



STO₃RM project: Simulation study for ground-based measurements of O₃ and OH at 11-13 GHz

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ARTS 2017 workshop,
7th September 2017

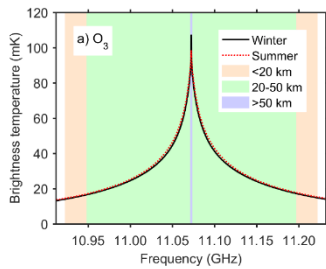
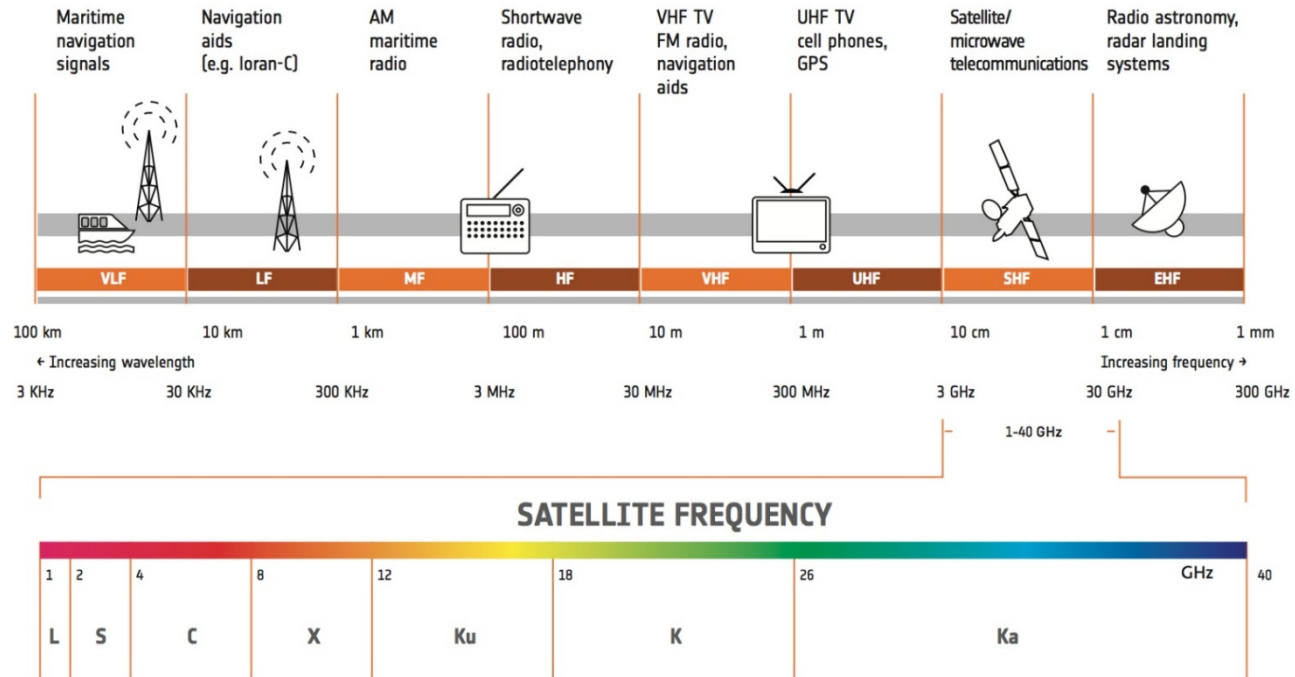


NERC Technologies
Proof-of-Concept grant
NE/P003478/1

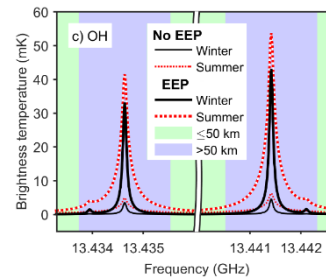


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Ku-band microwave region

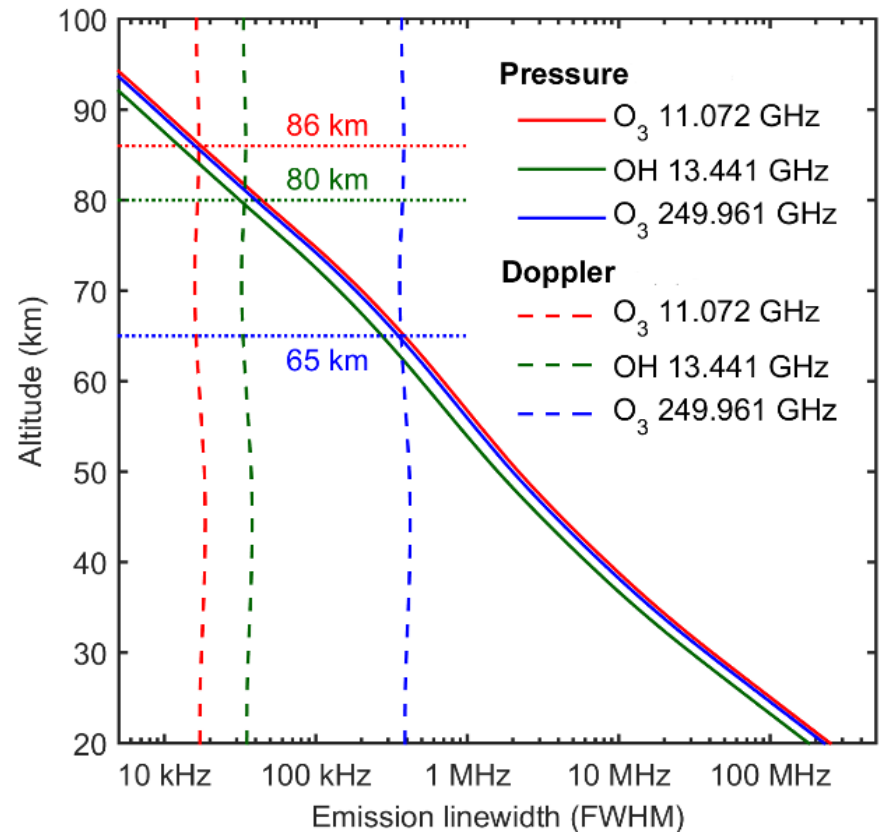
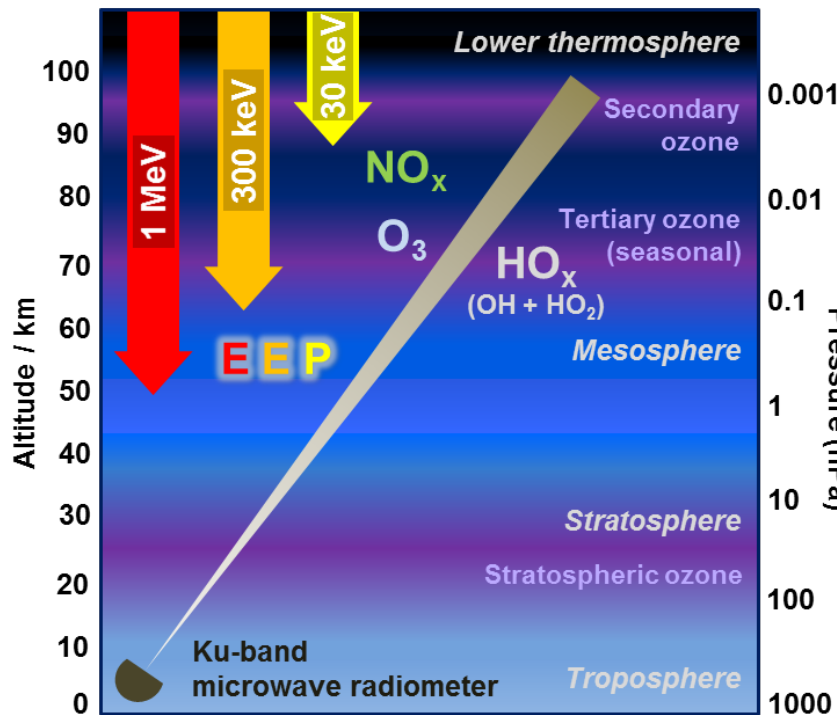


★
 ★
 O₃ 11.072 GHz
 OH 13.44 GHz



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Space weather and the polar atmosphere



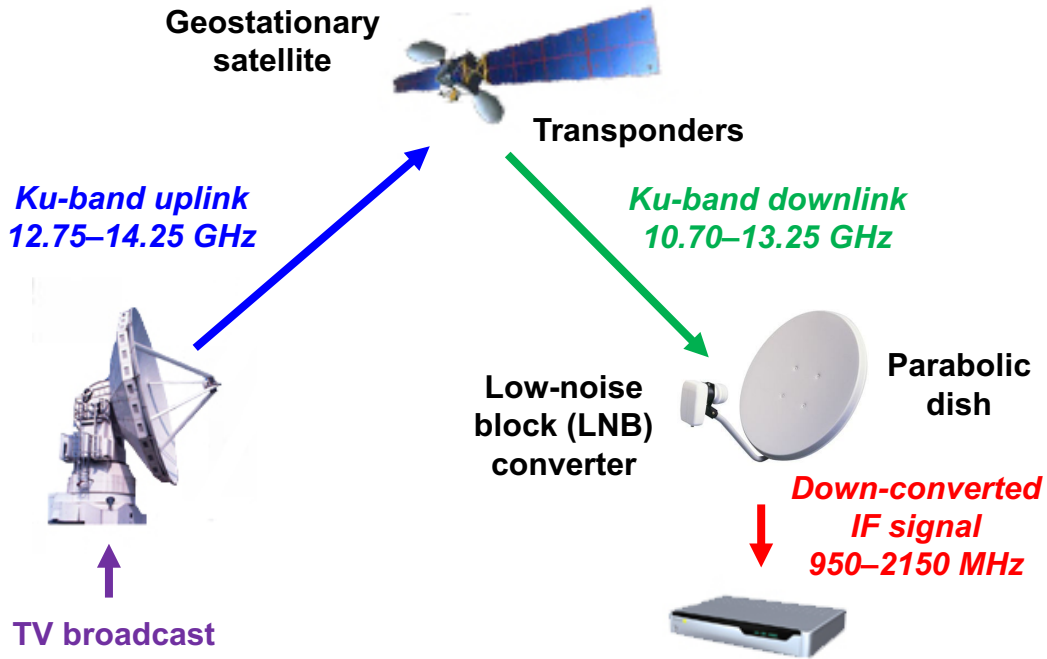
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From satellite TV to remote sensing



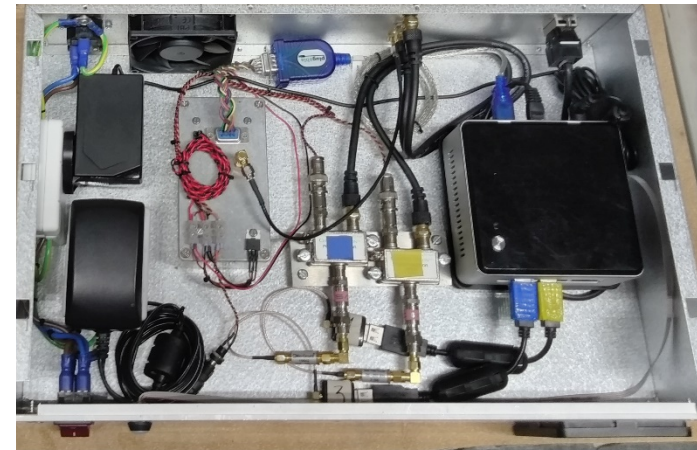
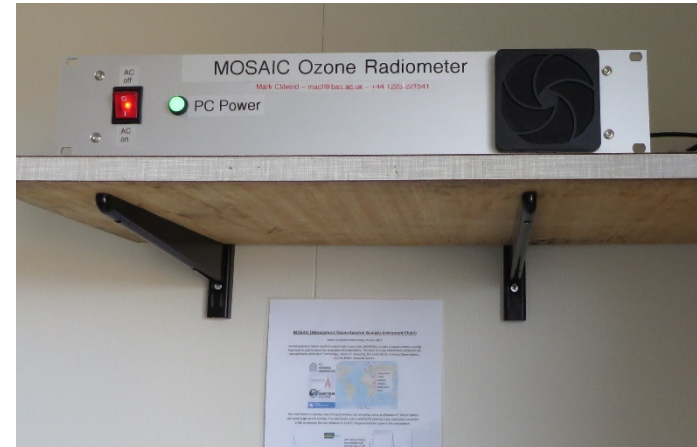
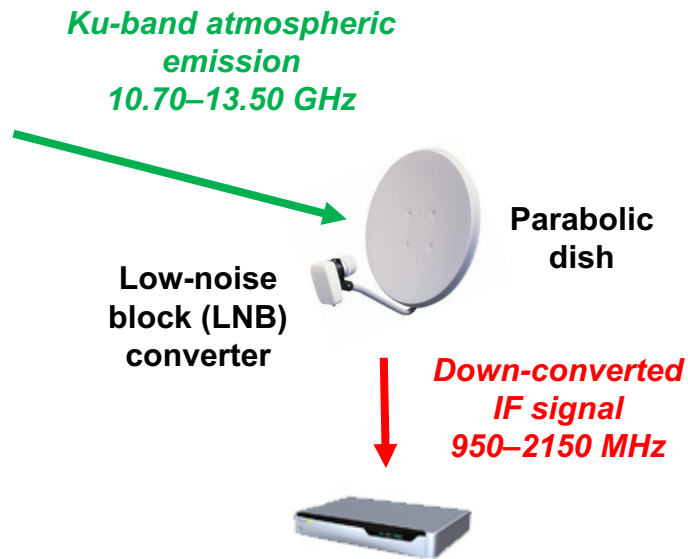
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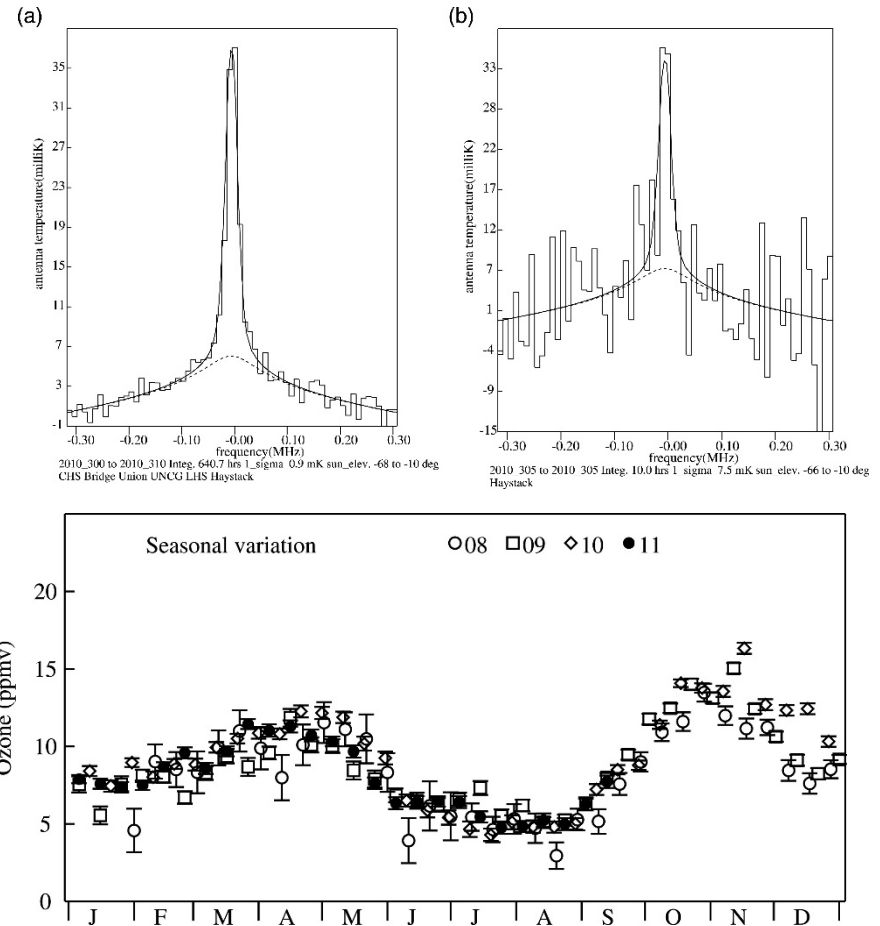
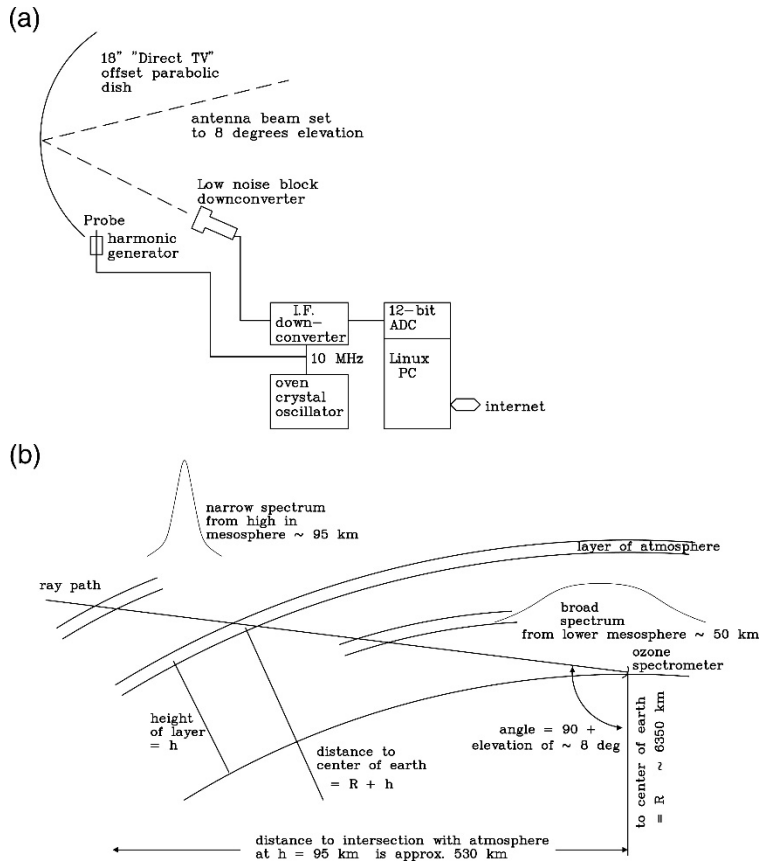
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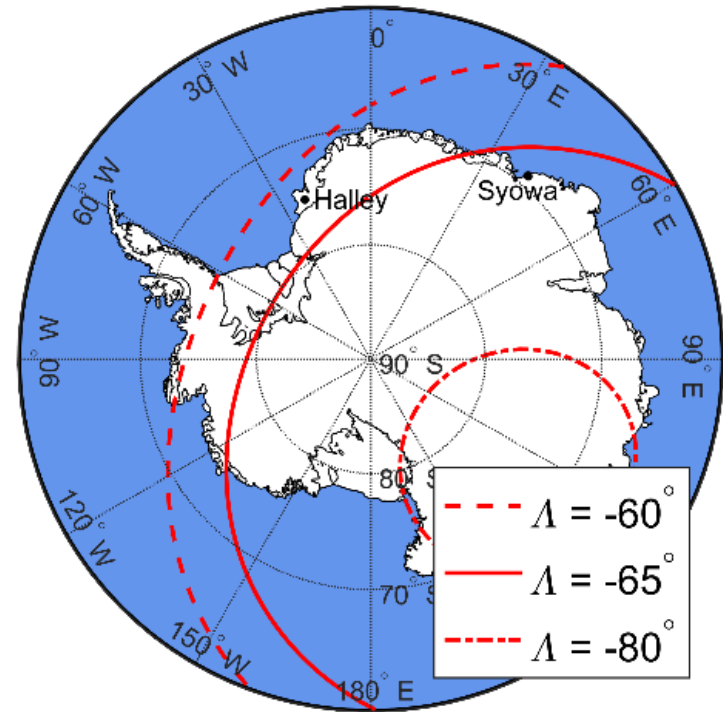
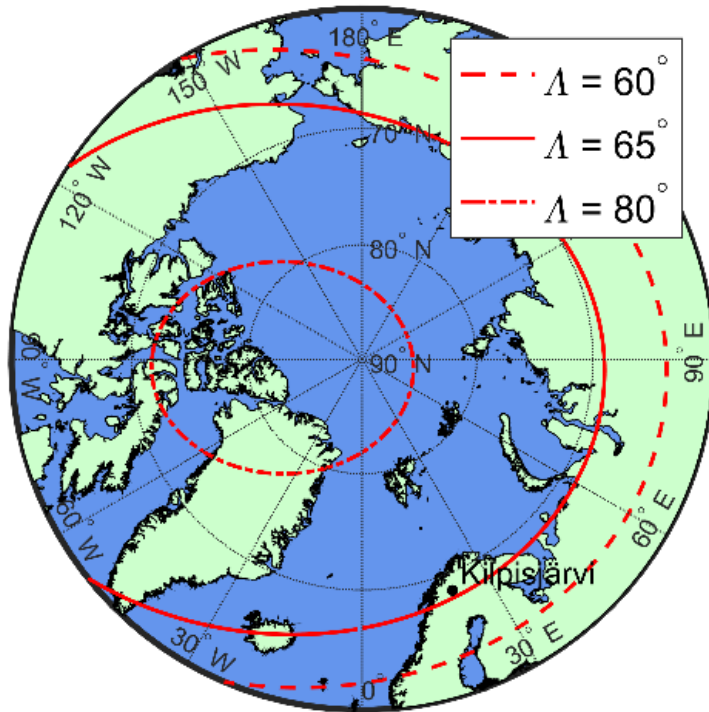
O₃ 11.072 GHz measurements



Rogers, A. E. E. et al. (2012), *J. Atmos. Oceanic Technol.*, 29, 1492–1504, doi:10.1175/JTECH-D-11-00193.1

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Geomagnetic storms & energetic particle precipitation



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Atmospheric profiles from SIC model & WACCM-D runs

- SIC model data for the April-May 2007 sub-storms.
 - O₃ and OH number density & VMR vertical profiles above Kilpisjärvi, Finland.
 - Sub-storm (EEP) and background conditions.
 - Altitudes 20-100 km.
- WACCM-D data.
 - O₃, OH, H₂O, O₂, N₂, HO₂, H₂O₂, & HNO₃ VMR.
 - Temperature, pressure, altitude, & geopotential height.
 - All data over the altitude range 0-140 km.

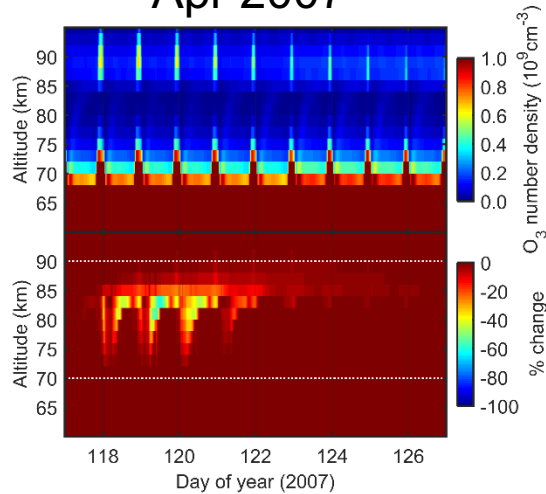


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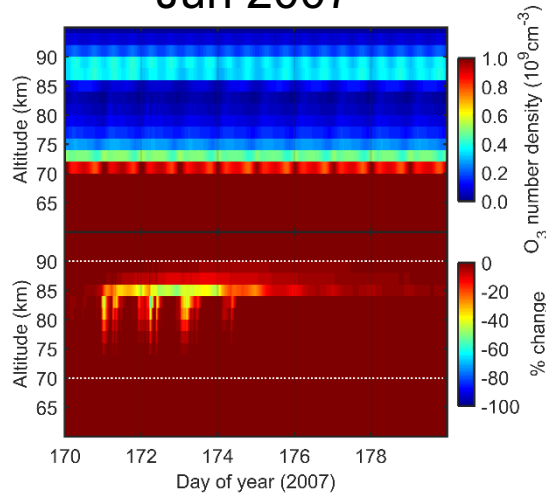
Atmospheric profiles from SIC model runs

O₃

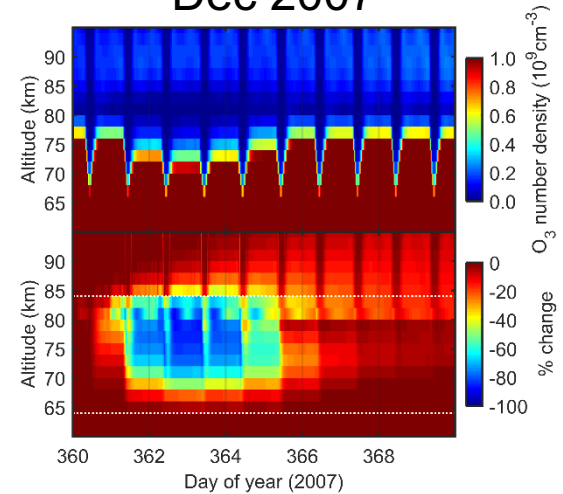
Apr 2007



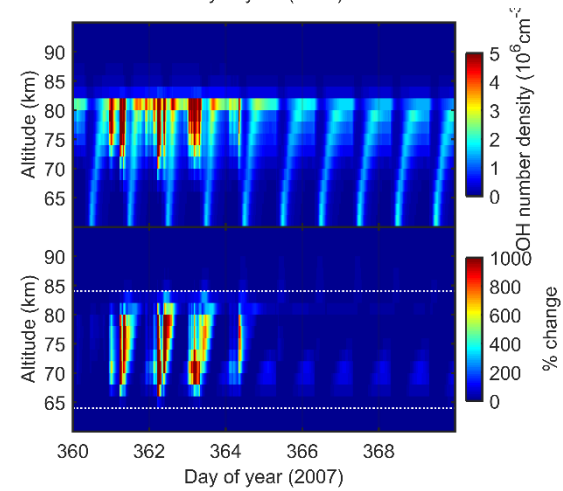
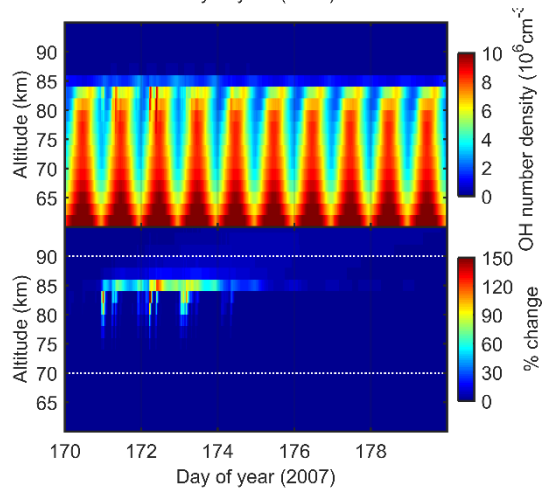
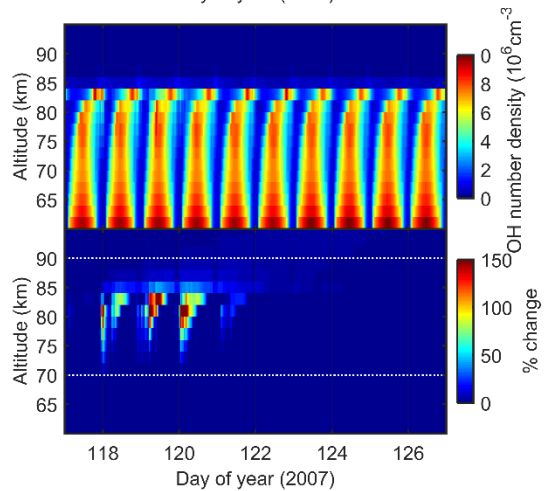
Jun 2007



Dec 2007



OH

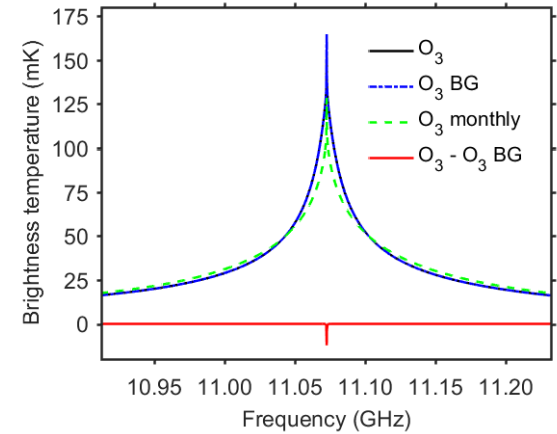
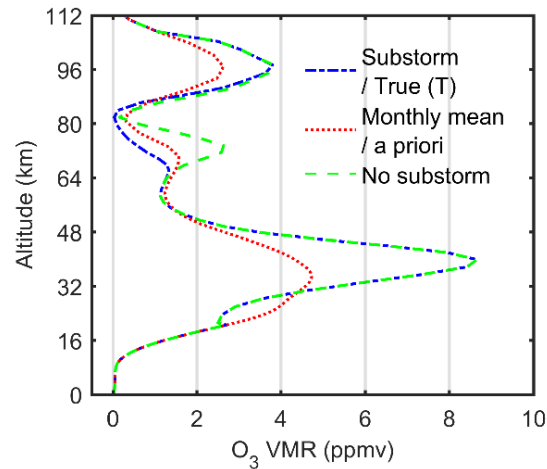
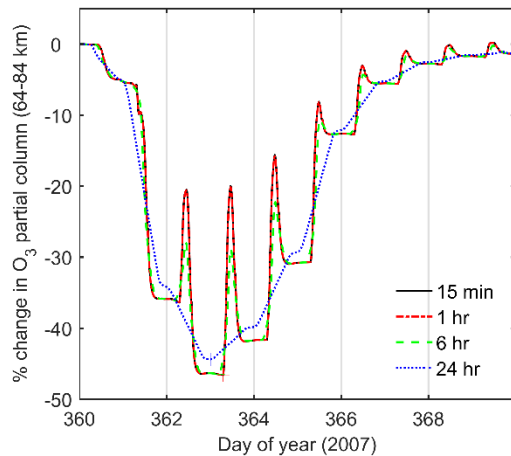


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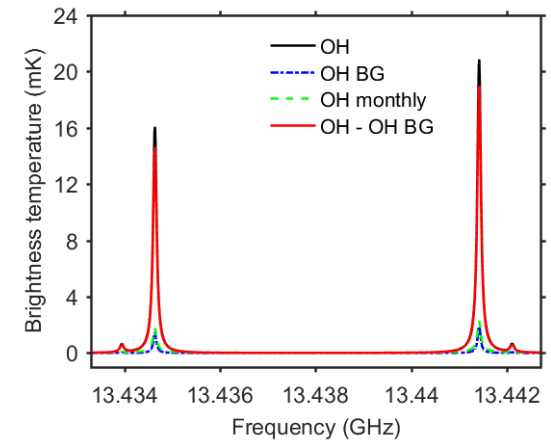
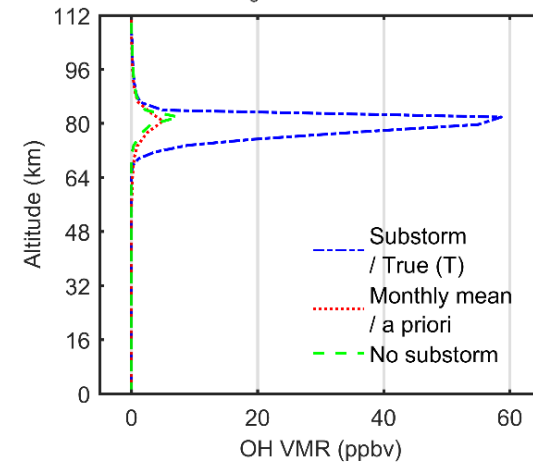
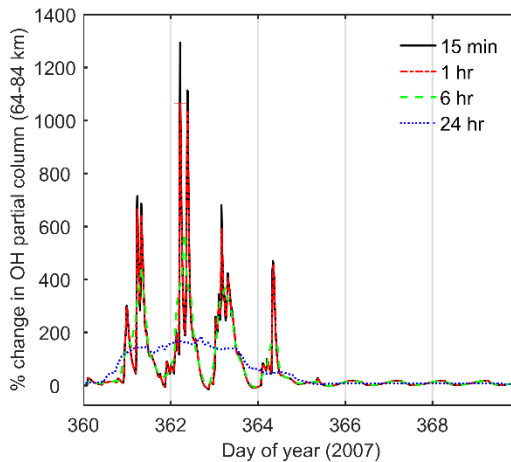
Atmospheric microwave spectrum simulations

Dec 2007

O₃



OH



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Optimal estimation retrieval

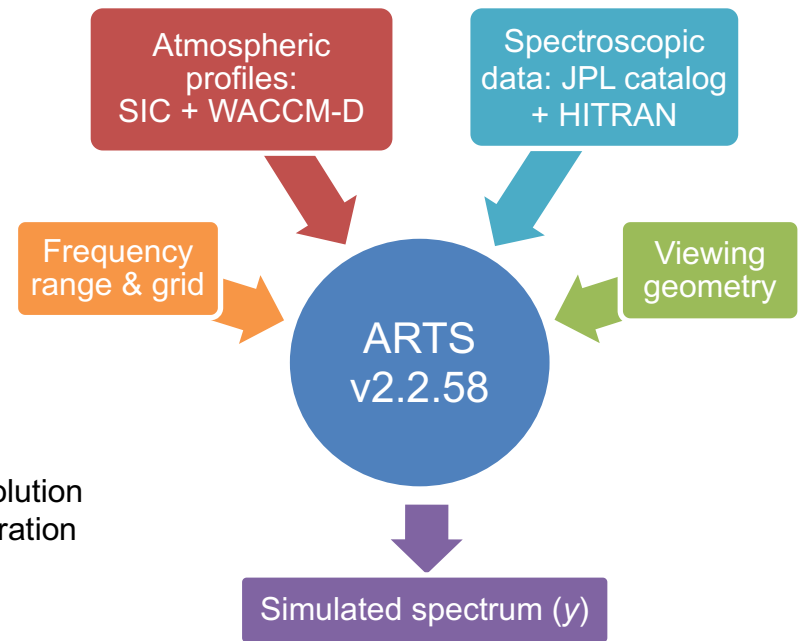
- Measured calibrated spectrum,

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

- Linearised forward model,

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

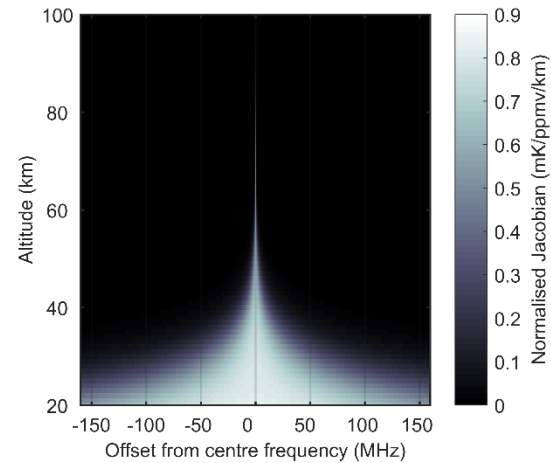
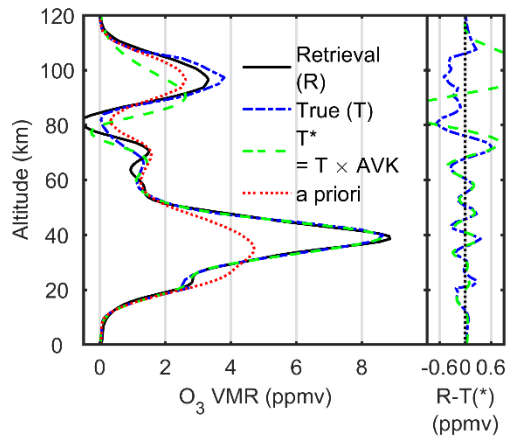
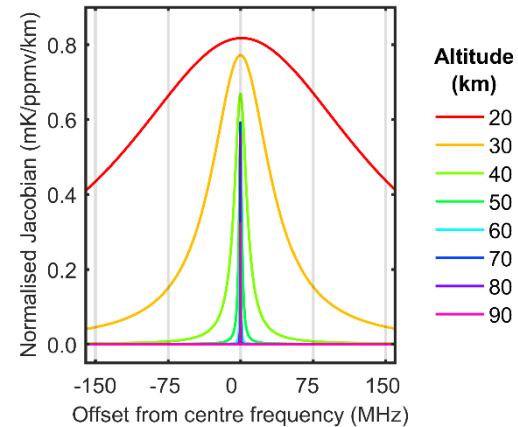
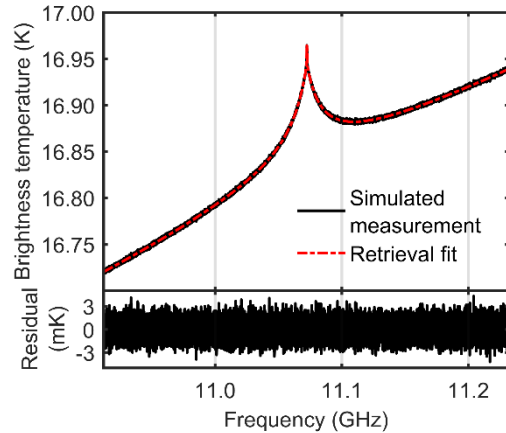
- Jacobian matrix, $\mathbf{K} = \left. \frac{\partial F}{\partial x} \right|_{\hat{x}_i, b}$ \hat{x}_i - Retrieval solution after i th iteration



Frequency (GHz)	Target species	Retrieved interfering* and background species	Bandwidth (MHz)	ΔT (mK)
11.072	O ₃	H ₂ O continuum*, OH, N ₂ , O ₂ , CO ₂ , HNO ₃ , H ₂ O ₂ , HO ₂	12, 320	1–5
13.434, 13.441	OH	H ₂ O continuum*, O ₃ , N ₂ , O ₂ , CO ₂ , HNO ₃ , H ₂ O ₂ , HO ₂	1, 12	1–10

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Retrieval simulation: O₃ VMR, 320 MHz bandwidth



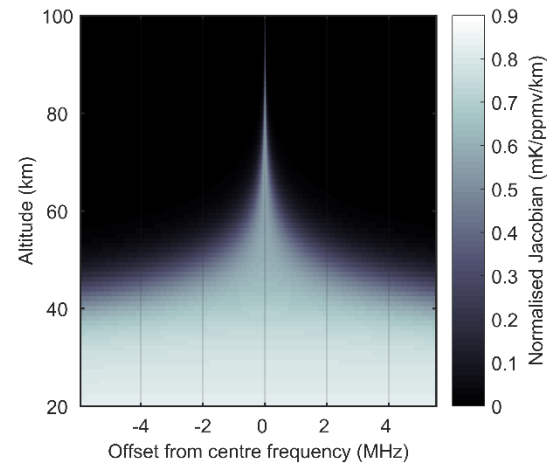
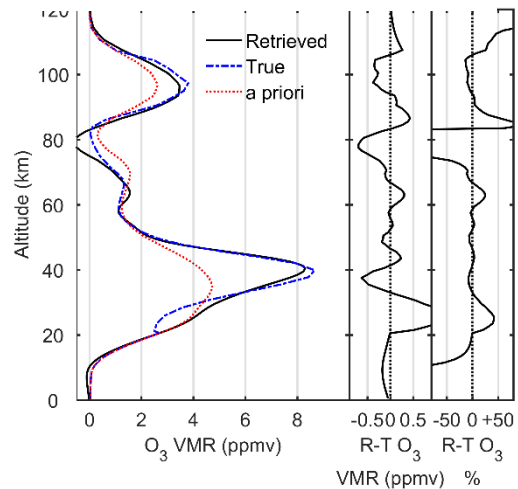
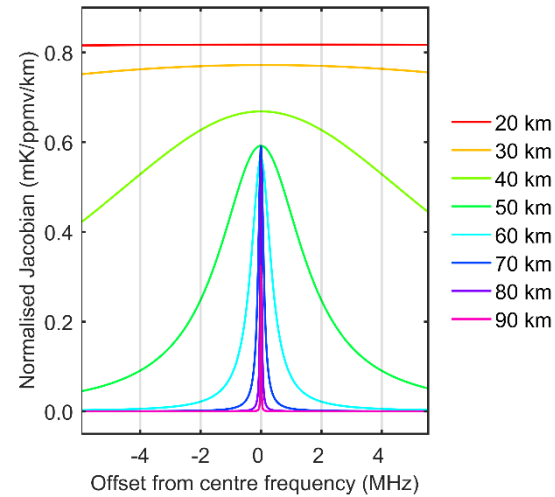
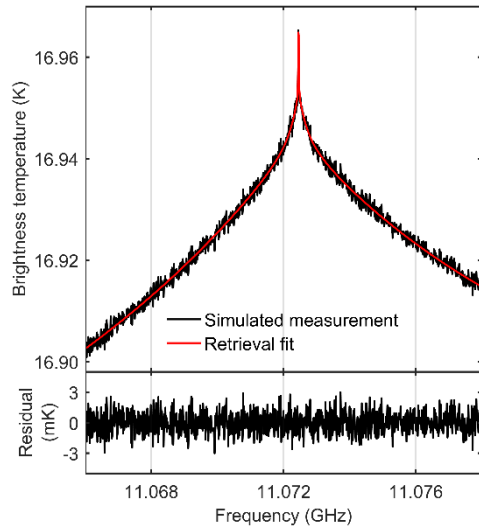
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Retrieval simulation: O₃ VMR, 12 MHz bandwidth



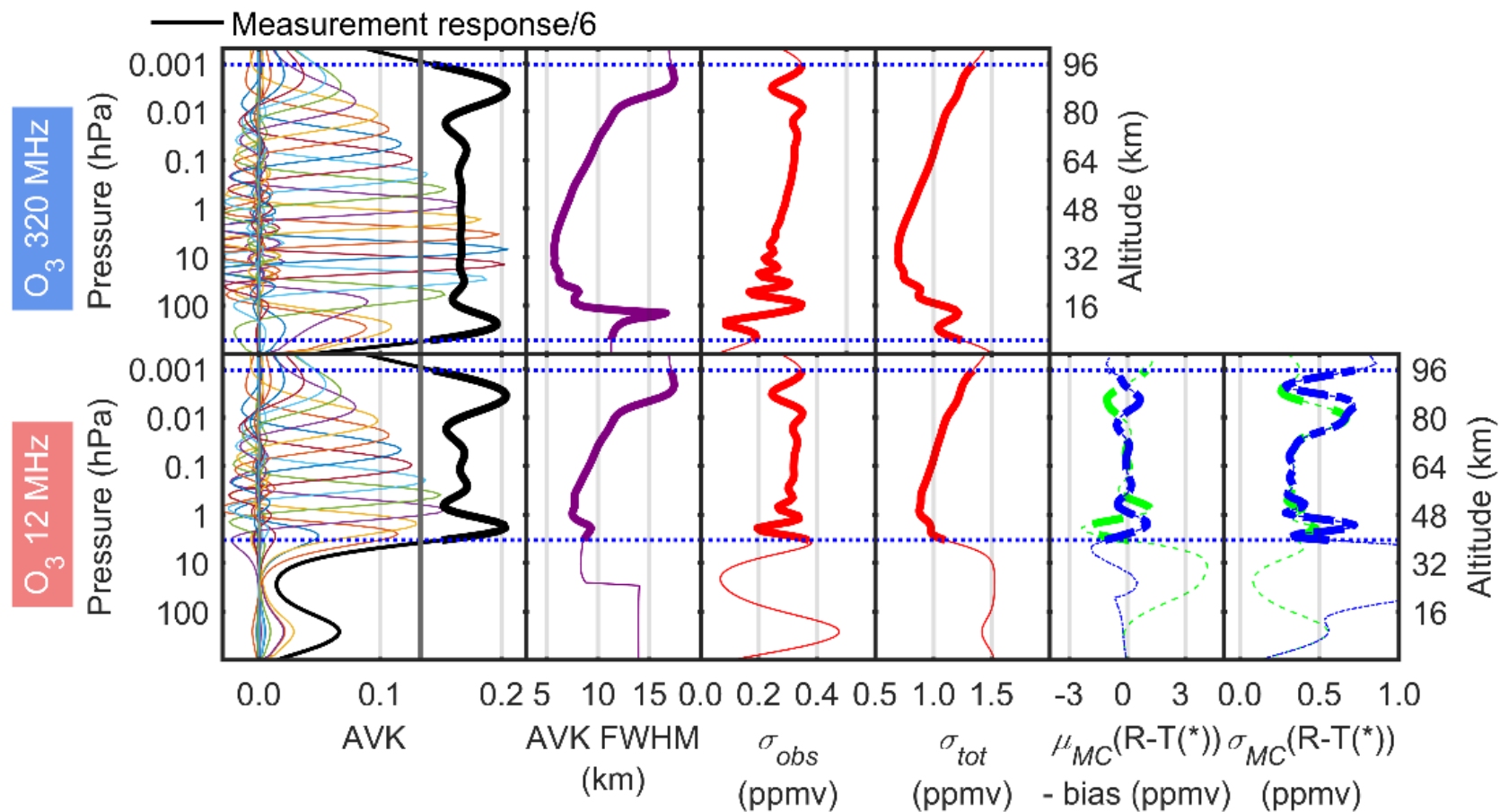
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Retrieval simulation: O₃ VMR, 320 MHz & 12 MHz bandwidth



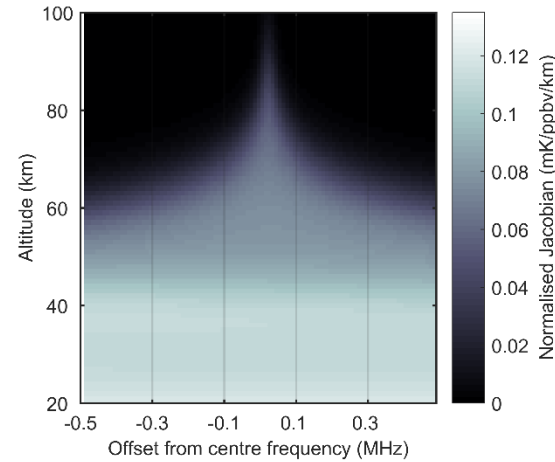
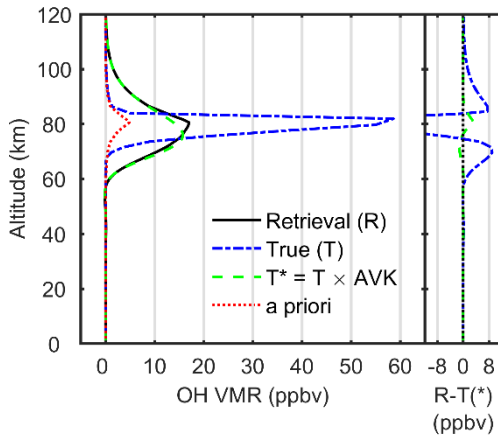
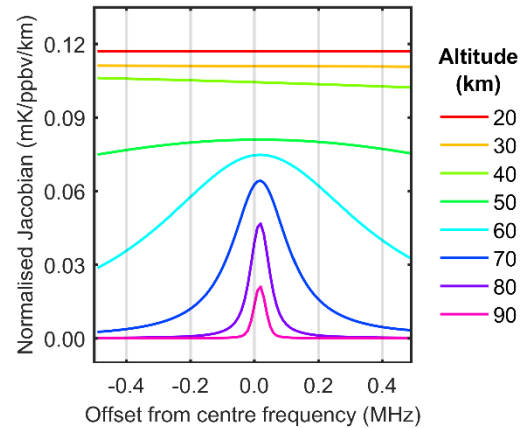
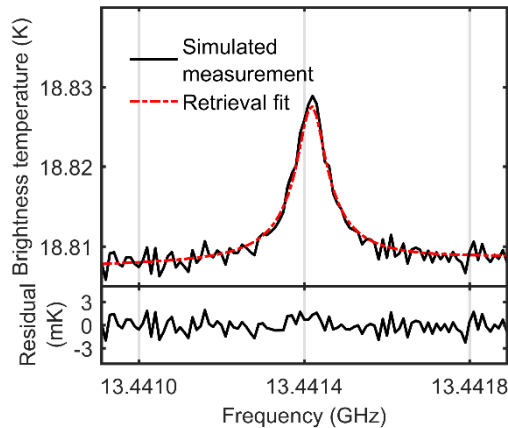
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Retrieval simulation: OH VMR, 1 MHz bandwidth



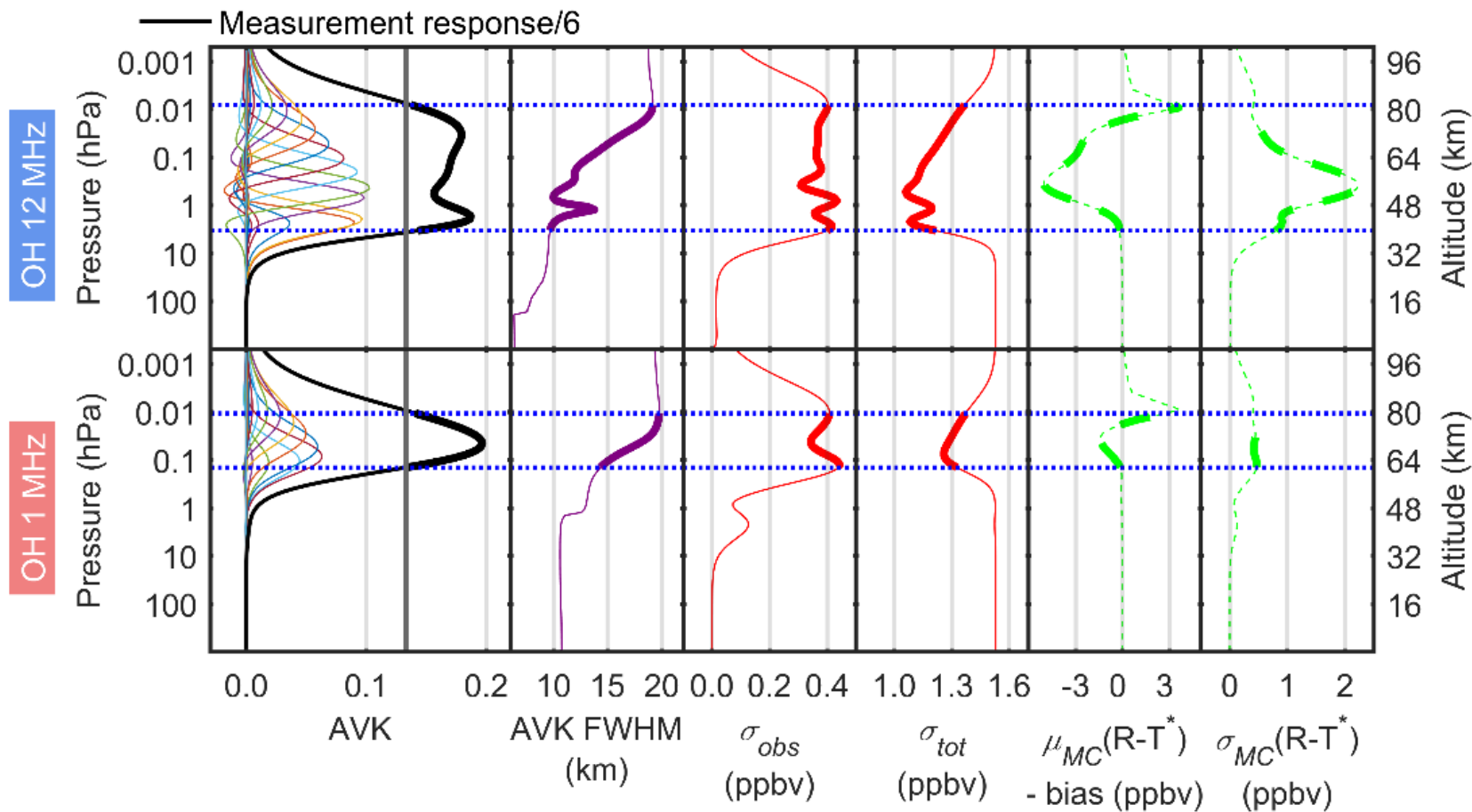
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Retrieval simulation: OH VMR, 1 MHz & 12 MHz bandwidth



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Conclusions

- Simulation techniques 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.
 - O₃, NO_x (NO + NO₂), HO_x (OH + HO₂), NO_y species, tracers, temperature, humidity, zonal and meridional winds, vertical transport.

