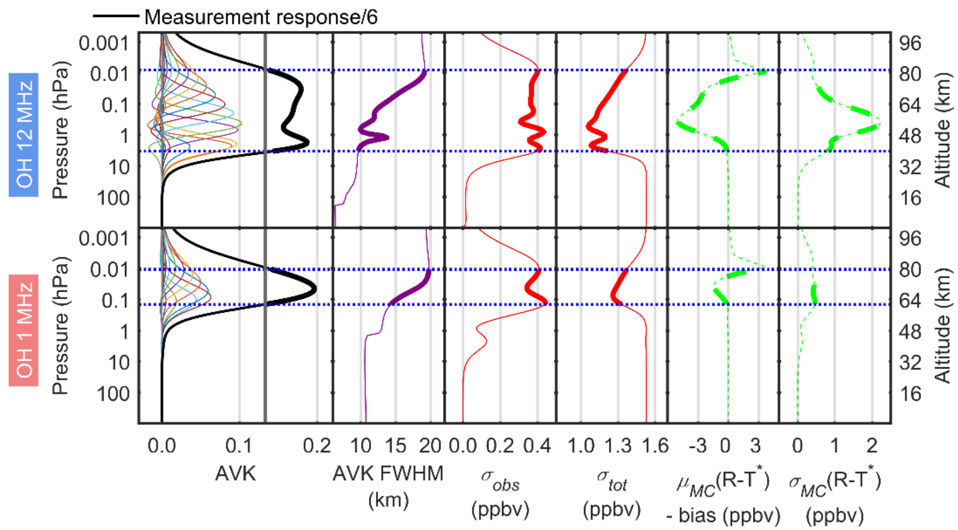
Ku-band atmospheric microwave radiometry

Simulation results – Hydroxyl (OH)









Ku-band atmospheric microwave radiometry
Conclusions

- Simulation techniques have been developed for modelling the retrieval of ozone and OH vertical profiles from 11–14 GHz microwave observations.

- Ku-band observations are highly applicable to future microwave instruments designed to study space weather events, atmospheric dynamics, planetary scale circulation, and chemical transport for polar and global climate modelling.

- Ground-based passive microwave remote sensing complements space-based EO.
  - O_3, NO_x ($NO + NO_2$), HO_x ($OH + HO_2$), NO_y species, tracers, temperature, humidity, zonal and meridional winds, vertical transport.