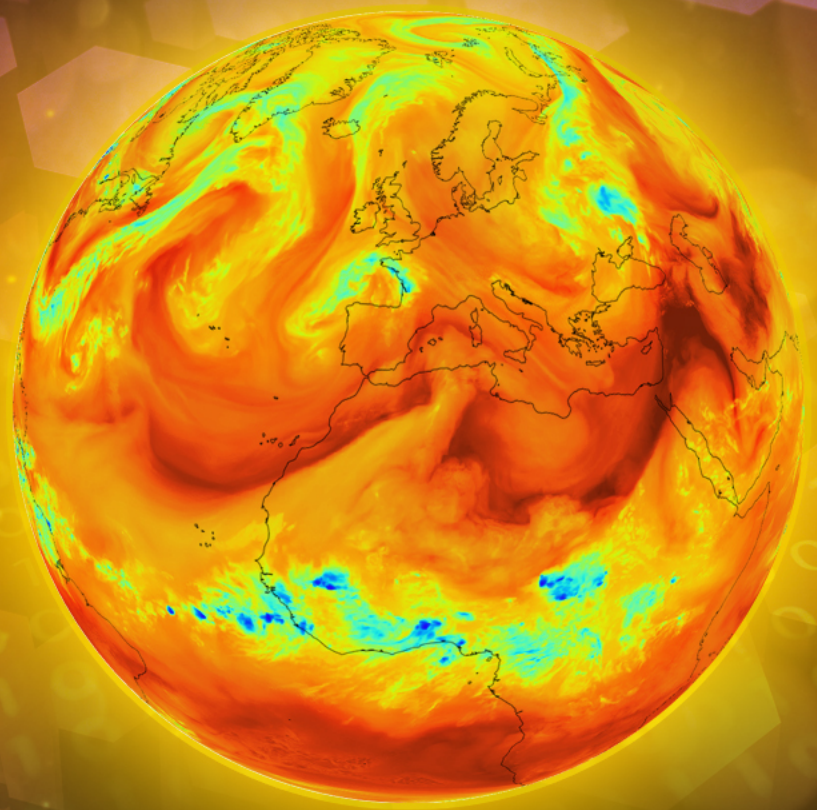
Far-infrared Outgoing Radiation Understanding and Monitoring



forum

→ UNDERSTANDING HOW EARTH IS LOSING ITS COOL

Helen Brindley (& the FORUM team)

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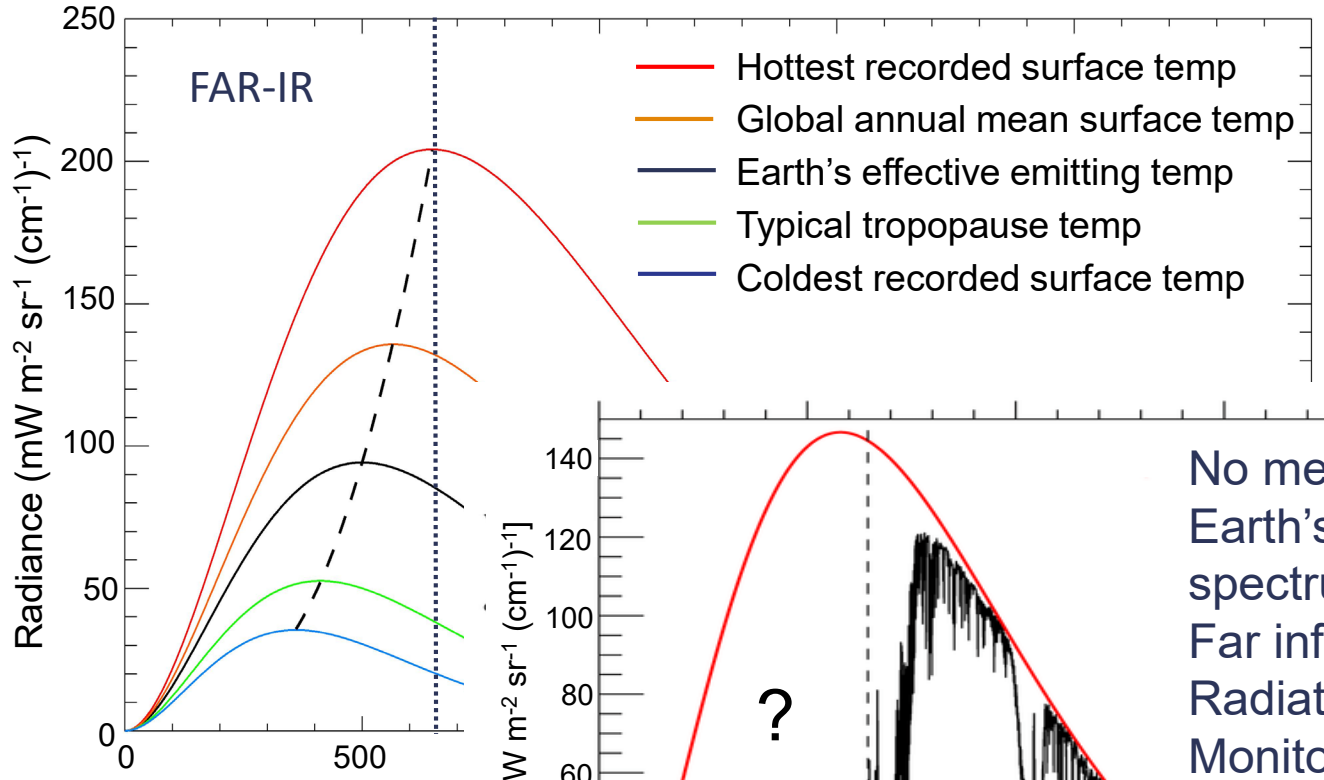
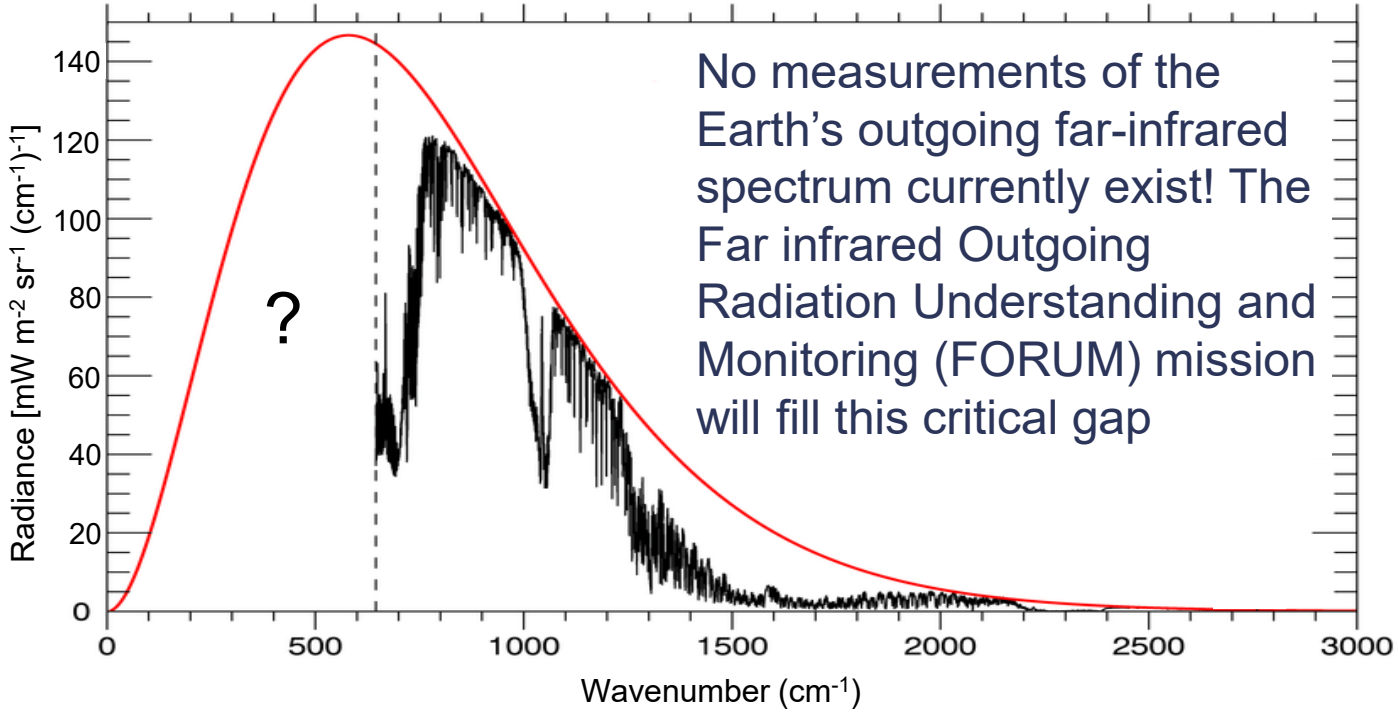
Why observe the Earth's outgoing far-infrared spectrum?



Over the temperature range of the Earth's surface and atmosphere, peak energetic emission is seen in the far infrared

FIR emission is highly



No measurements of the Earth's outgoing far-infrared spectrum currently exist! The Far infrared Outgoing Radiation Understanding and Monitoring (FORUM) mission will fill this critical gap

FORUM Payload and Mission requirements

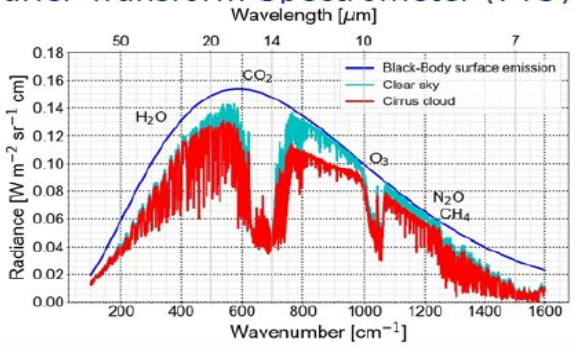
2 instruments – Sounder and Imager

FORUM Sounding Instrument (FSI)

What for? **Spectrally resolved** measurement of the Top-of-atmosphere (TOA) spectrum in the **infrared from 100 to 1600 cm-1** (100 µm to 6.25 µm)

How? **SPECTROMETER**
Fourier Transform Spectrometer (FTS)

15 km footprint;
< 100 km spatial sampling



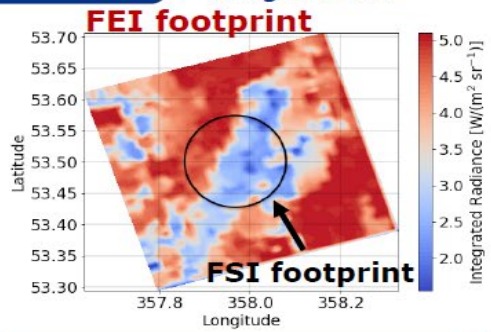
Spectral Resolution FWHM: 0.5 cm^{-1}

Radiometric Accuracy 3σ (Goal) [Threshold]	**300-1100 cm^{-1}:** (0.1 K) [0.25 K] **200-300 cm^{-1}:** (0.2 K) [0.25 K] **1100-1300 cm^{-1}:** (0.2 K) [0.25 K] **Elsewhere:** (<1 K) [<1 K]
Radiometric Precision (Goal) [Threshold]	**200-800 cm^{-1}:** (0.4) [0.4] mW/(m^2 sr cm^{-1}) **Elsewhere:** (<1.0) [2.0] mW/(m^2 sr cm^{-1})

FORUM Embedded Imager (FEI)

What for? **Scene uniformity** Assessment

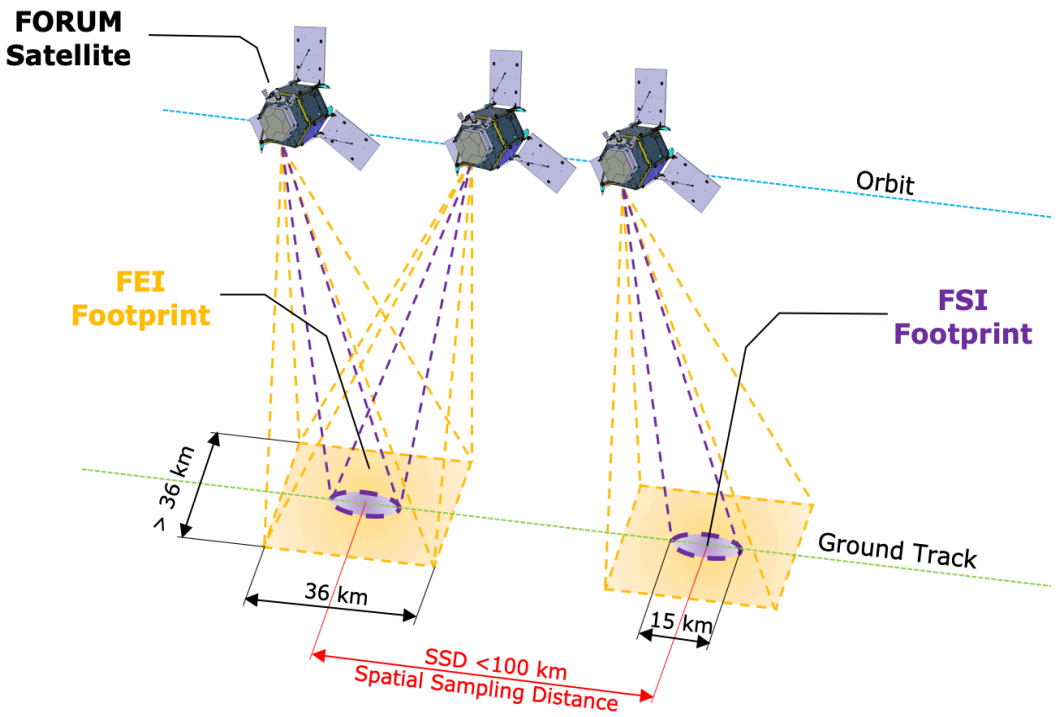
How? **THERMAL IMAGER**
Single band

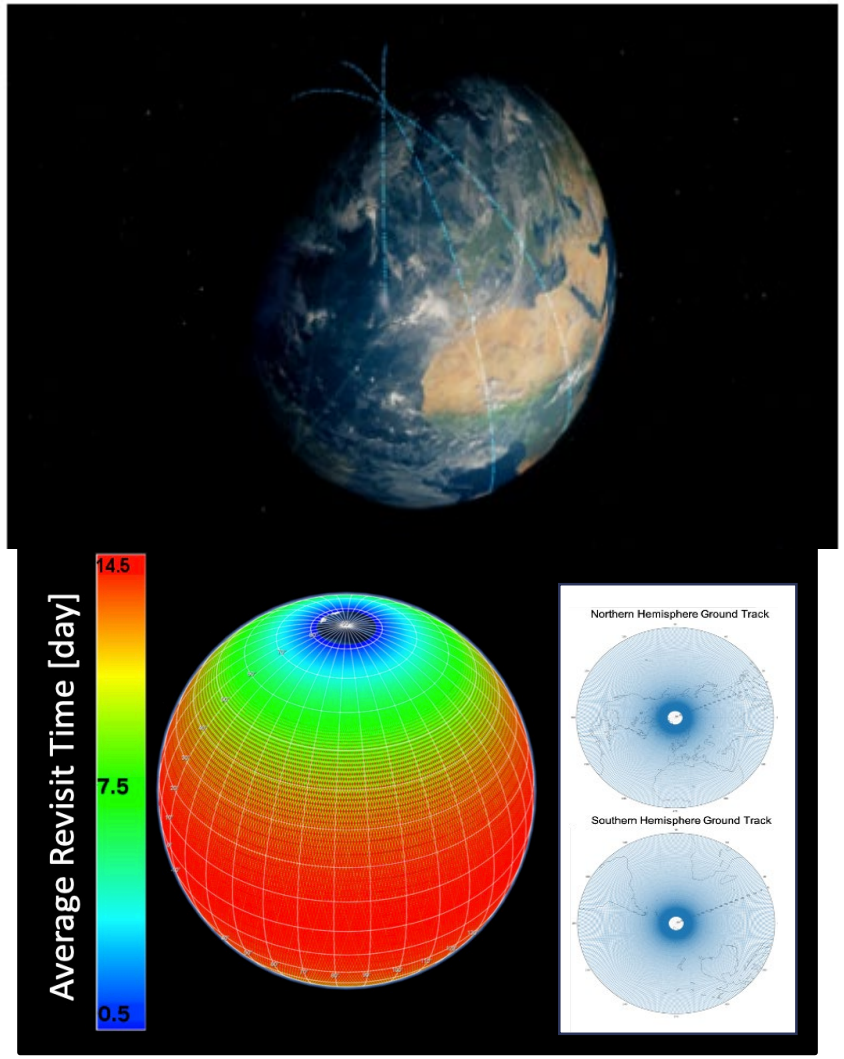


Single channel @ 10.5 µm (FWHM: 1.5 µm)

Radiometric accuracy	(1 K) [2 K]
NeDT (at 210 K)	(0.3 K) [0.8 K]

FORUM: Observation Concept and Sampling





Loose formation with MetOp-SG-A1 to obtain full IR spectrum (IASI-NG)

Observational studies in support of FORUM

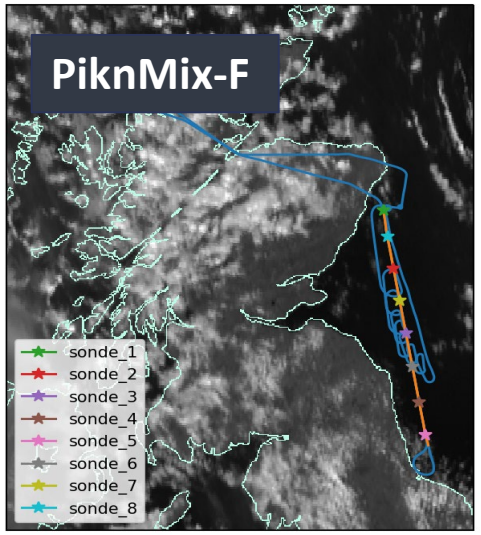
Campaign(s) Overview

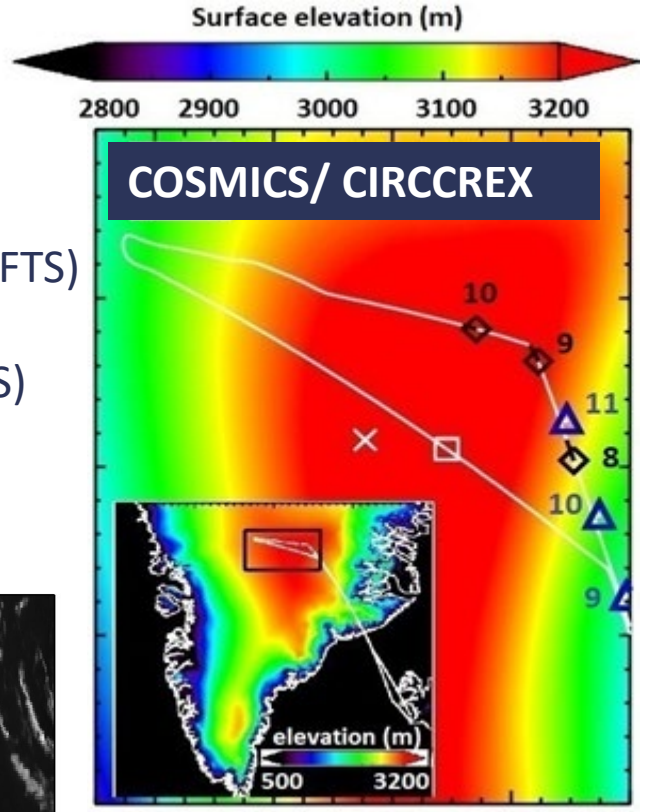
- COSMICS/CIRCCREX – March 2015 (Keflavik, Iceland)
- PiknMix-F – March 2019 (Stornoway, Scotland)

Instrumentation

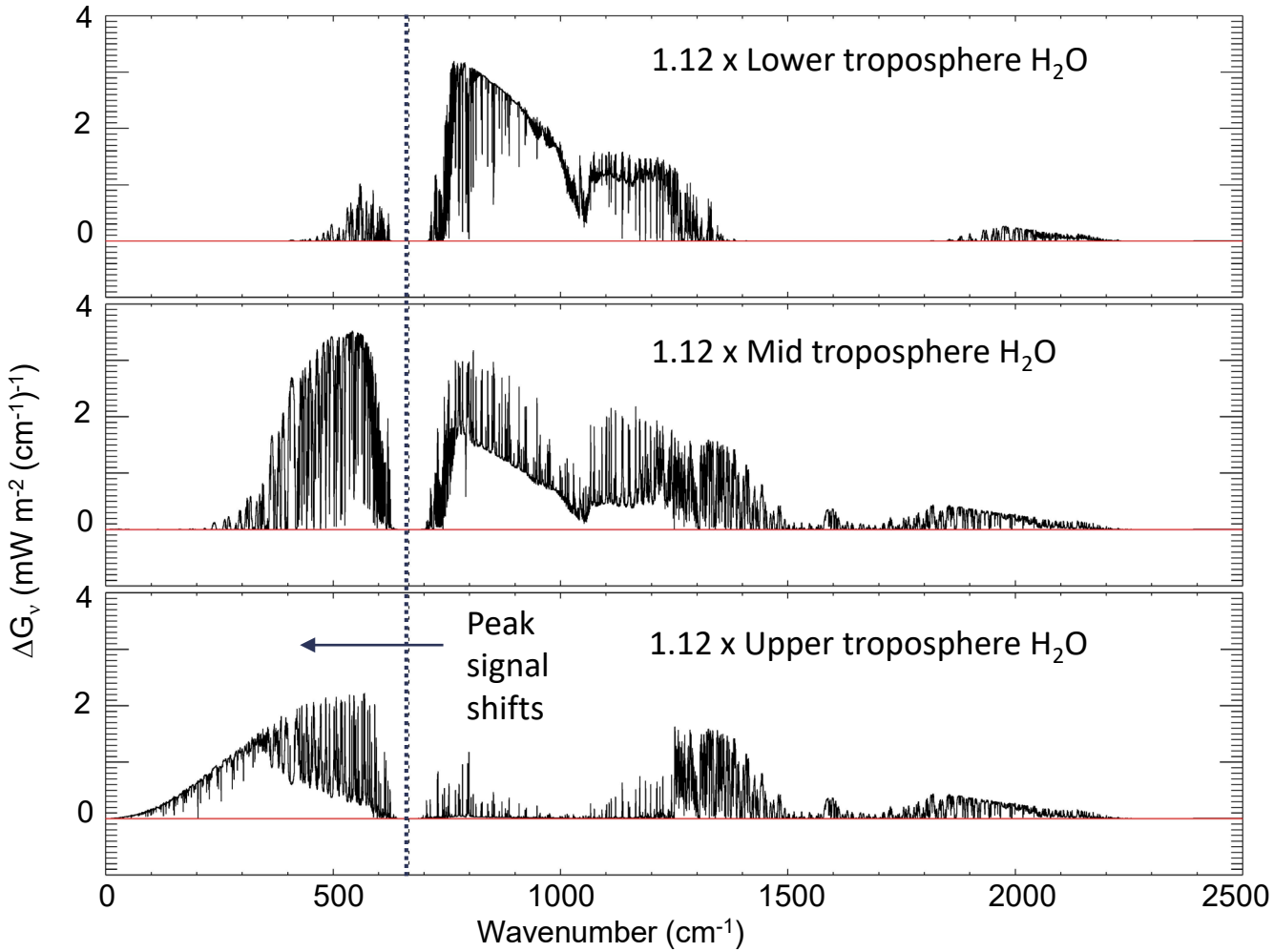
- Tropospheric Airborne Fourier Transform Spectrometer (TAFTS)
  - 80-600 cm^{-1} range, nominal 0.12 cm^{-1} resolution
- Airborne Research Interferometer Evaluation System (ARIES)
  - 550-3000 cm^{-1} range, 1 cm^{-1} resolution
- In-situ aircraft temperature and humidity sensors, UV lidar
- Dropsondes: profiles of temperature and humidity

UK Facility for Airborne Atmospheric Measurements (FAAM)





Tropospheric water vapour and the far-infrared



After Brindley and Harries, 1998

Simulated changes in the Earth's Greenhouse Effect due to perturbations in atmospheric water vapour

A relatively small increase in water vapour can induce a change in trapping equivalent to doubling CO_2.

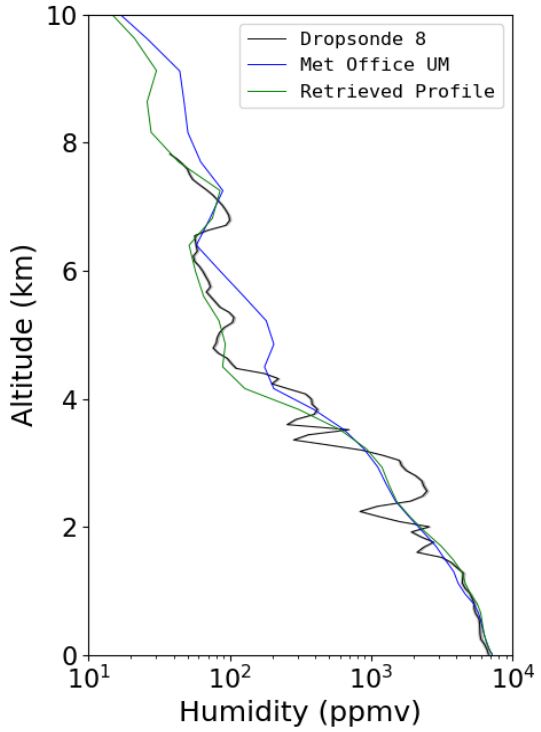
Significant fraction in far infrared, especially if the perturbation occurs in the colder upper-troposphere

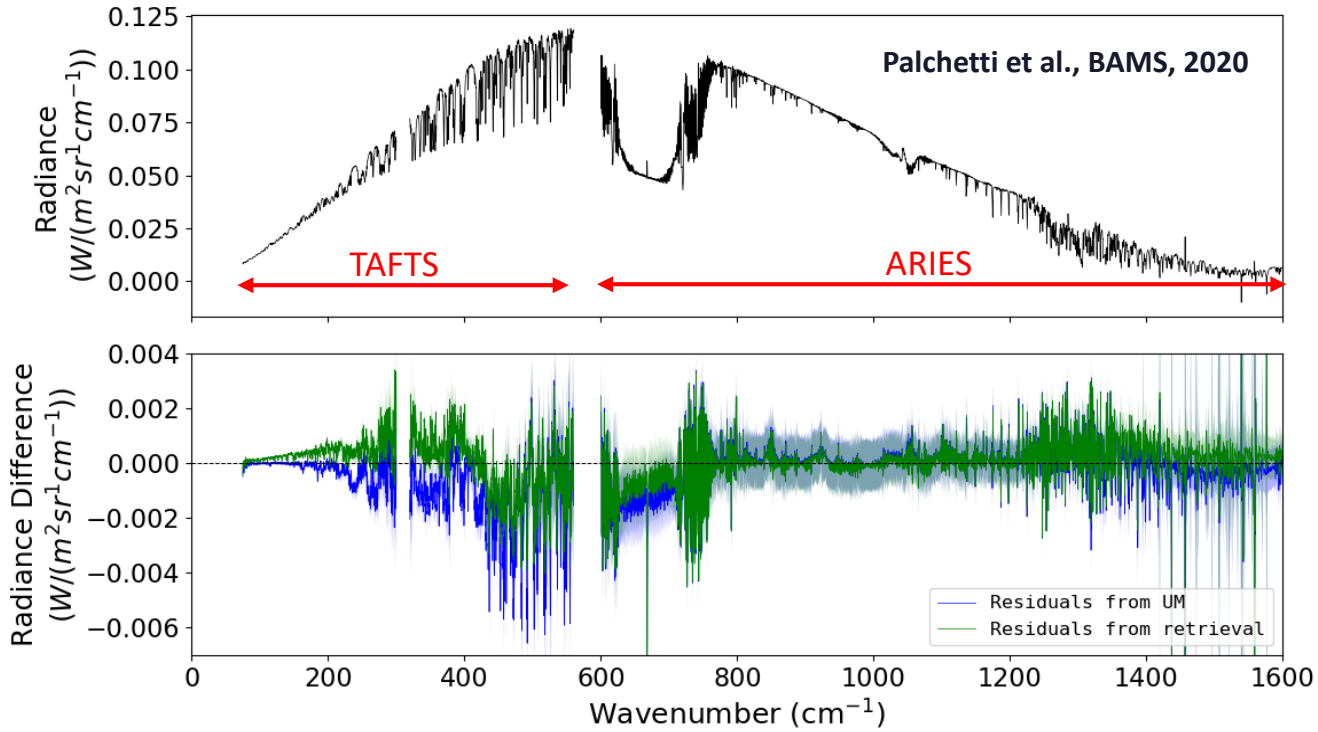
Tropospheric water vapour and the far-infrared

Clear-sky forward modelling and water vapour retrievals (Warwick et al., submitted)

Simulated observed far and mid-ir clear-sky radiances over ocean using nearest Met Office forecast, AIRS retrievals and dropsonde observations

Retrieved humidity and temperature profiles using Met Office 1D Var scheme





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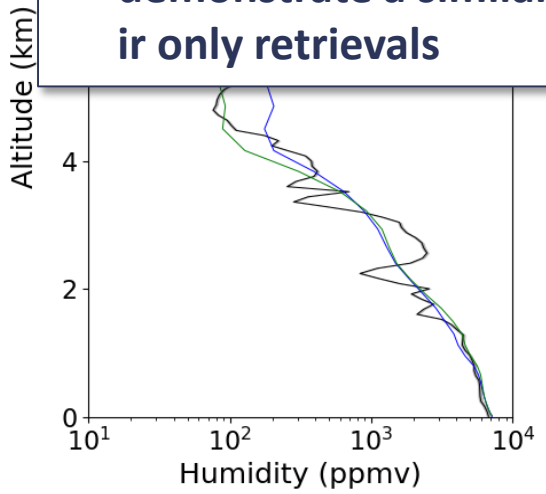
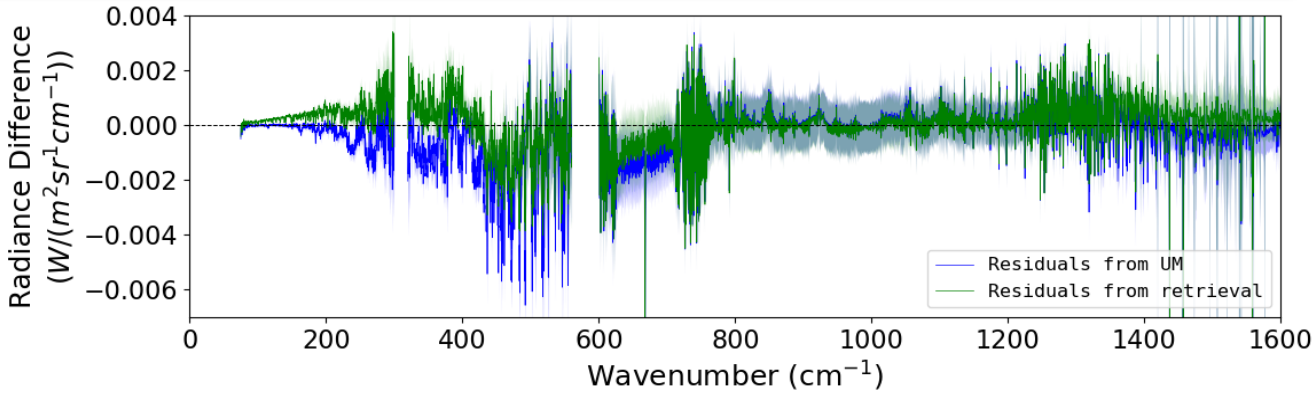
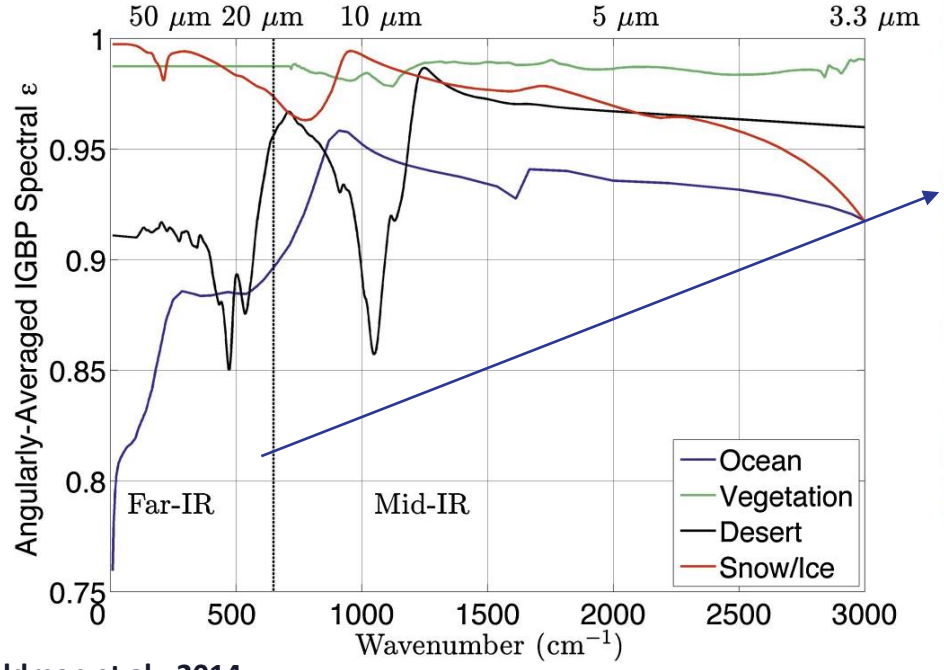
Take Home Messages:

- **Humidity retrievals using far-ir radiances alone outperform those using the mid-ir alone: first time this has been shown from observations**
- **Combining far and mid-ir radiances improves knowledge of the atmosphere and surface further, predominantly via an improved estimate of surface temperature**
- **Given anticipated noise performance, far-ir measurements from FORUM should demonstrate a similar benefit for characterising the atmospheric state relative to mid-ir only retrievals**

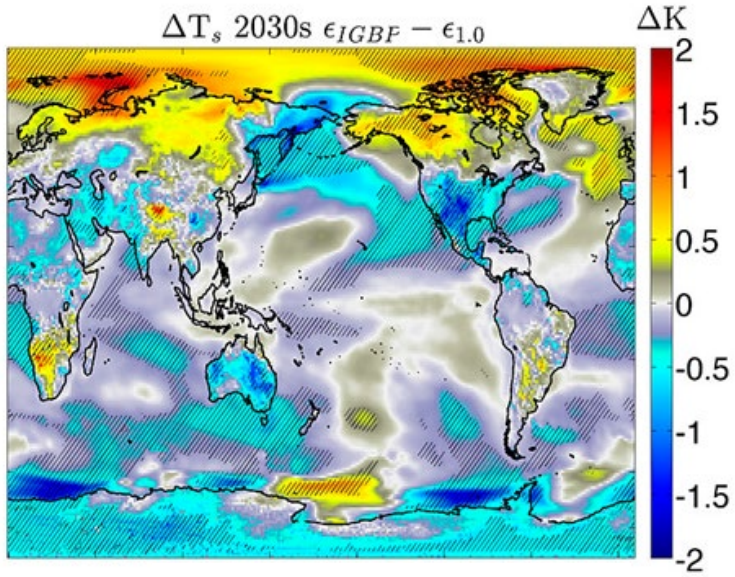


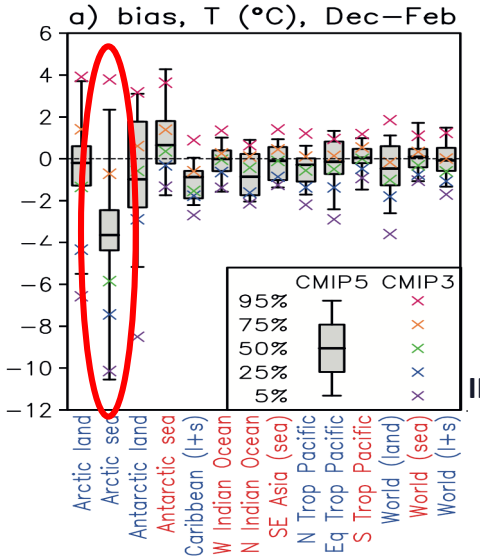


Far-infrared surface emissivity



Feldman et al., 2014



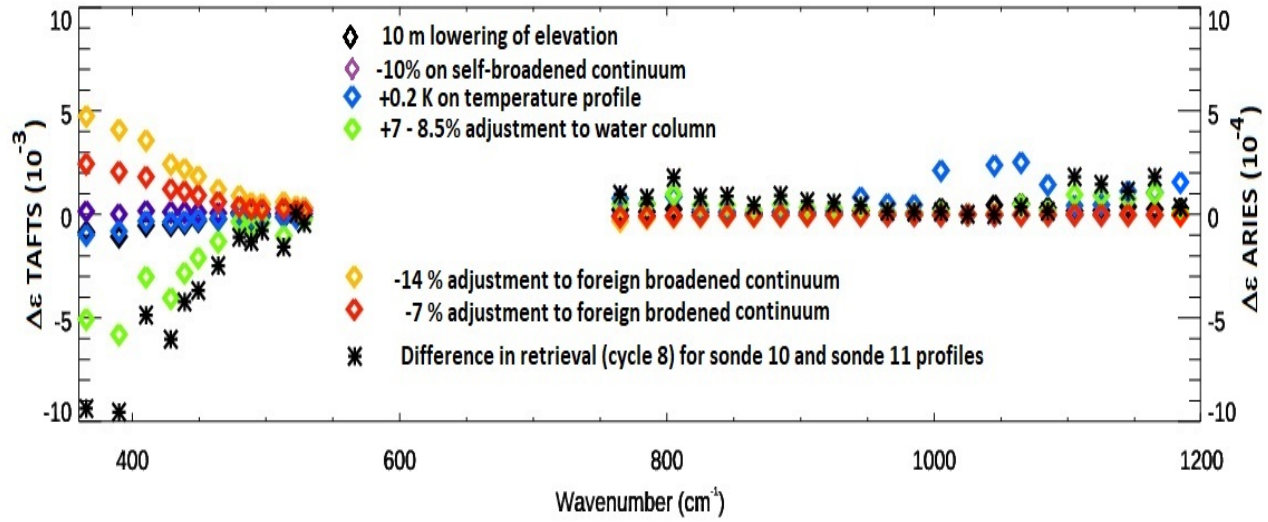


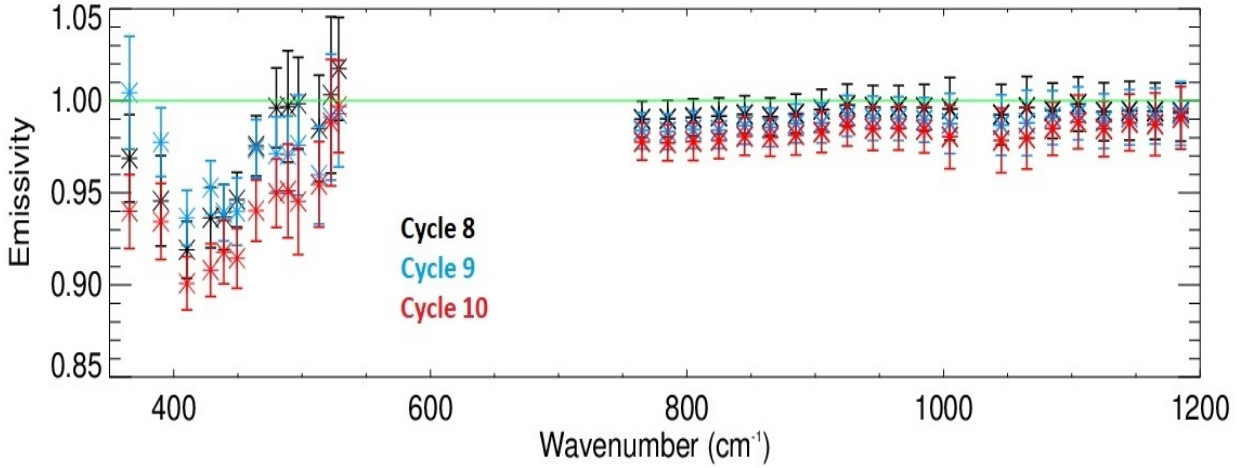
IPCC, 2007

Far infrared surface emissivity strongly impacts Arctic surface energy budget and may explain some of the persistent bias seen in modelled Arctic wintertime surface temperatures – but is very poorly constrained.

Far-infrared surface emissivity

Retrieval of high latitude surface emissivity (Murray et al., JGR, accepted)





Exploits high-level radiance observations over Greenland to infer surface temperature and emissivity across the infrared

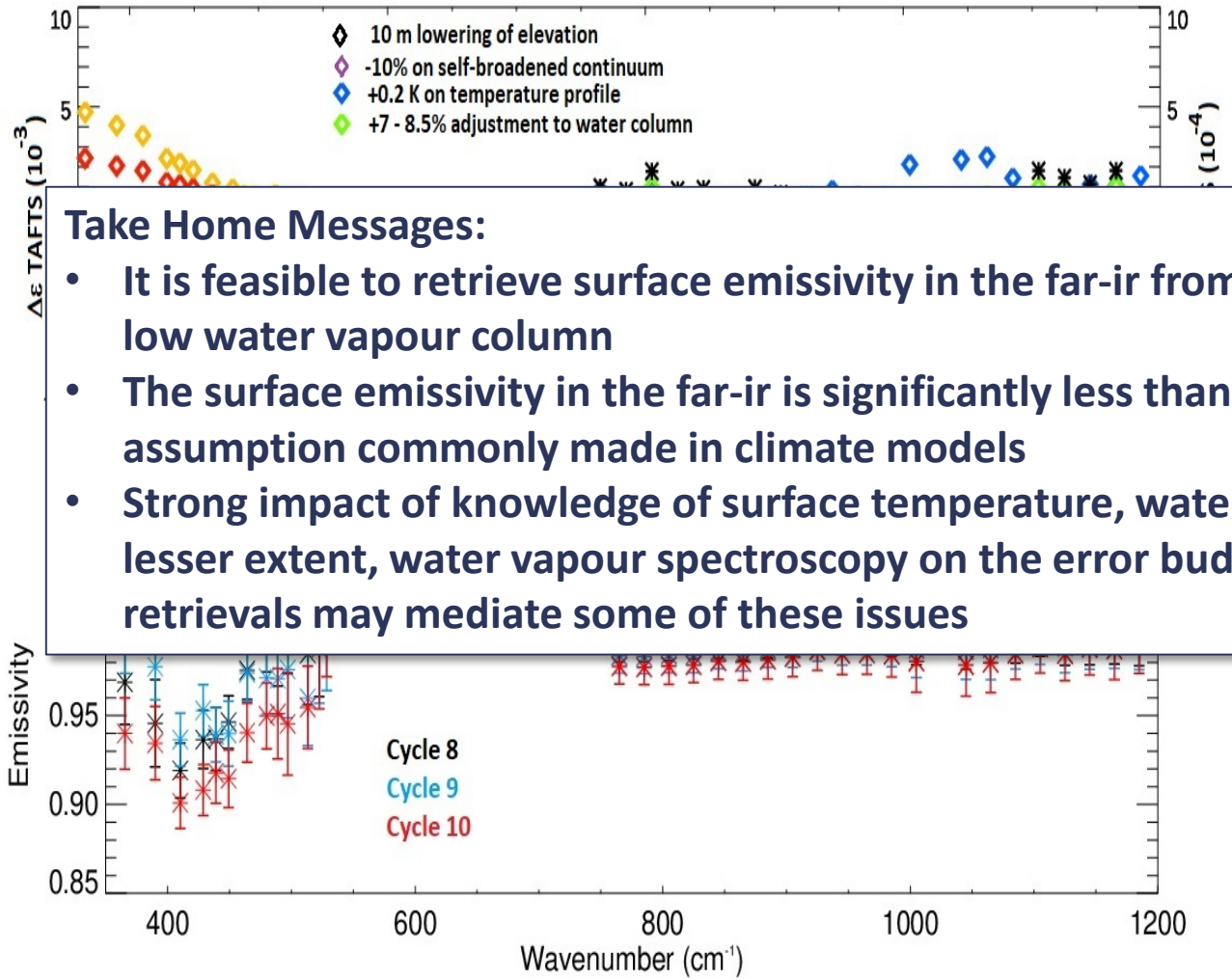
Atmospheric state constrained by dropsondes

Surface temperatures derived from mid-IR window radiances after Knuteson et al. (2004)

Detailed analysis of emissivity error budget

Far-infrared surface emissivity

Retrieval of high latitude surface emissivity (Murray et al., JGR, accepted)



Take Home Messages:

- **It is feasible to retrieve surface emissivity in the far-ir from altitude given a sufficiently low water vapour column**
- **The surface emissivity in the far-ir is significantly less than that of a black body, an assumption commonly made in climate models**
- **Strong impact of knowledge of surface temperature, water vapour column, and to a lesser extent, water vapour spectroscopy on the error budget: optimised multi-target retrievals may mediate some of these issues**

Exploits high-level radiance observations over Greenland to infer surface temperature

radiances after Knuteson et al. (2004)

Detailed analysis of emissivity error budget

FORUM: Earth Explorer 9

Overarching Research Objective

- evaluate the role of the far-infrared in shaping the current climate and thus reduce uncertainty in predictions of future climate change

by

- building a highly accurate global dataset of far-infrared radiances for validation of the present-day state as captured by Earth system models
- using these measurements to understand and constrain the processes that control far-infrared radiative transfer and hence the Earth's Greenhouse Effect
- updating the parametrisations of these processes for implementation in radiative transfer codes, and ultimately in Earth system models
- characterising critical feedback mechanisms

Anticipated Launch: 2026