Far-infrared-Outgoing-Radiation
Understanding and Monitoring

forum

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and

The FORUM Science Team and Mission Advisory Group

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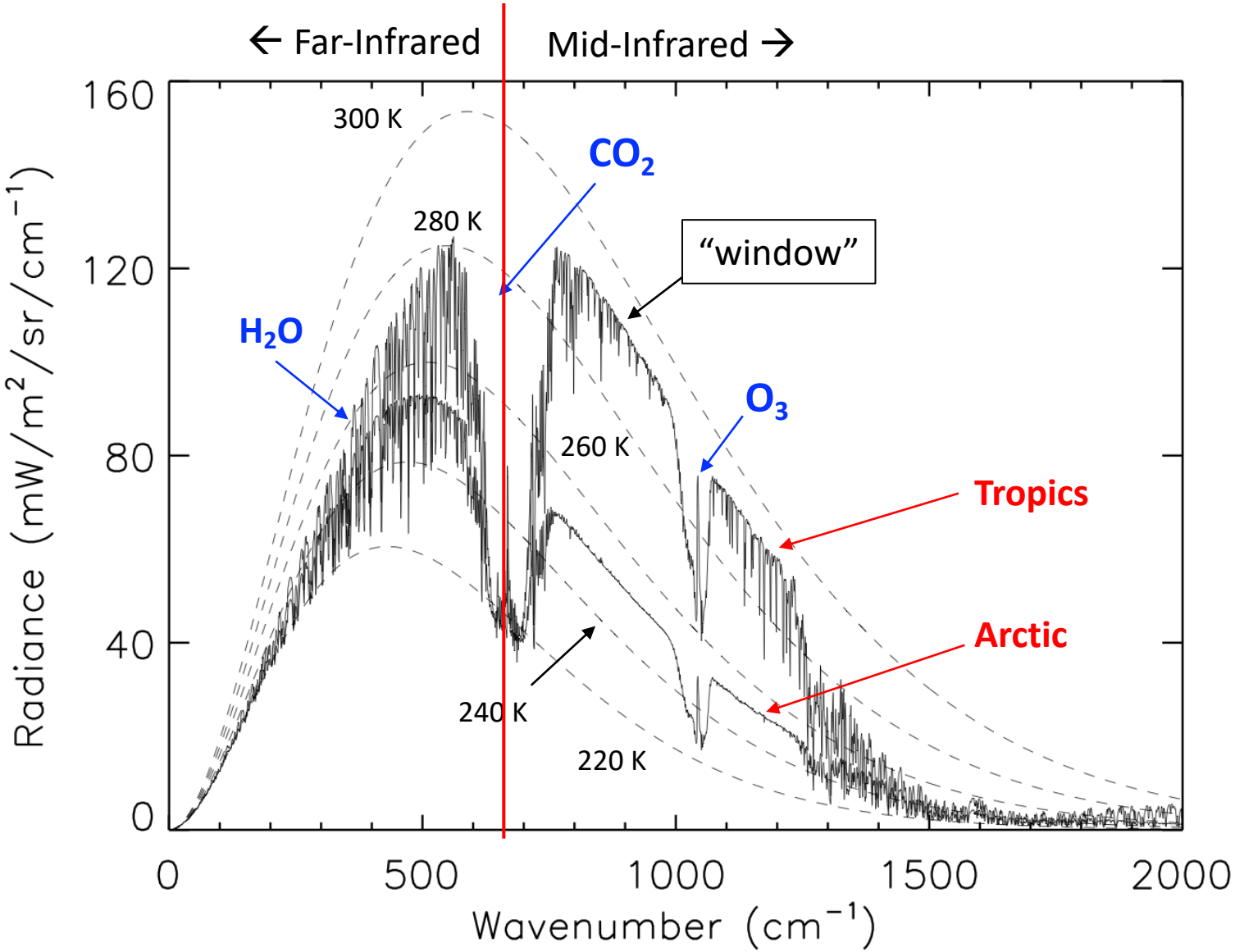
Tropical & Arctic Top-of-Atmosphere Emission Spectra



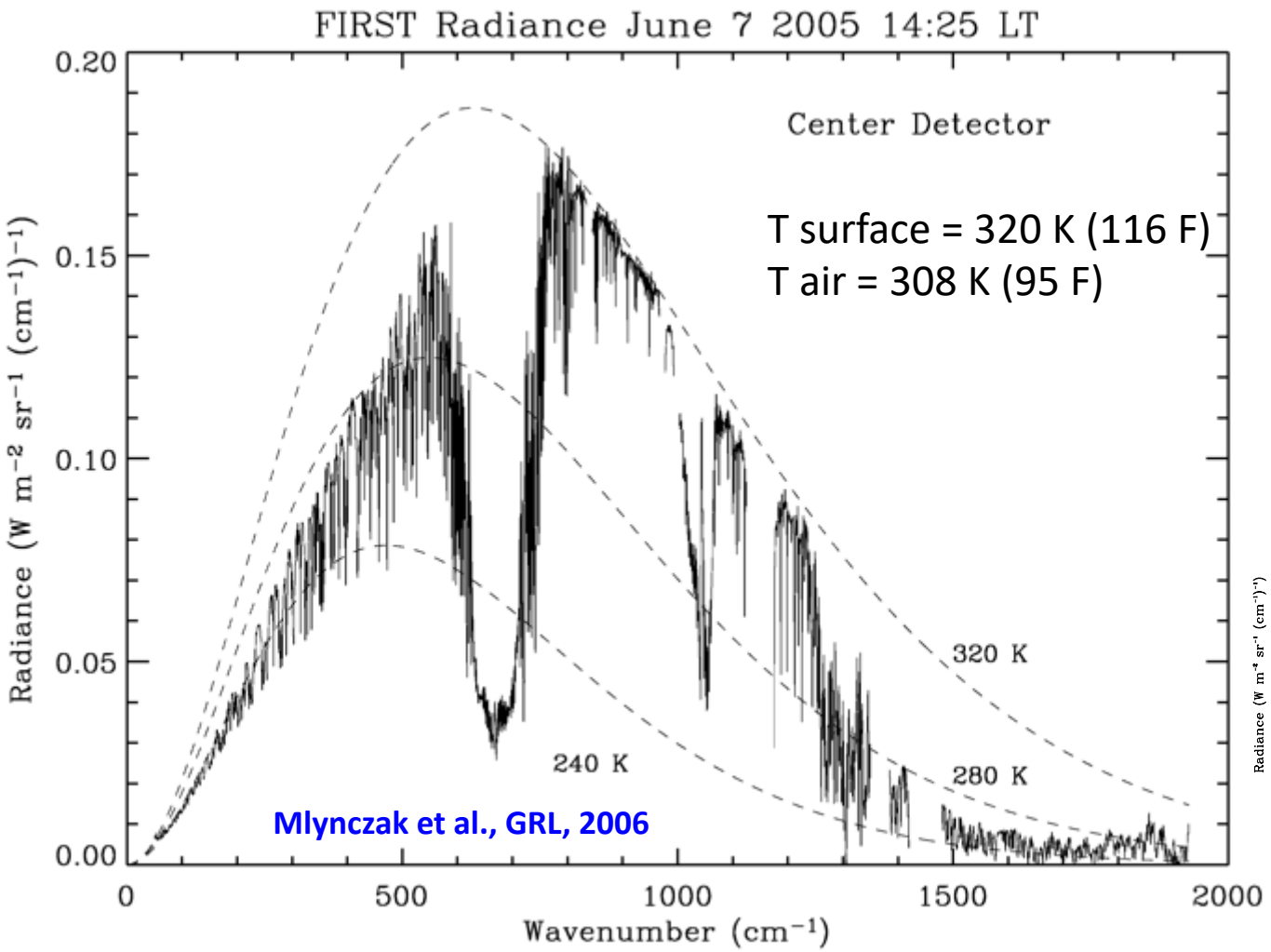
FORUM Mission Overview

- FORUM is a new space flight mission announced 9/2019 by the European Space Agency as its 9th Explorer Mission
- FORUM directly measures the previously unobserved far-infrared wavelengths longer than 15.5 μm (650 cm^{-1})
- FORUM mission consists of a Fourier Transform Spectrometer (FTS) for measuring the infrared spectrum and an imager for scene identification
- FORUM will fly in approximate formation with one of the METOP satellites and will have close synergy with IASI
- Launch is ~ 2025/26

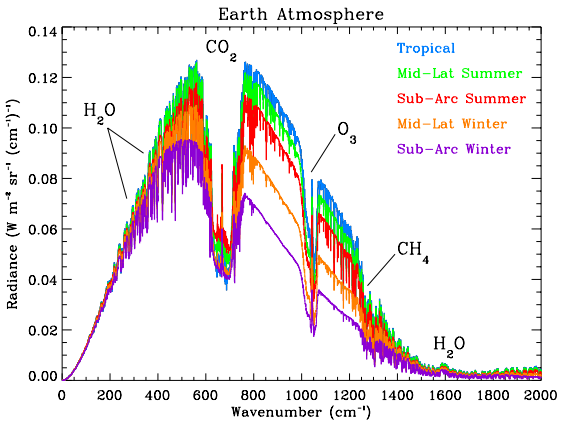
FORUM Background

- FORUM is the culmination of a 20-year international quest to achieve direct measurement of the far-IR from space
- Multiple teams developed ground, aircraft, and balloon-borne instruments to demonstrate science need and technology for measuring the far-IR
- These include:
  - Tropospheric Airborne FTS (TAFTS) – Imperial College, UK
  - Radiation Explorer in the Far-InfraRed (REFIR) – Italy
  - Far-Infrared Spectroscopy of the Troposphere (FIRST) – NASA
  - Atmospheric Emitted Radiation Interferometer (AERI Extended) – U. Wisconsin
- A number of aircraft flights, balloon flights, and ground campaigns since late 1990's
- In addition, spectroscopy of the far-IR, the water vapor continuum, has been and continues as a forefront of scientific inquiry

Measured Top-of-Atmosphere IR Spectrum



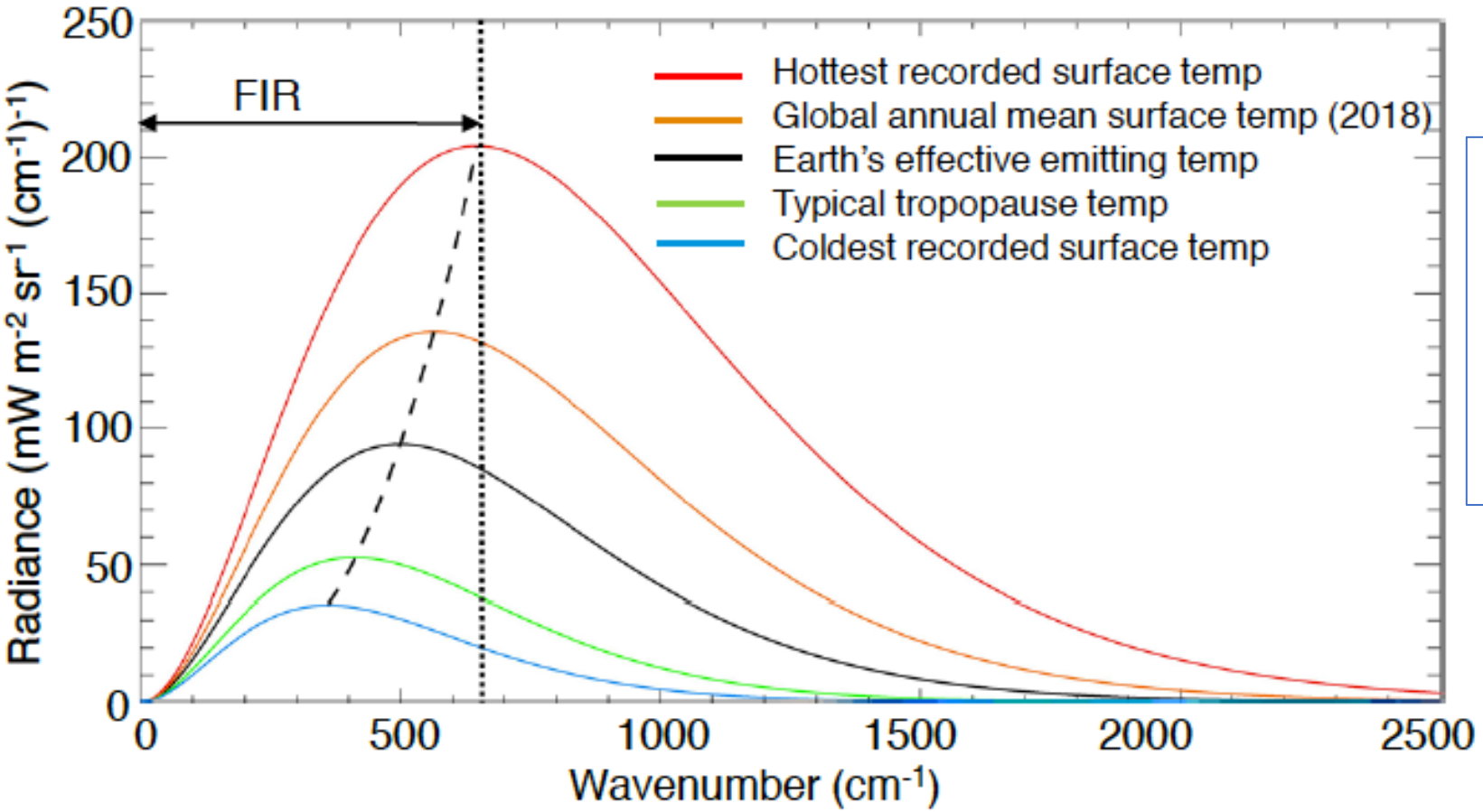
Ft. Sumner, NM



FORUM Mission Advisory Group (MAG)

- Helen Brindley – *Imperial College, London*
- Stefan Buhler – *University of Hamburg*
- Dorothee Coppens – *EUMETSAT*
- Adrien Deschamps – *CNES*
- Steven DeWitte - *RMIB*
- Bianca Maria Dinelli – *ISAC-CNR*
- Laurent Labonnote – *University of Lille*
- Quentin Libois – *Meteo France*
- Marty Mlynczak – *NASA Langley Research Center*
- Luca Palchetti – CNR National Institute of Optics
- Marco Ridolfi – *University of Bologna*
- Martin Riese – *Forschungszentrum Julich*
- Roger Saunders – *UK Met Office*

Why is the Far-IR so special?

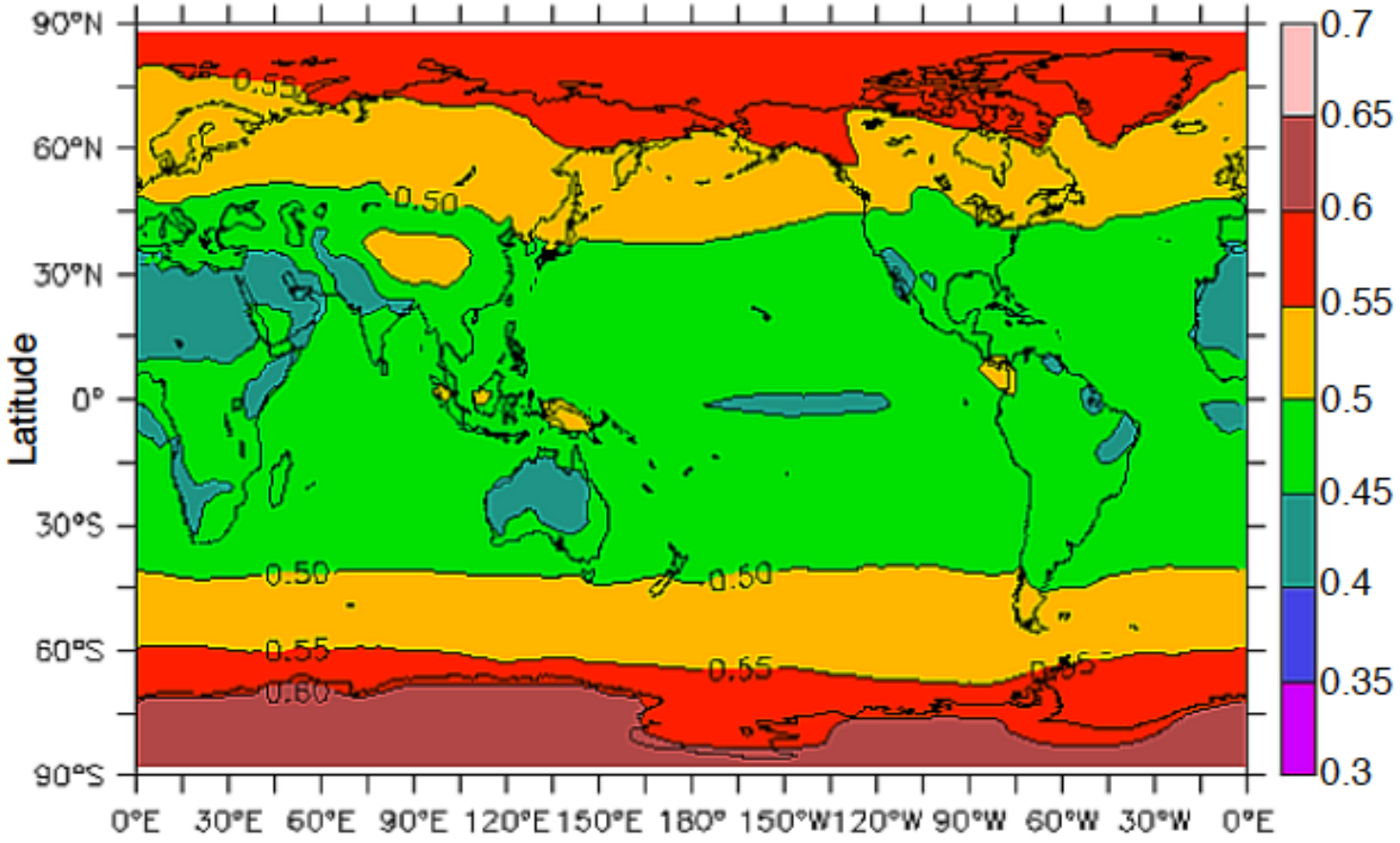


Over the observed range of Earth's surface temperature and atmosphere, **the peak energetic emission** is in the far-infrared!

Why is the Far-Infrared so special?

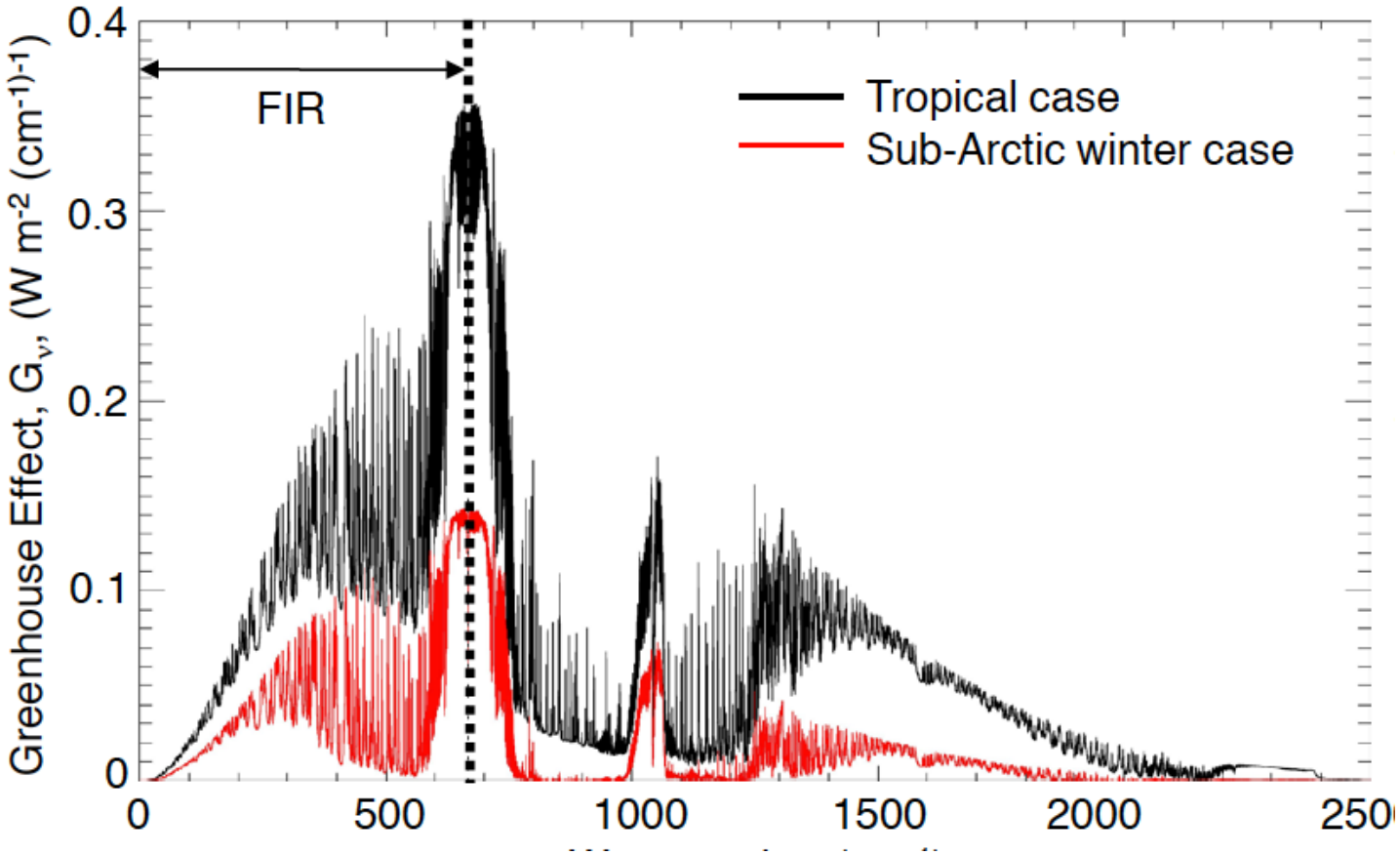
Consistent with the TOA spectra, the Global OLR is dominated by the Far-IR

Fraction of OLR in the Far-IR



Collins and Mlynczak, 2001

Why is the Far-Infrared so special? – Greenhouse Effect



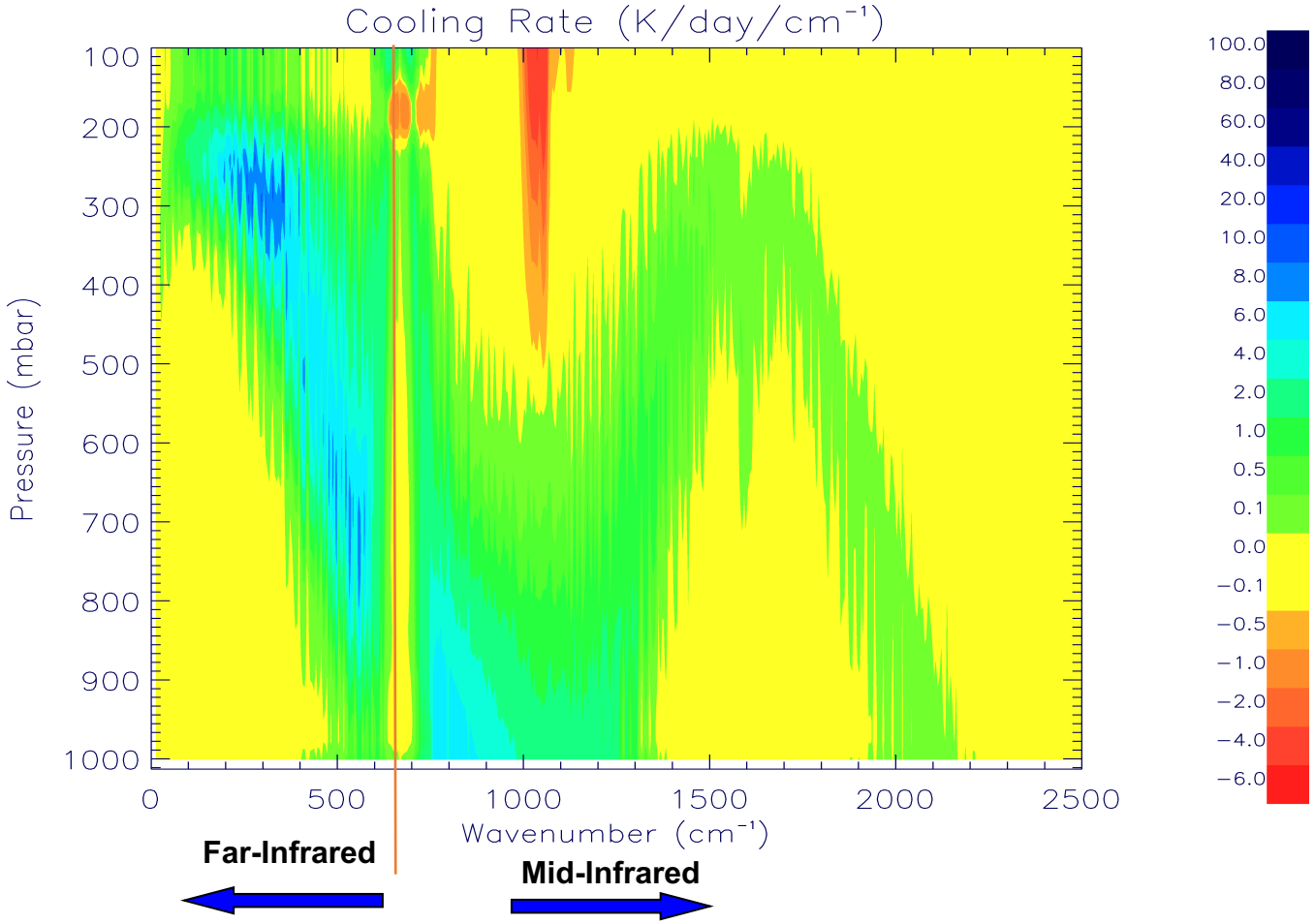
Contribution to atmospheric trapping:

Absorption in the far-infrared contributes ~ 50 % to the total clear-sky Greenhouse Effect, G_ν

Importance of the Far-IR: Infrared Radiative Cooling Rate

Impact throughout the atmosphere:

Dominant contribution to clear-sky atmospheric radiative cooling also located within the far-infrared: key driver of atmospheric dynamics



FORUM: A true explorer

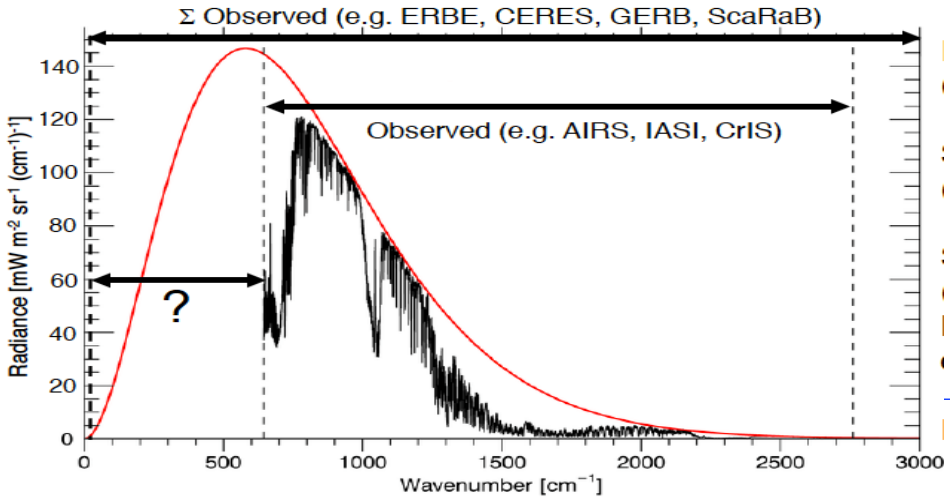
Research Objective

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

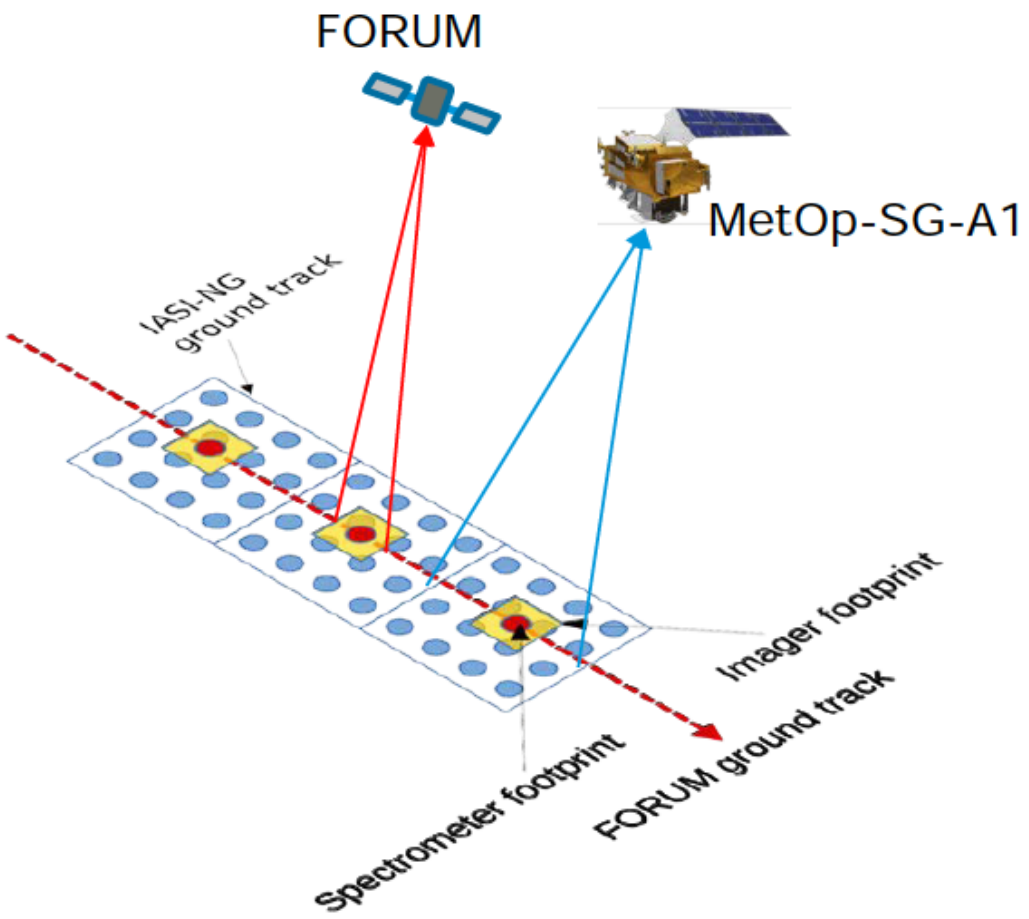
by

- 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

Additional benefit for ice cloud, surface emissivity and water vapour retrievals



Mission Concept: Footprint and Spatial Sampling



Nadir-looking observations

Spectrometer footprint

- single circular **pixel Ø = 15 km**

Along-track sampling step
Goal = 70 km, Threshold = 100 km

Thermal imager footprint

- 60x60 pixels, 36x36 km²
- **resolution = 0.6 km**

Lifetime = at least 4 years to resolve seasonal & inter-annual variability

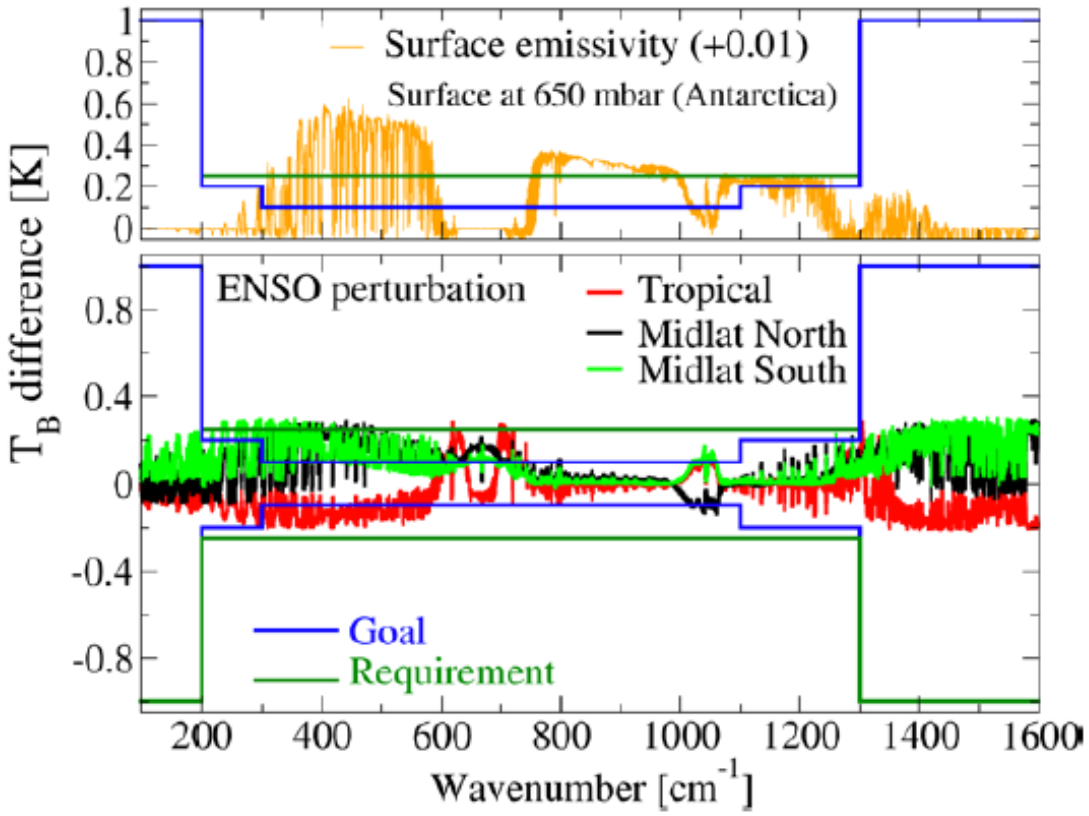
Flight in **loose formation with MetOp-SG-A1**
LEO, SSO at 9:30 LTDN – average altitude = 830 km to exploit synergy with IASI-NG

FORUM Absolute Radiometric Accuracy

Radiometric accuracy is the difference between the true value and the measurement in absence of random errors

High accuracy is required at 3σ

- to provide benchmark spectral observations against which climate models and future observations can be compared, which is the overarching goal of FORUM
- to derive FIR surface emissivity with accuracy better than 0.01
- to observe the effects of small perturbations in UTLS due to ENSO, QBO, etc. on zonal, monthly means



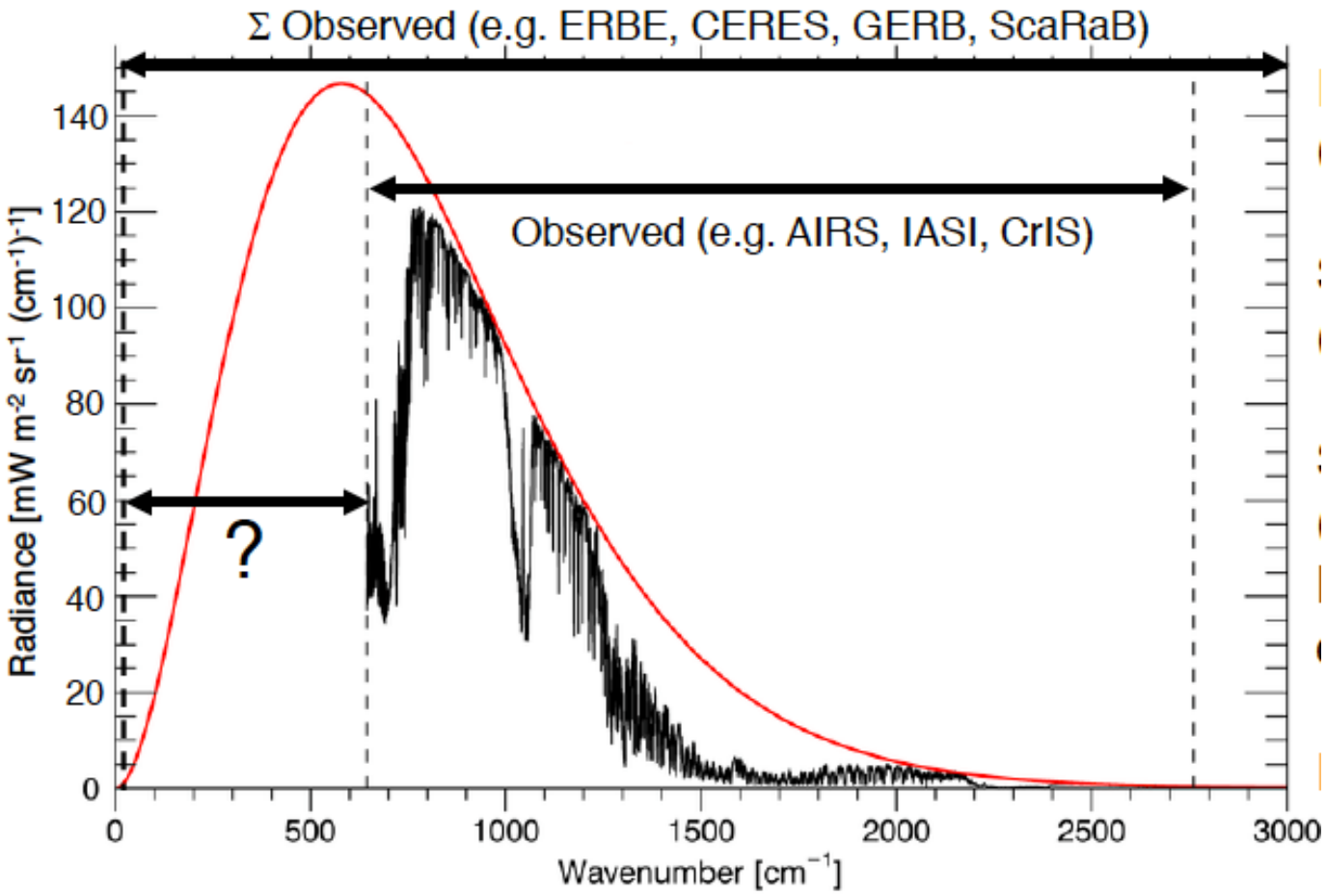
Goal = 0.1 K in 300-1100 cm^{-1}, 0.2 K in 200-300 cm^{-1} and 1100- 1300 cm^{-1}
Threshold = 0.25 K in 200-1300 cm^{-1}

FORUM Summary

- FORUM is the 9th ESA Explorer Mission
- Selection announced 9/24/19 after a 1.5 year Phase A competition
- Instrument specifics pending ESA selection of Industry Partner/Vendor
  - ESA competes the flight instrument build separately from the science team
  - Two Industry teams competing – selection at end of 2020
  - FORUM's Mission Advisory Group provided input on science and measurement requirements
- FORUM opens a new window on our understanding of the climate system
- Strong synergy with CERES
  - FORUM and CERES will have SNO's in polar regions
- Launch NET 2025/26

Backup Slides

The missing link: Far-Infrared Spectra



Broadband integrated radiation (ERBE, CERES ,GERB, ScaRAB) since 1975

Mid-IR spectra (5-15 um; AIRS, IASI, CrIS) continuous since 2002

No science quality far-IR spectra from space (Nimbus-III and Nimbus-IV < 10 months)

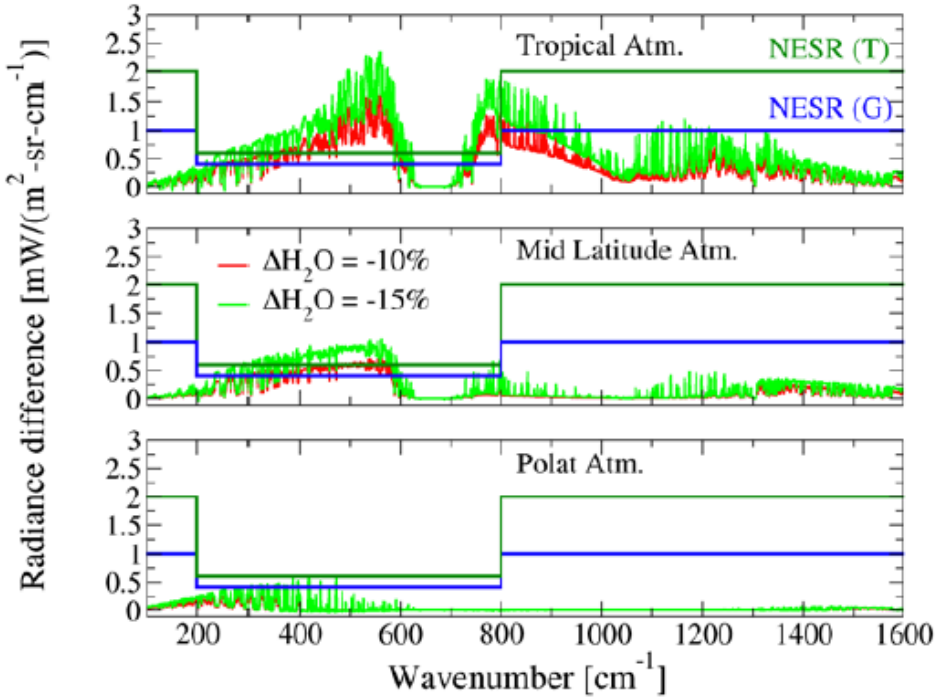
No observations < 400 cm^{-1}

FORUM fills the critical gap!!

FORUM Radiometric Precision

Clear sky

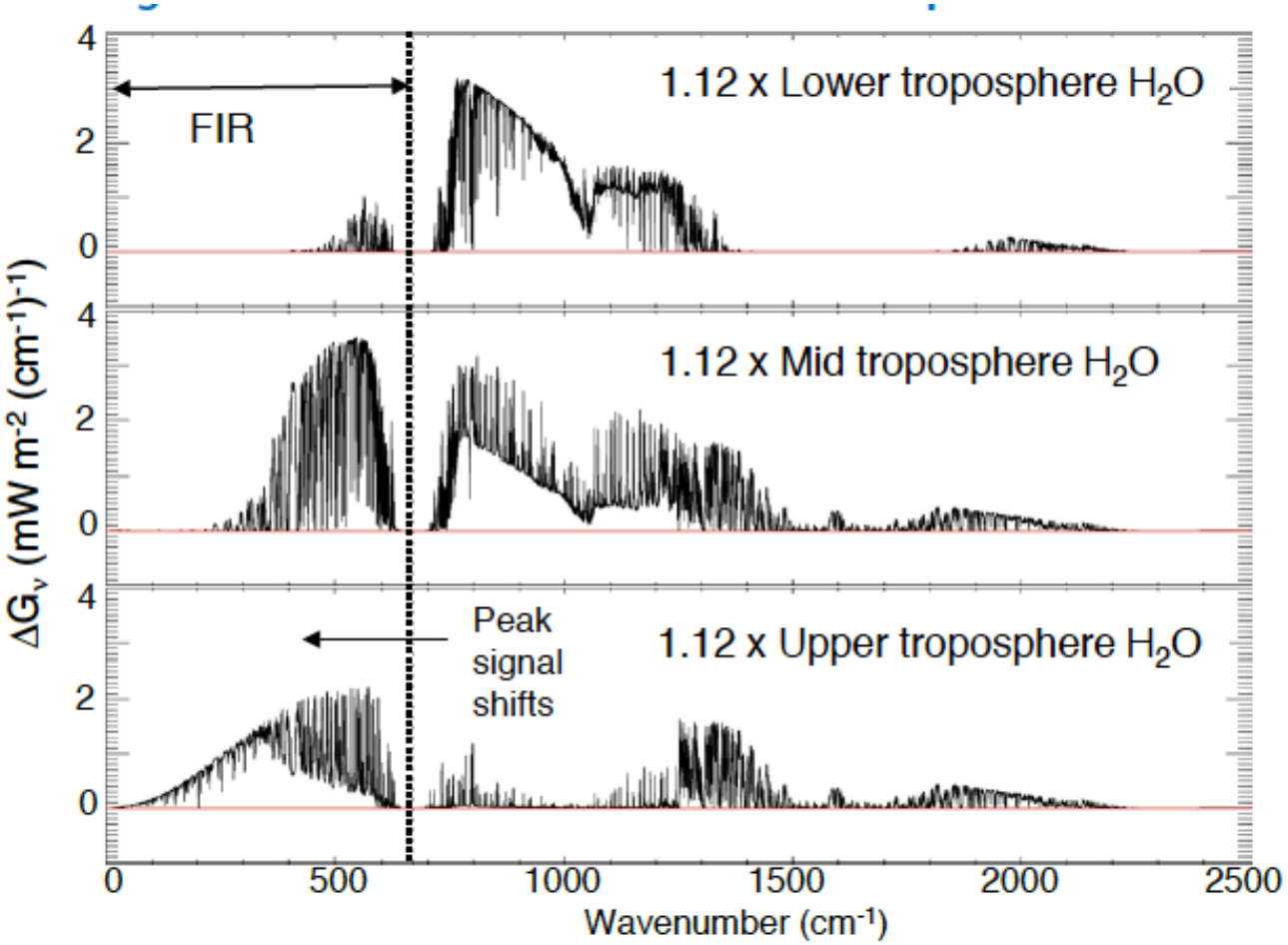
Sensitivity study to water vapour perturbation for different scenarios



Goal = 0.4 mW/(m² sr cm⁻¹) in 200-800 cm⁻¹, 1 mW/(m² sr cm⁻¹) elsewhere

Threshold = 0.6 mW/(m² sr cm⁻¹) in 200-800 cm⁻¹, 2 mW/(m² sr cm⁻¹) elsewhere

The Greenhouse Effect: Sensitivity to water vapor in Far-IR

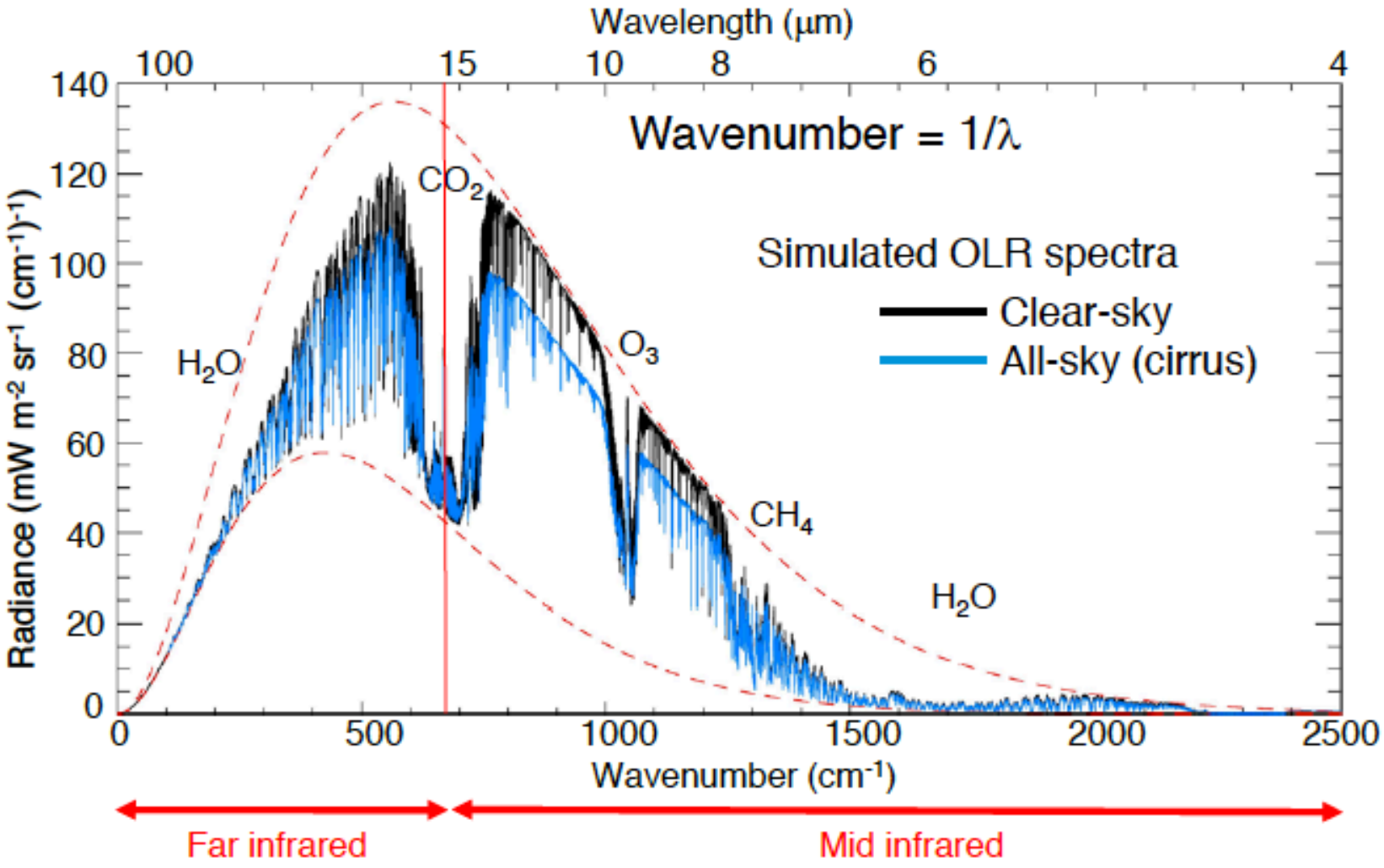


Signatures of changes in atmospheric water vapour:

A 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

Why the Far-Infrared?



FORUM Mission Objectives

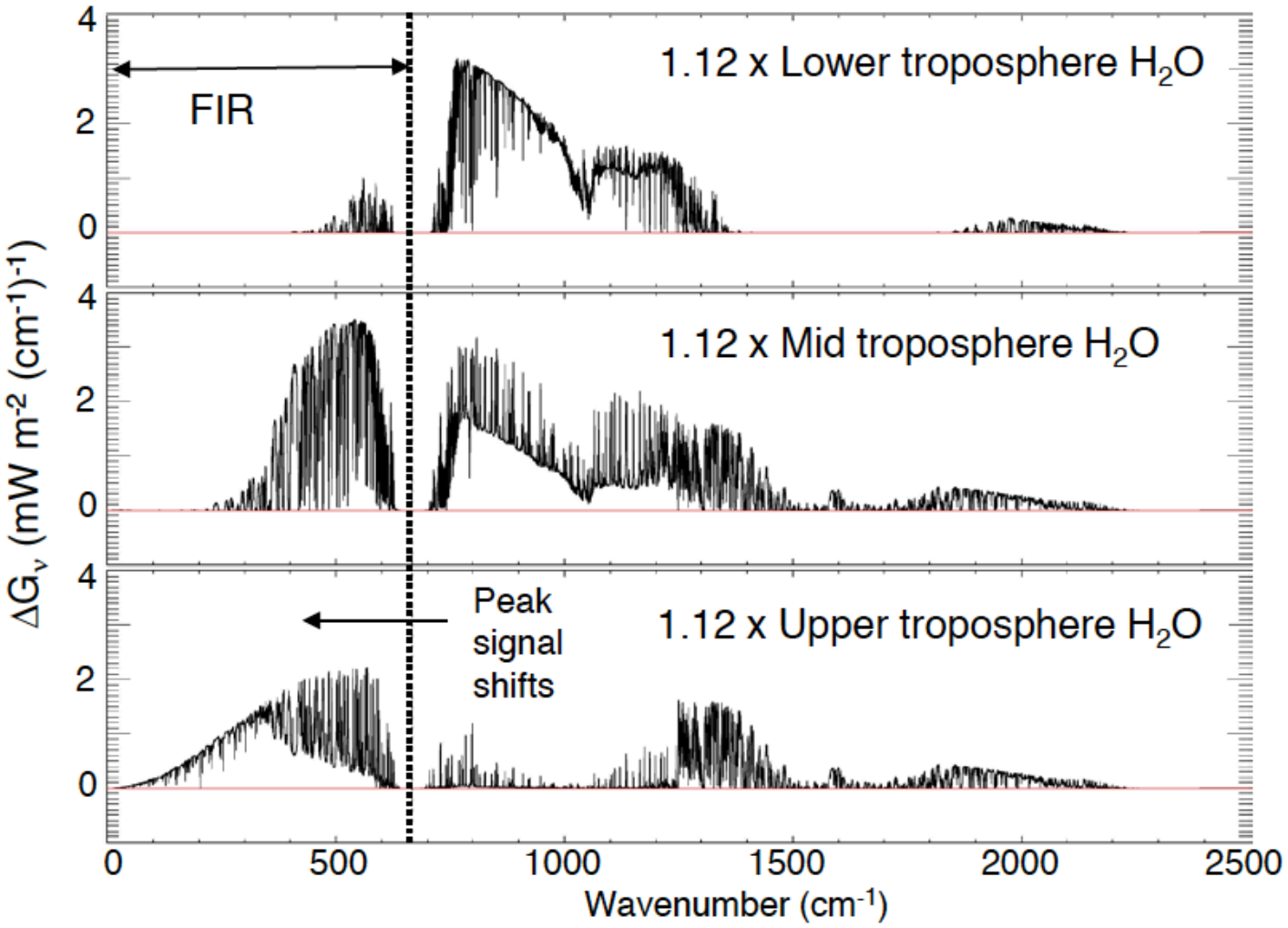
Primary

- Measure the spectral distribution of the Earth's OLR encompassing, for the first time, the far-ir
- Evaluate the underlying spectroscopy and cloud models currently employed in the far-ir
- Tie the observed radiative signatures directly to variability in, in particular, water vapour, greenhouse gases, cloud and surface properties
- Provide a stringent evaluation of key radiative processes/feedback mechanisms as currently represented in climate models

Additional

- Retrieval of FIR surface emissivity in appropriate conditions (clear-sky, dry conditions)
- Assessment of additional benefit of FIR spectral observations compared to state-of-the-art hyperspectral mid-infrared radiances for water vapour retrieval
- Detection of optically thin and sub-visual ice-cloud
- Retrieval of ice-cloud optical depth, cloud top height and particle size

Far-Infrared: Sensitivity to upper troposphere H_2O



Signatures of changes in atmospheric water vapour:

A 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