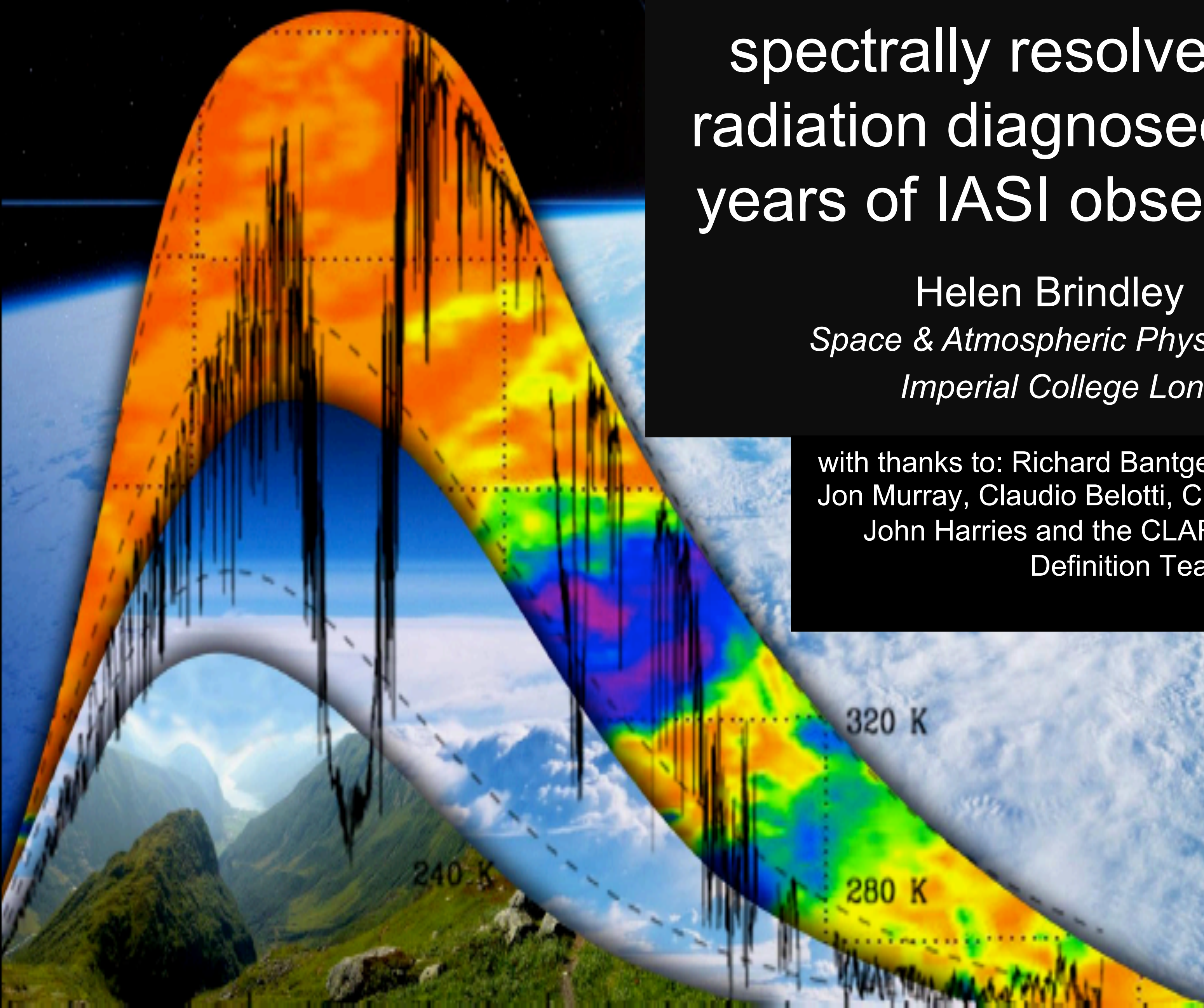
Interannual variability in spectrally resolved TOA radiation diagnosed from 5 years of IASI observations

Helen Brindley

Space & Atmospheric Physics Group

Imperial College London

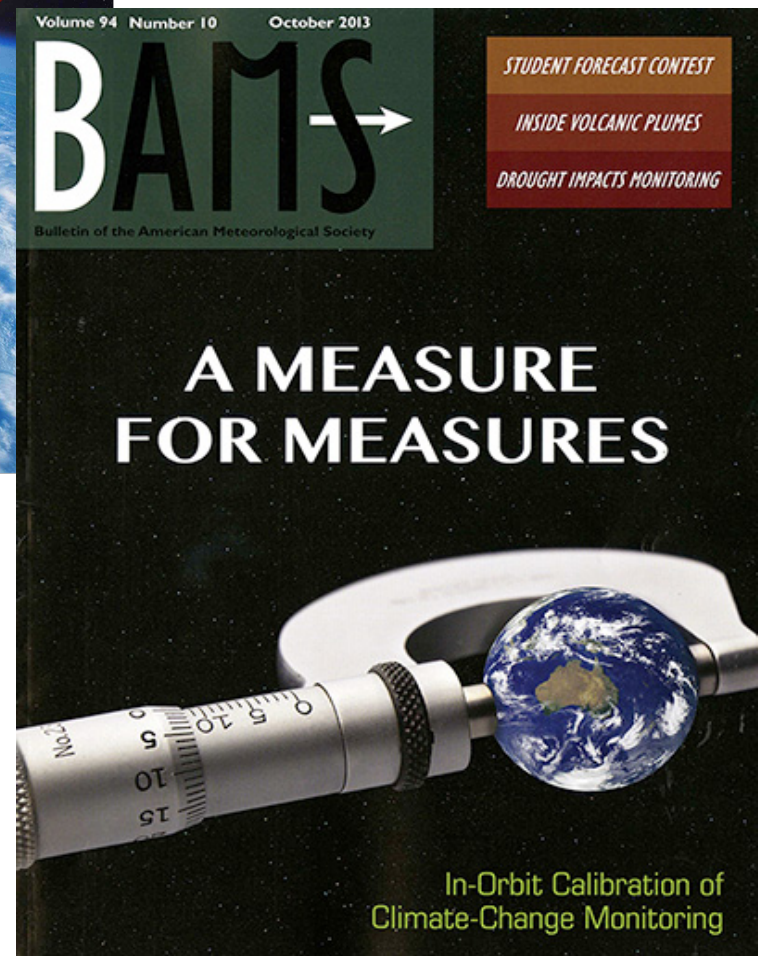
with thanks to: Richard Bantges, Jacqui Russell, Jon Murray, Claudio Belotti, Christopher Dancel, John Harries and the CLARREO Science Definition Team



NASA Tier 1 Decadal Survey Mission

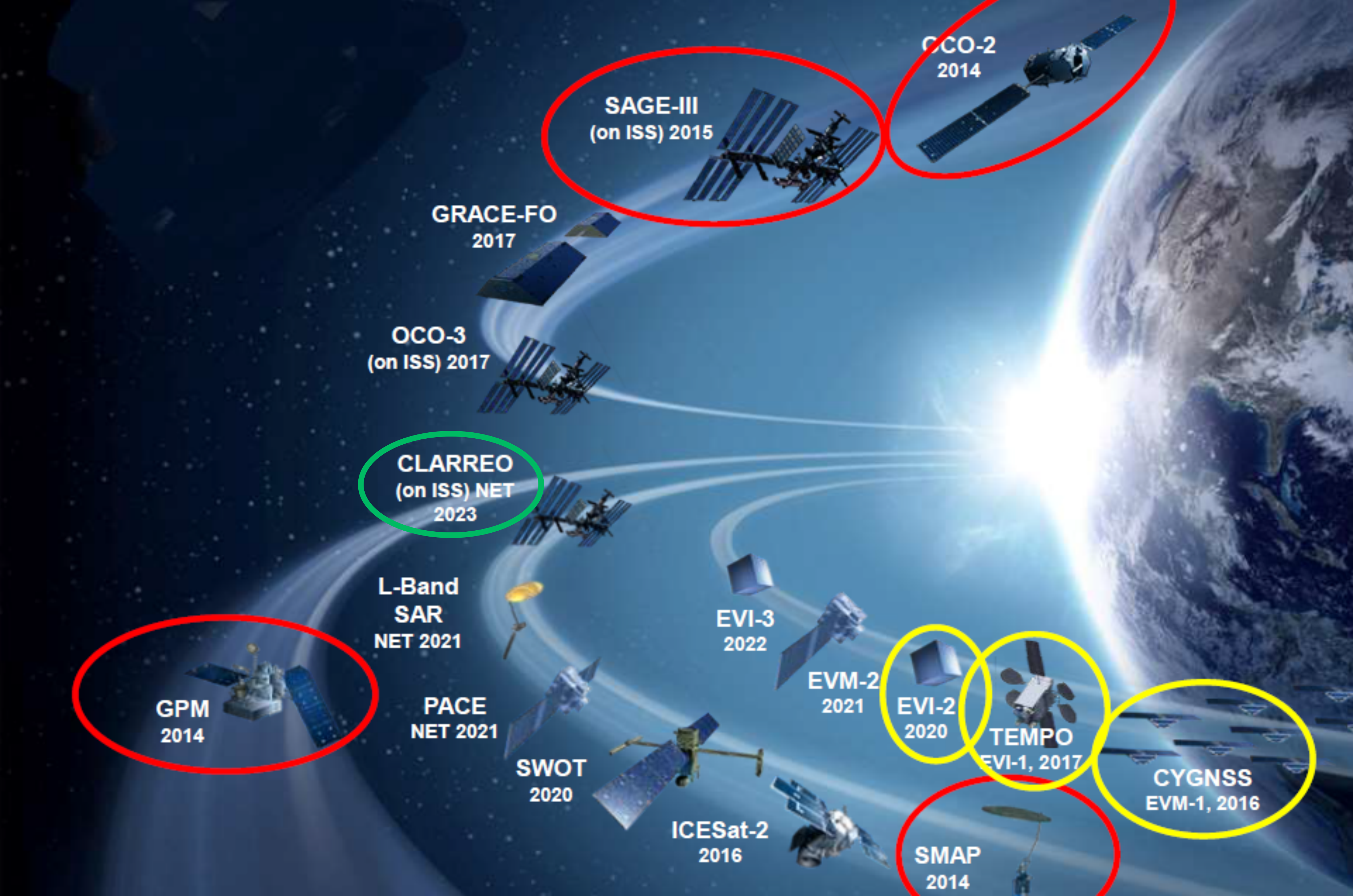
CLARREO

High in-orbit absolute accuracy coupled with tailored sampling and sufficient spectral resolution and range across EM spectrum + GNSS radio occultation

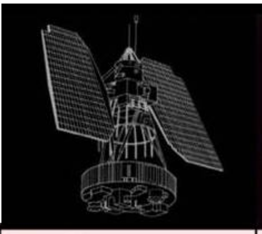


Wielicki *et al.*, 2013

Upcoming Orbital Missions



Can we use current/past instruments to get us part way there?

				
Instrument	**IRIS**	**IMG**	**AIRS**	**IASI**
Satellite	Nimbus 4	ADEOS	AQUA	METOP-A
Spectro-meter type	FTS	FTS	grating spectrometer	FTS
Data available	Apr 1970 – Jan 1971	Oct 1996 – Jun 1997	2002 - present	2007 - present
Spectral coverage (cm^{-1})	400 – 1600 cm^{-1} continuous	715 – 3030 cm^{-1} 3 bands	650 – 2700 cm^{-1} 2378 bands	645 – 2760 cm^{-1} 3 bands
Spectral resolution	2.8 cm^{-1}	0.1 cm^{-1}	0.4–1.0 cm^{-1}	0.5 cm^{-1}
Footprint (nadir)	95 km diameter	8km x 8km	13 km diameter	12 km diameter

Clear-sky only, no account of variability

Harries et al., 2001

Griggs and Harries, 2007

IASI and IRIS?

Major Questions

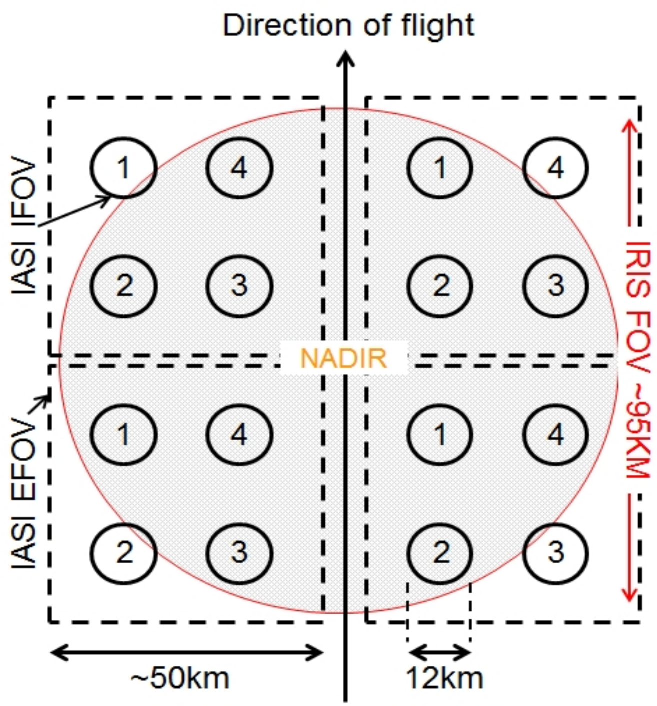
- What is the short-term variability seen in observed radiance spectra?
- How do these signals compare to those seen in model simulations and what can this tell us about the representation of the processes driving variability/change?
- Are observed long-term change signals robust?

Major Questions

- What is the short-term variability seen in observed radiance spectra?
- How do these signals compare to those seen in model simulations and what can this tell us about the representation of the processes driving variability/change?
- Are observed long-term change signals robust?

Ensure measurements are as consistent as possible

Spatial consistency:
average 16 IASI IFOV footprints



5 years of IASI L1c data: ~ 50 Tb
~ 160 million spectra

Spectral consistency

IRIS

Pad each spectrum to 0-2000 cm^{-1} at original sampling interval

FT padded spectrum

FT and output at 0.1 cm^{-1} sampling interval (~ 2.8 cm^{-1} resolution)

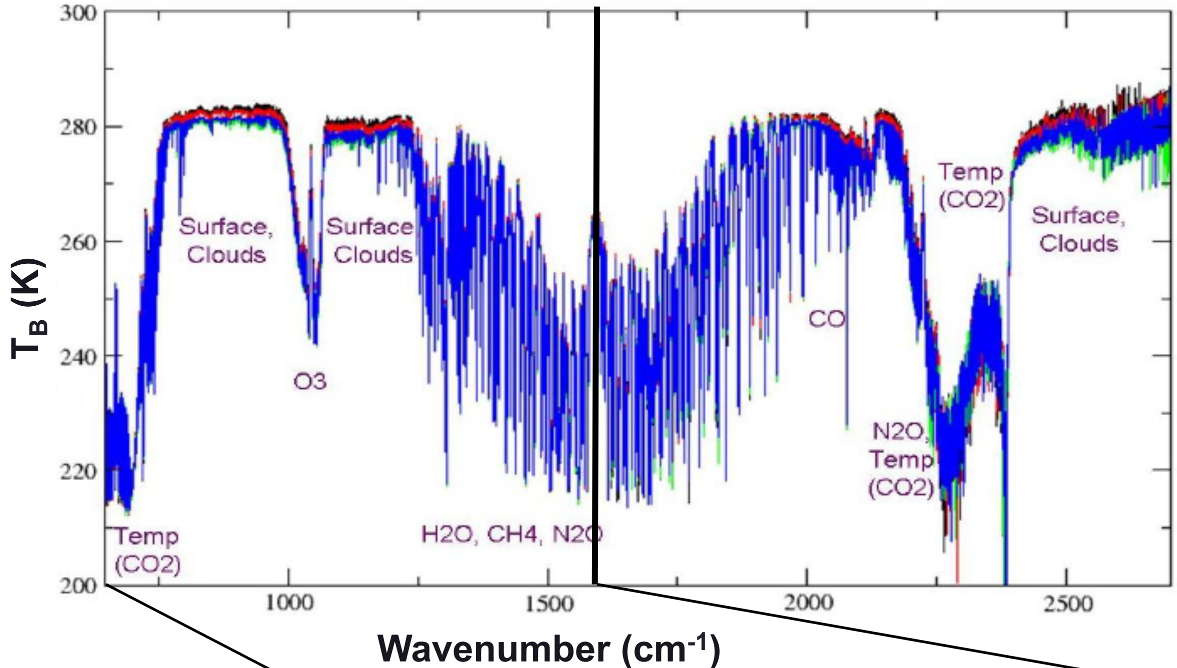
IASI

Pad and truncate average spectra to 0-2000 cm^{-1} at original sampling interval

FT, remove IASI apodisation function & apply varying length Hamming window

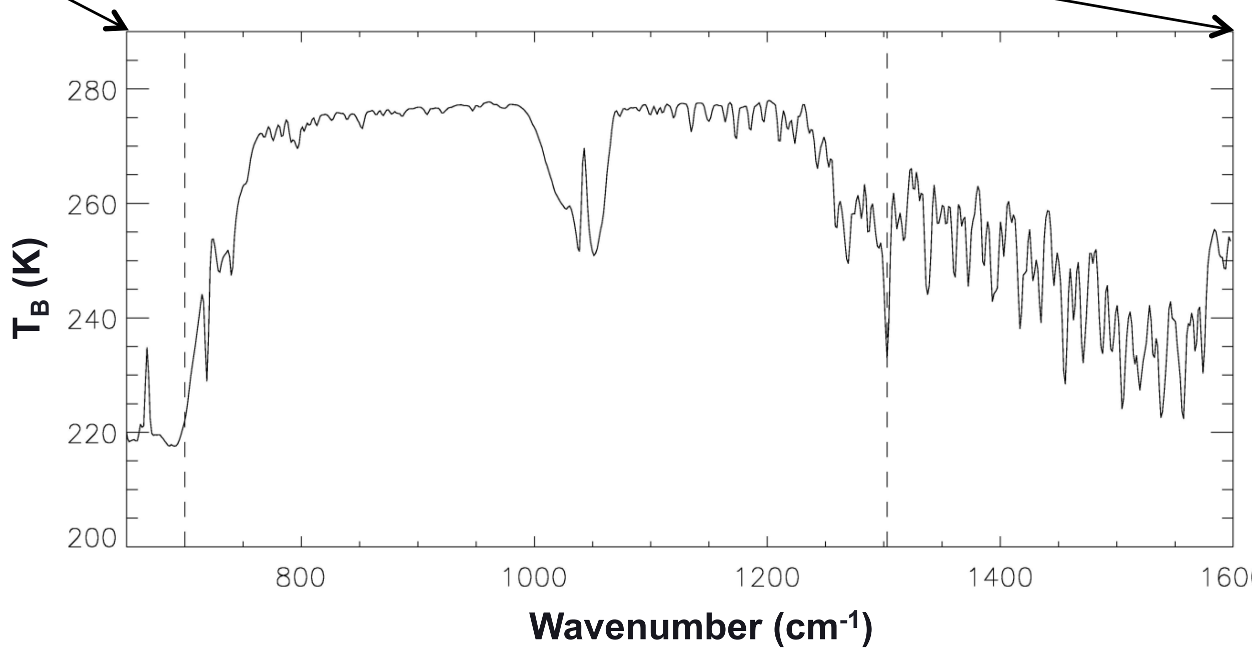
FT output at 0.1 cm^{-1} sampling interval (~ 2.8 cm^{-1} resolution)

Apply remaining FOV correction factor



Selection of first IASI L1C spectra from MetOp-A (EUMETSAT, 2010)

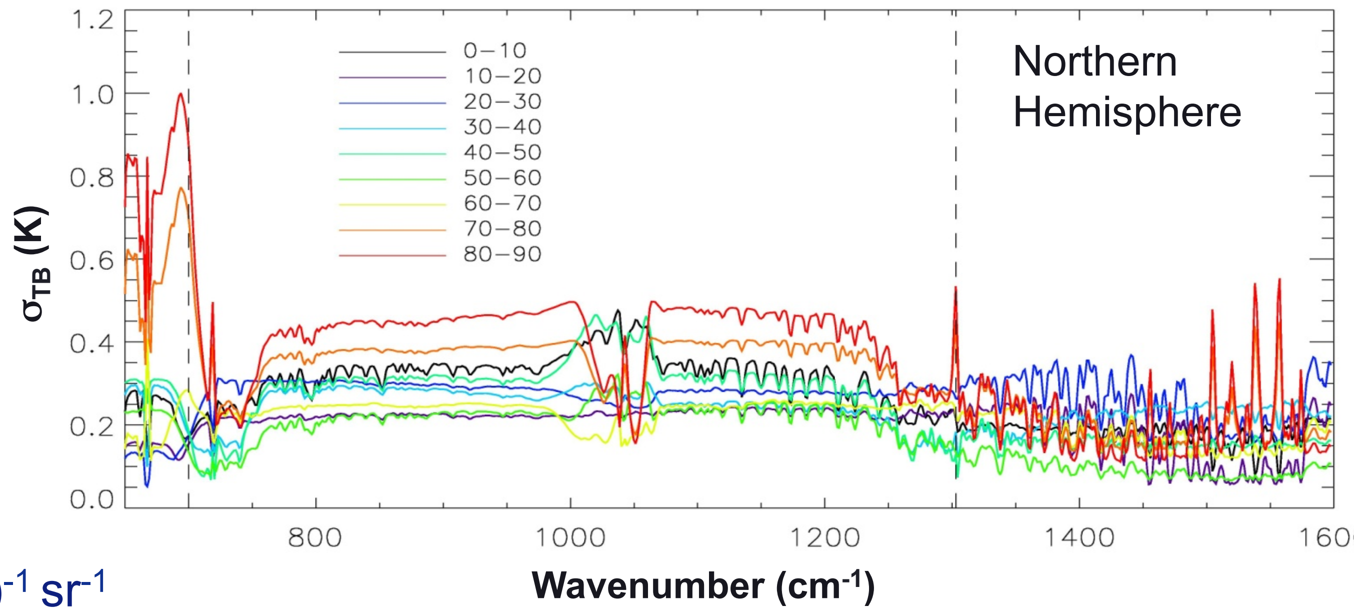
Example smoothed spectrum

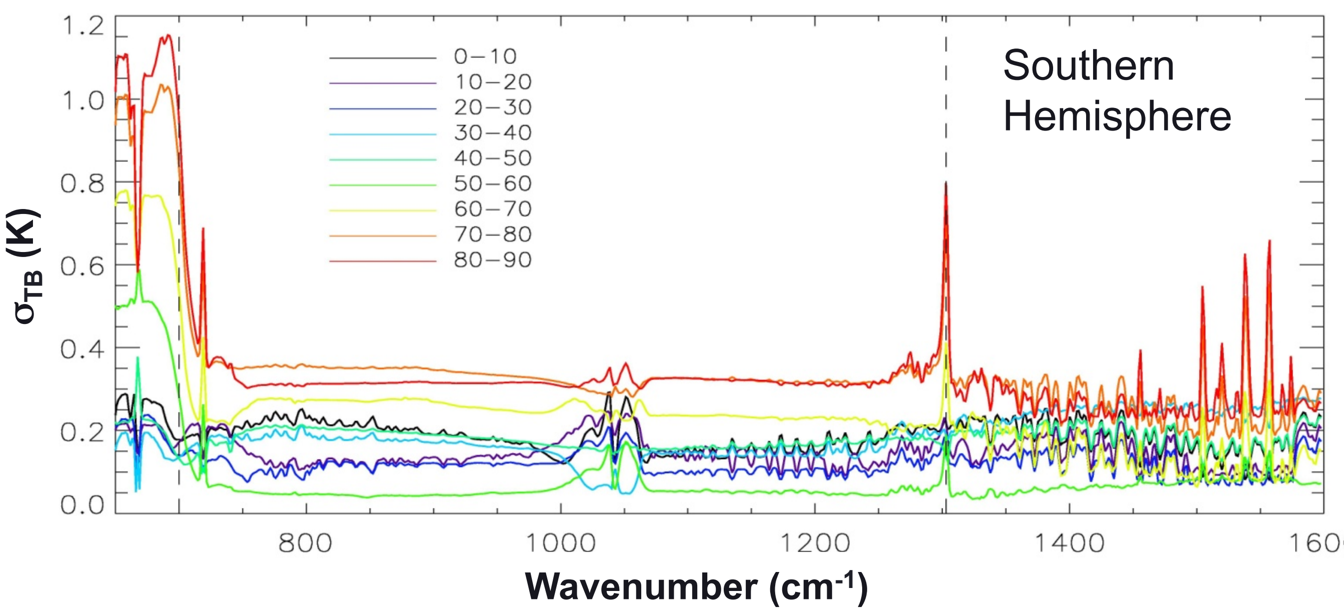


Short-term spectral variability

Standard deviation in **<u>10° latitude band</u>** annual means

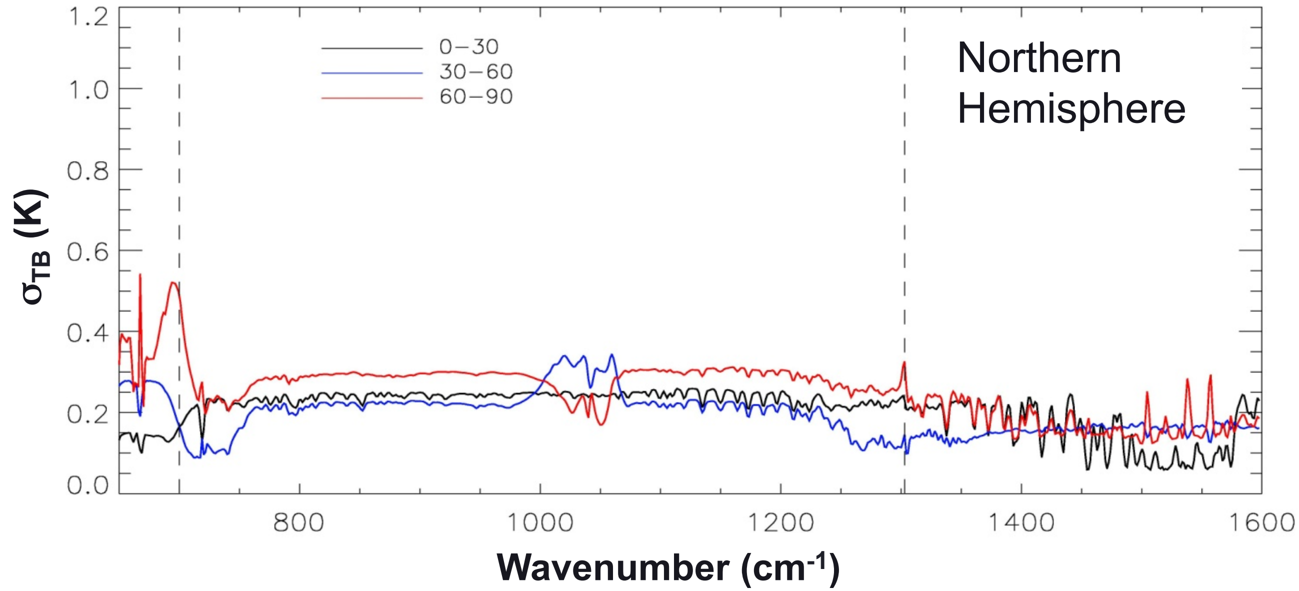
1 K ~ 1 mW m^{-2} $(cm^{-1})^{-1}$ sr^{-1}

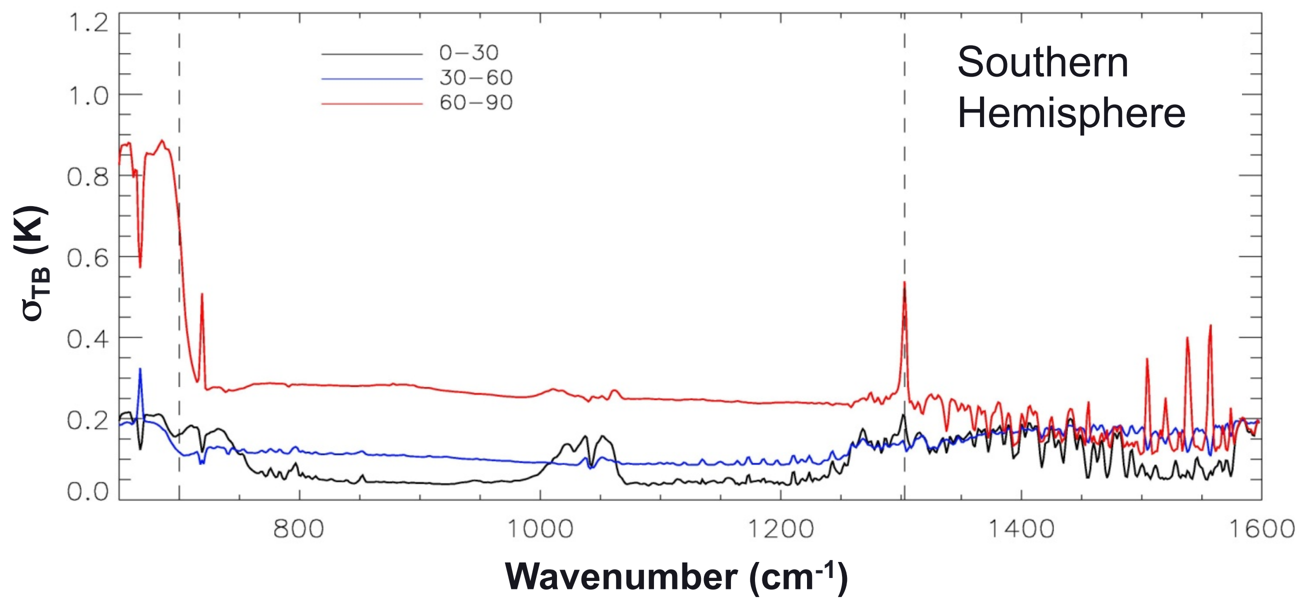




Short-term spectral variability

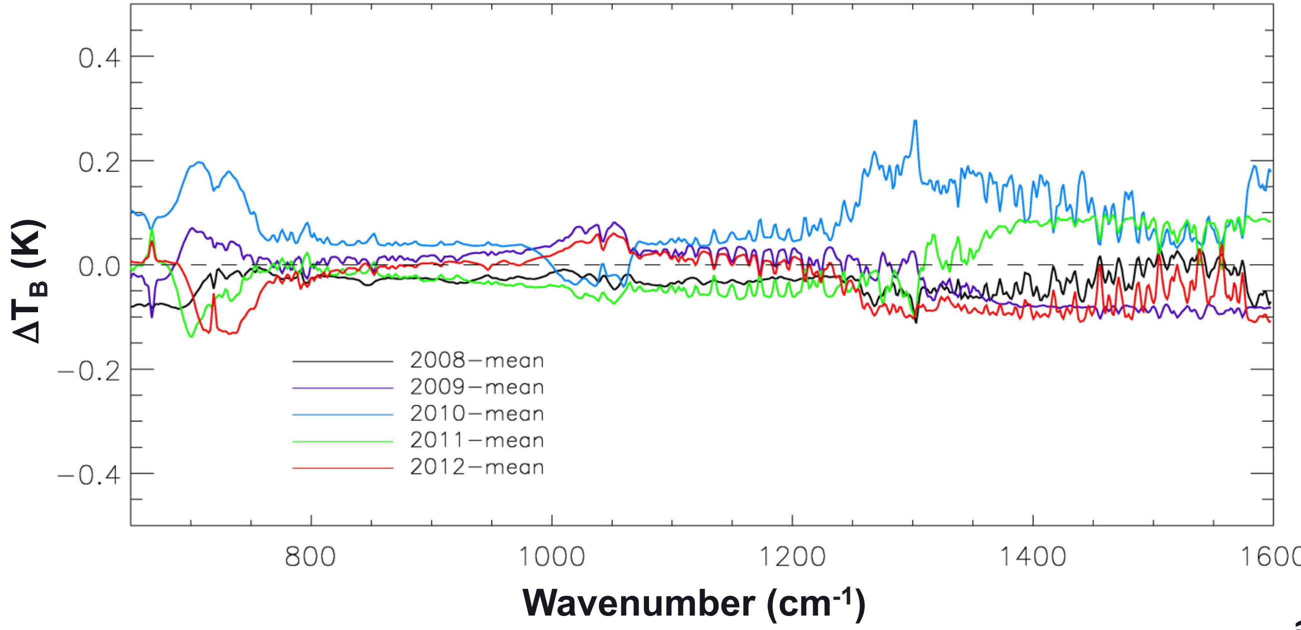
Standard deviation in **30° latitude band** annual means





Short-term spectral variability

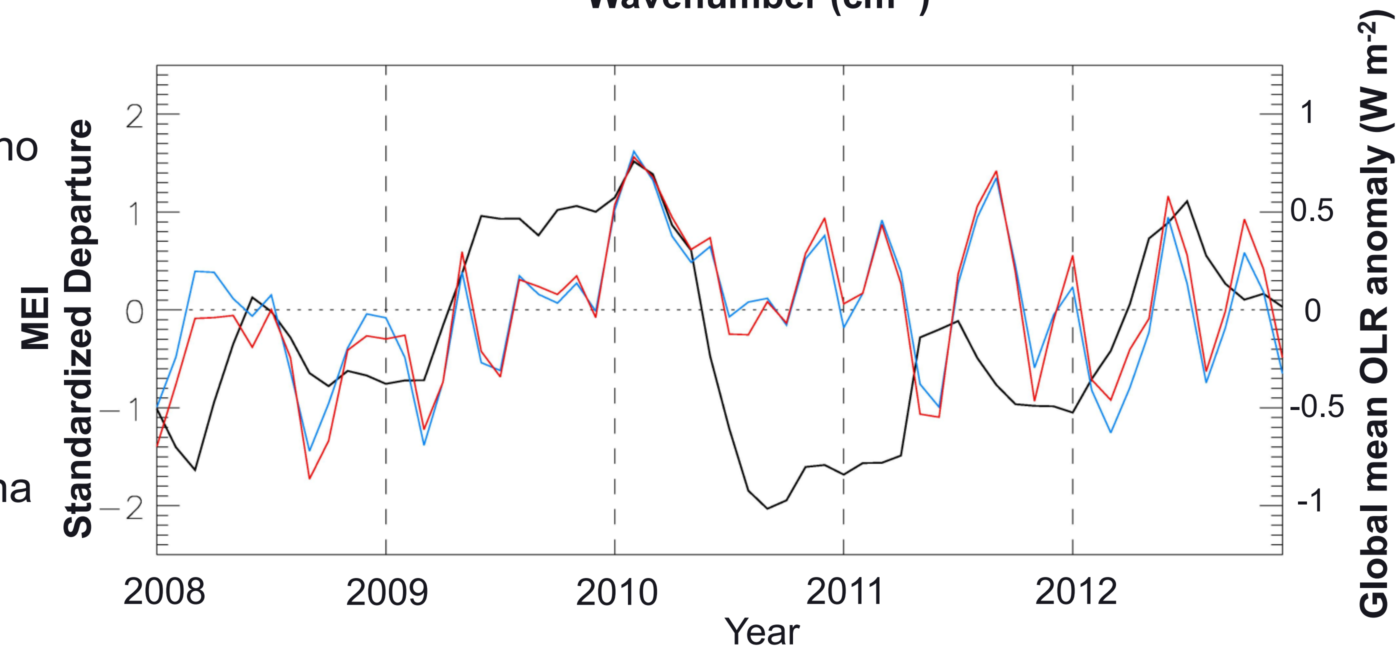
Deviation from overall global annual mean for each year



Multivariate ENSO Index (NOAA ESRL) [black]
Deseasonalised CERES OLR anomalies [red: aqua; blue: terra]

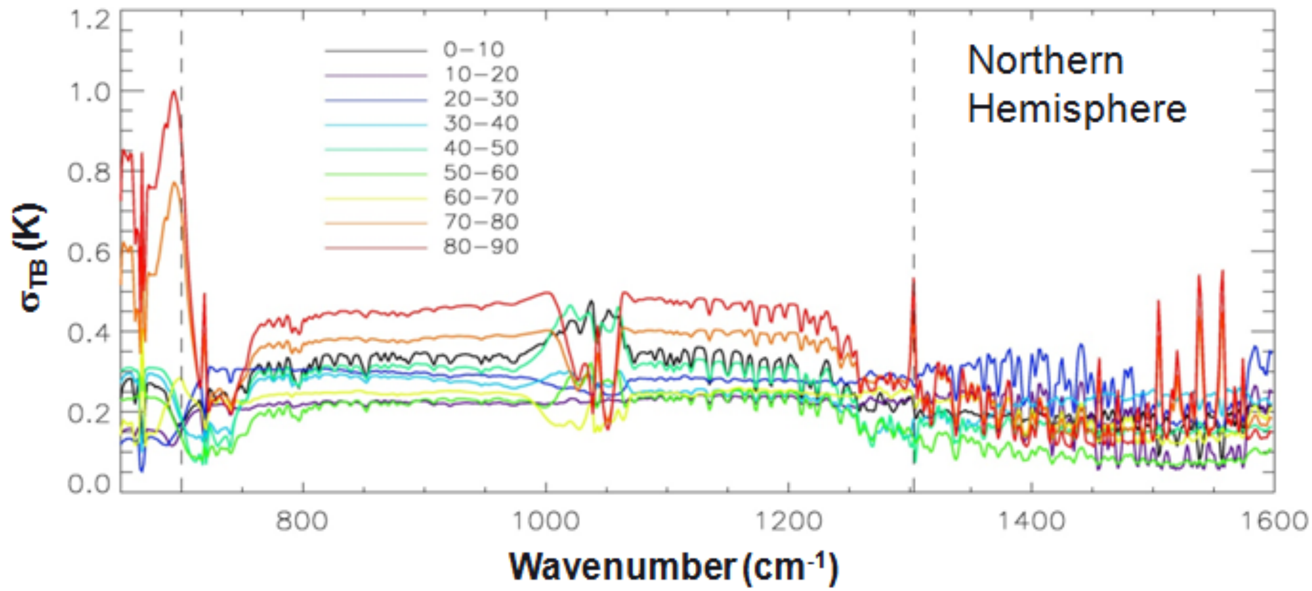
El Nino

La Nina

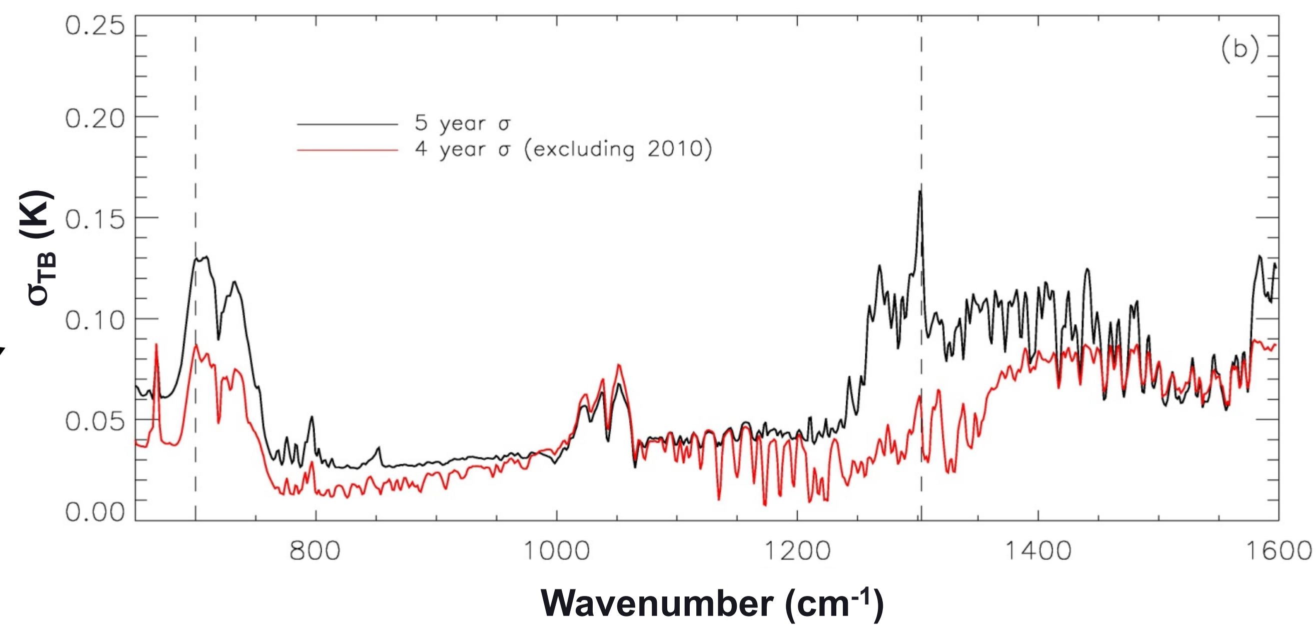


Short-term spectral variability

Standard deviation in **10° latitude band** annual means



Standard deviation in global annual means



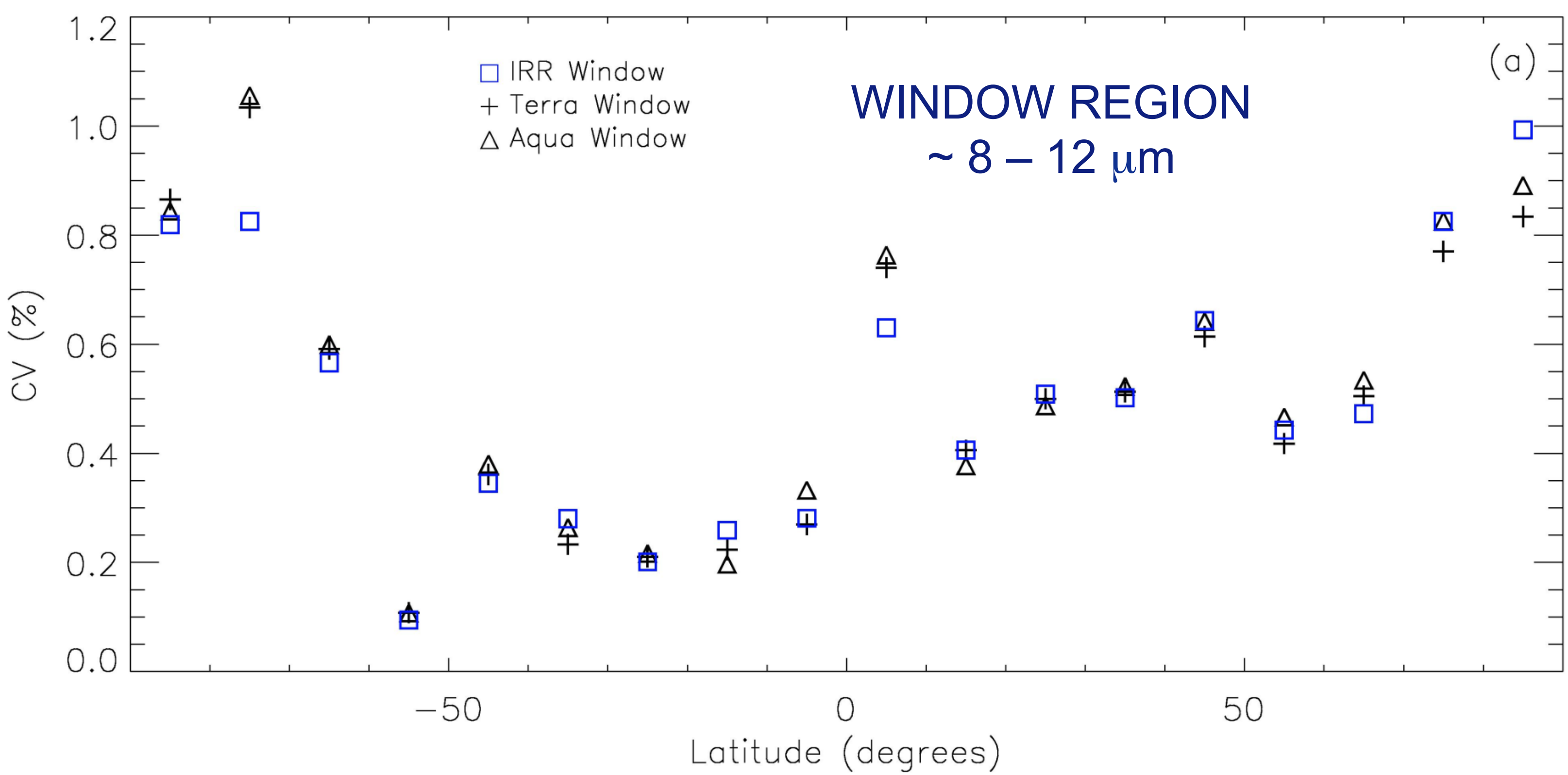
Note change in scale and change in shape

Consistency with broadband measurements?

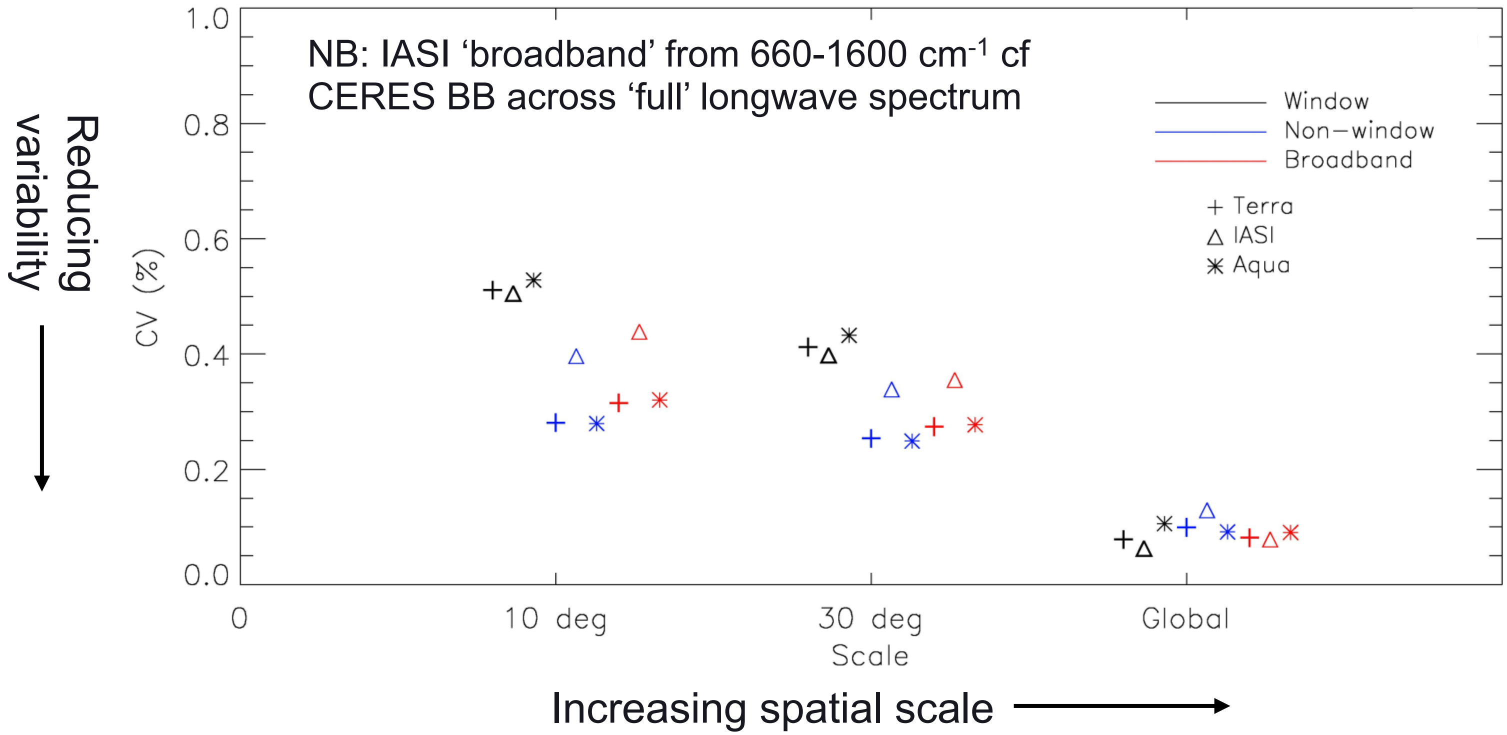
Employ observations from CERES: broadband and window ***fluxes***

Different measurement scales so use ***coefficient of variation, CV***

$$CV = \sigma / \mu \quad \text{and note that} \quad \sigma_{BB} = [\sigma_{win}{}^2 + \sigma_{nonwin}{}^2 + 2cov_{win,nonwin}]^{1/2}$$



Consistency with broadband measurements?



- Window inter-annual variability reduces most rapidly with increasing scale
- Results in non-window variability becoming dominant at global scale
- Difference between IASI BB and CERES BB behaviour suggests an important role for the far infra-red in determining all-sky inter-annual variability at the global scale
- Spectrally, global inter-annual variability < 0.17 K, < 0.05 K across window

Summary

- Used IASI data to probe how the emission to space varies spectrally on short timescales. While variability reduces with increasing spatial scale across the spectrum, the rate of change varies with wavenumber. Hence a more marked reduction is seen in window variability compared to that seen in regions sensitive to the upper troposphere.

- These findings are in agreement with observations from CERES over the same period and imply that at the largest spatial scales fluctuations in mid-upper tropospheric temperatures and water vapour, and not surface temperature or cloud, play the dominant role in determining the level of inter-annual all-sky OLR variability.

  (Brindley et al., *J. Clim*, in review)

- Although simulations from reanalysis show an encouraging level of agreement in general, they do not replicate this scaling behaviour.

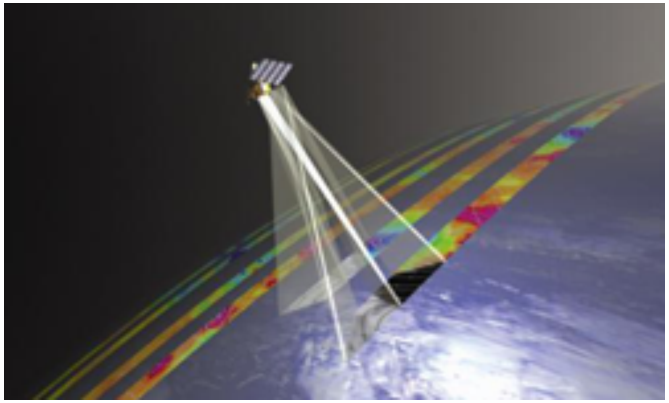
- To diagnose longer term spectral changes confidence in instrument calibration and stability is key.

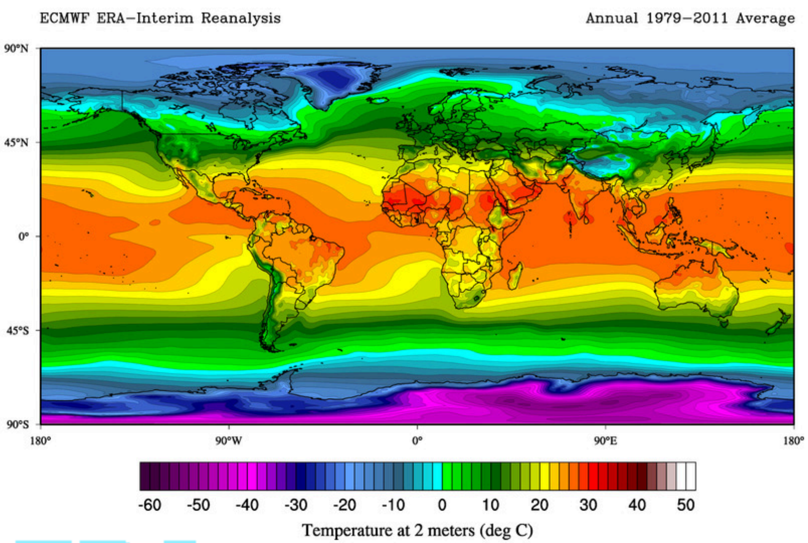
BACK UP SLIDES

Major Questions

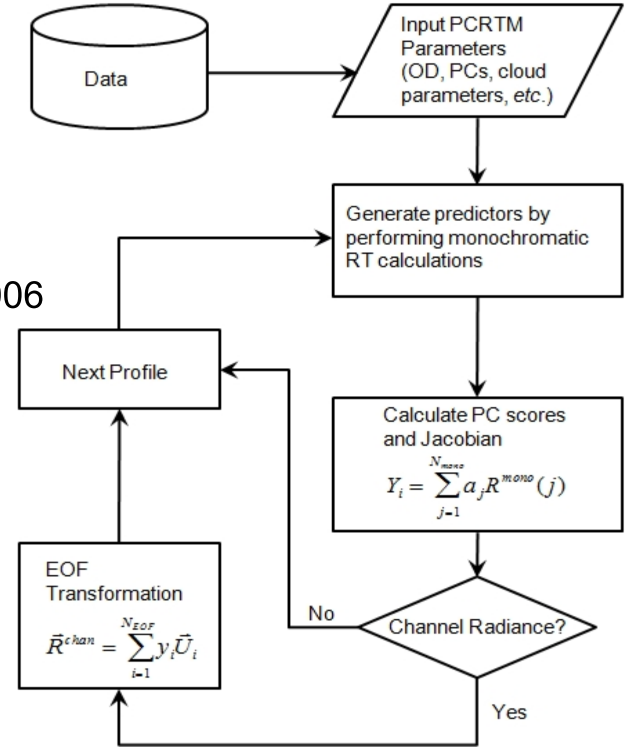
- What is the short-term variability seen in observed radiance spectra?
- How do these signals compare to those seen in model simulations and what can this tell us about the representation of the processes driving variability/change?
- Are observed long-term change signals robust?

Consistency with Reanalyses?





PCRTM
Liu *et al.*, 2006



X. Huang, University of Michigan

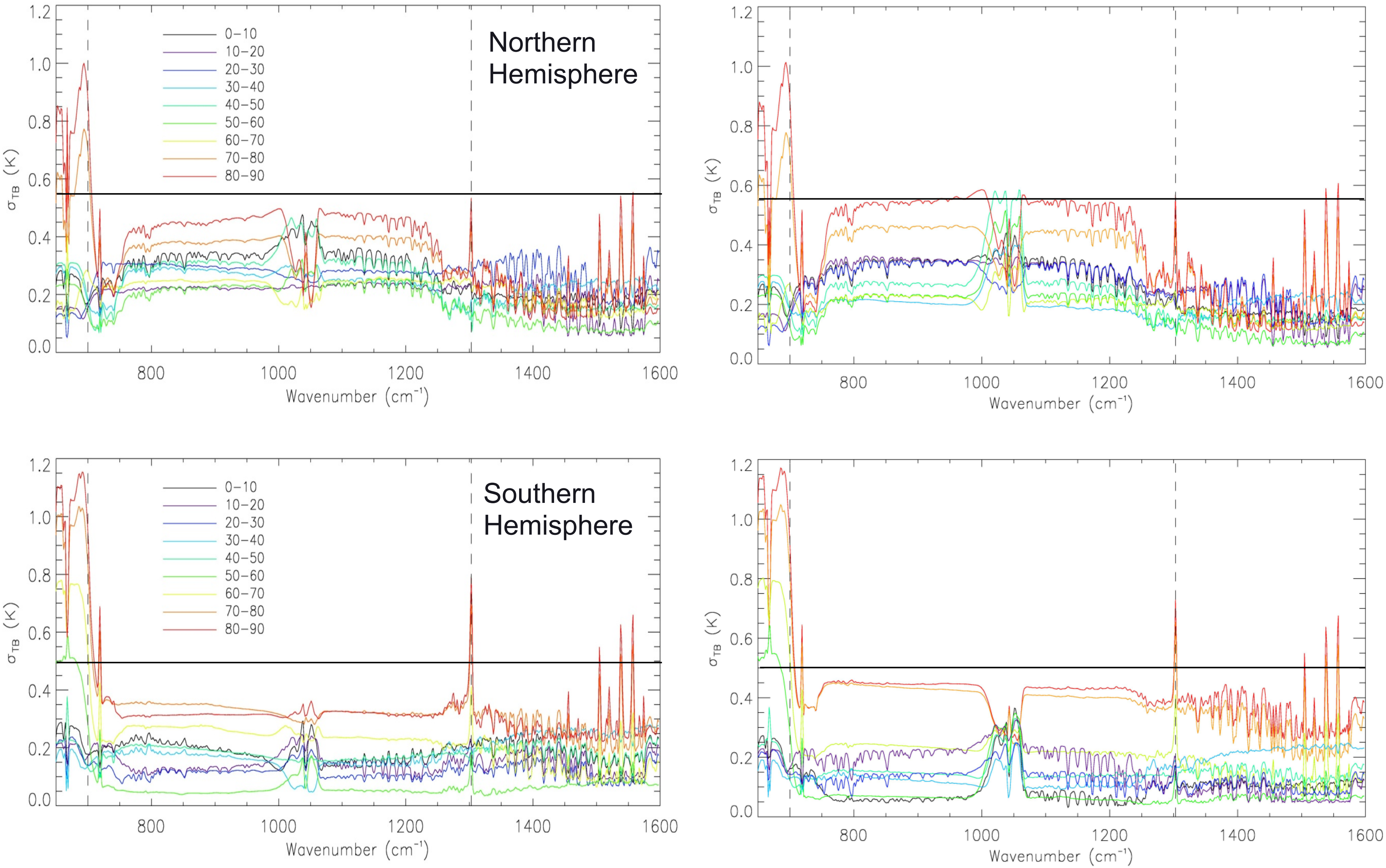
~ 10 million matched IRIS-like IASI spectra (in 10 days!)

Consistency with Reanalyses?

10° bands

OBSERVATIONS

SIMULATIONS

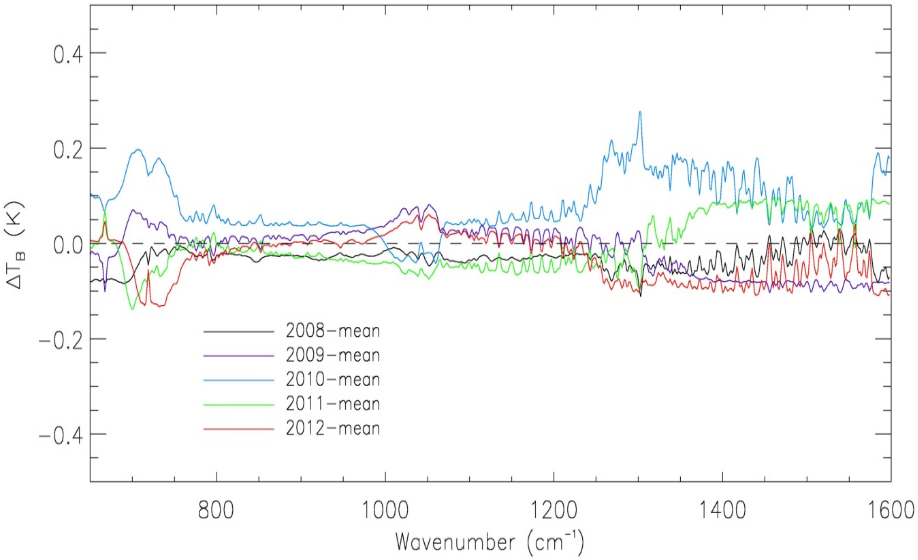


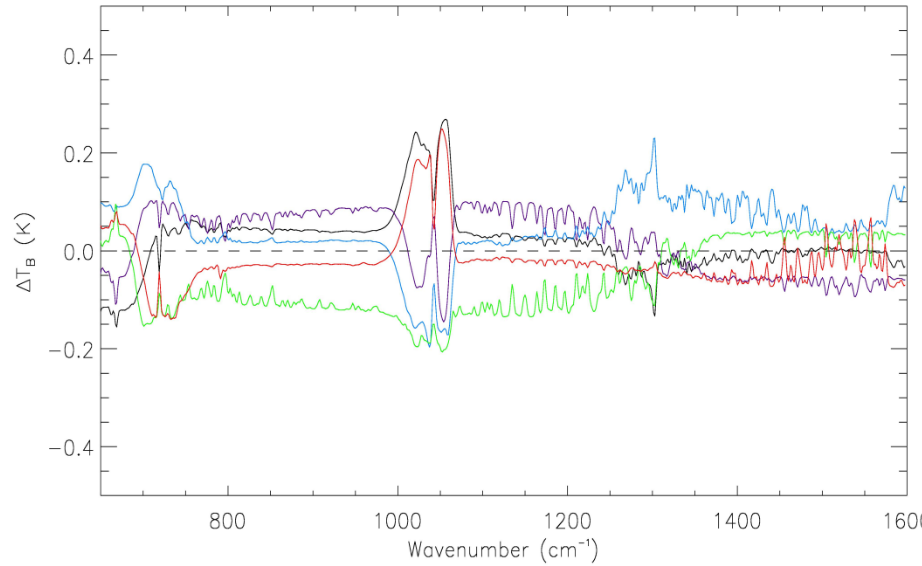
Consistency with Reanalyses?

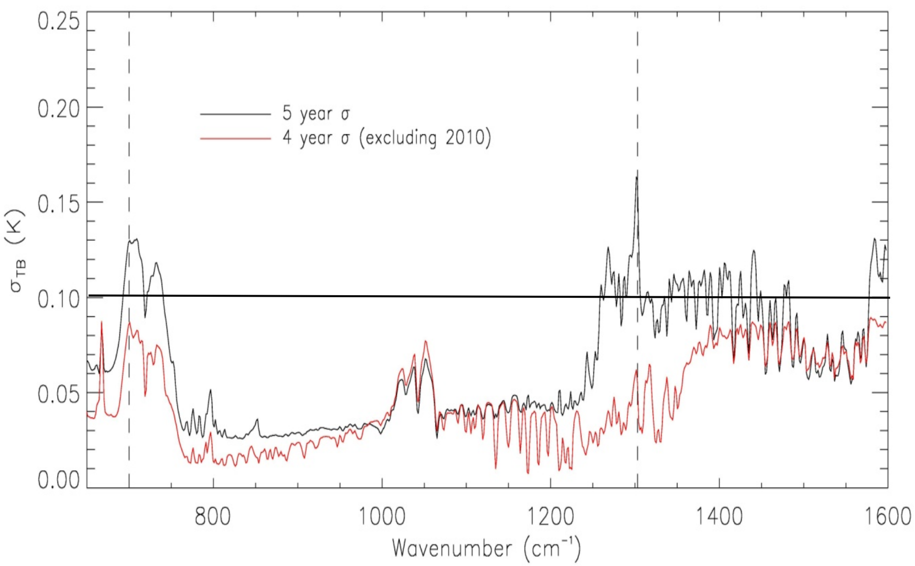
Global

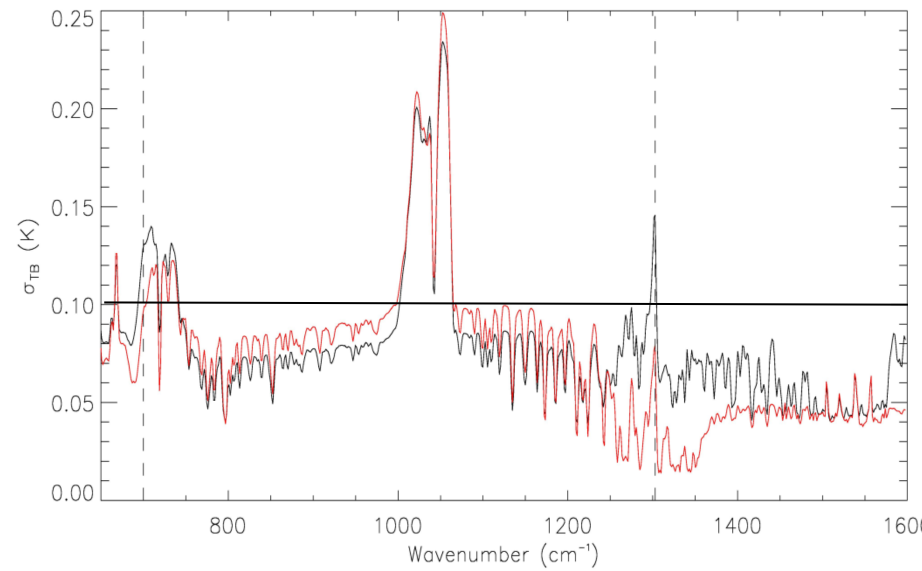
OBSERVATIONS

SIMULATIONS

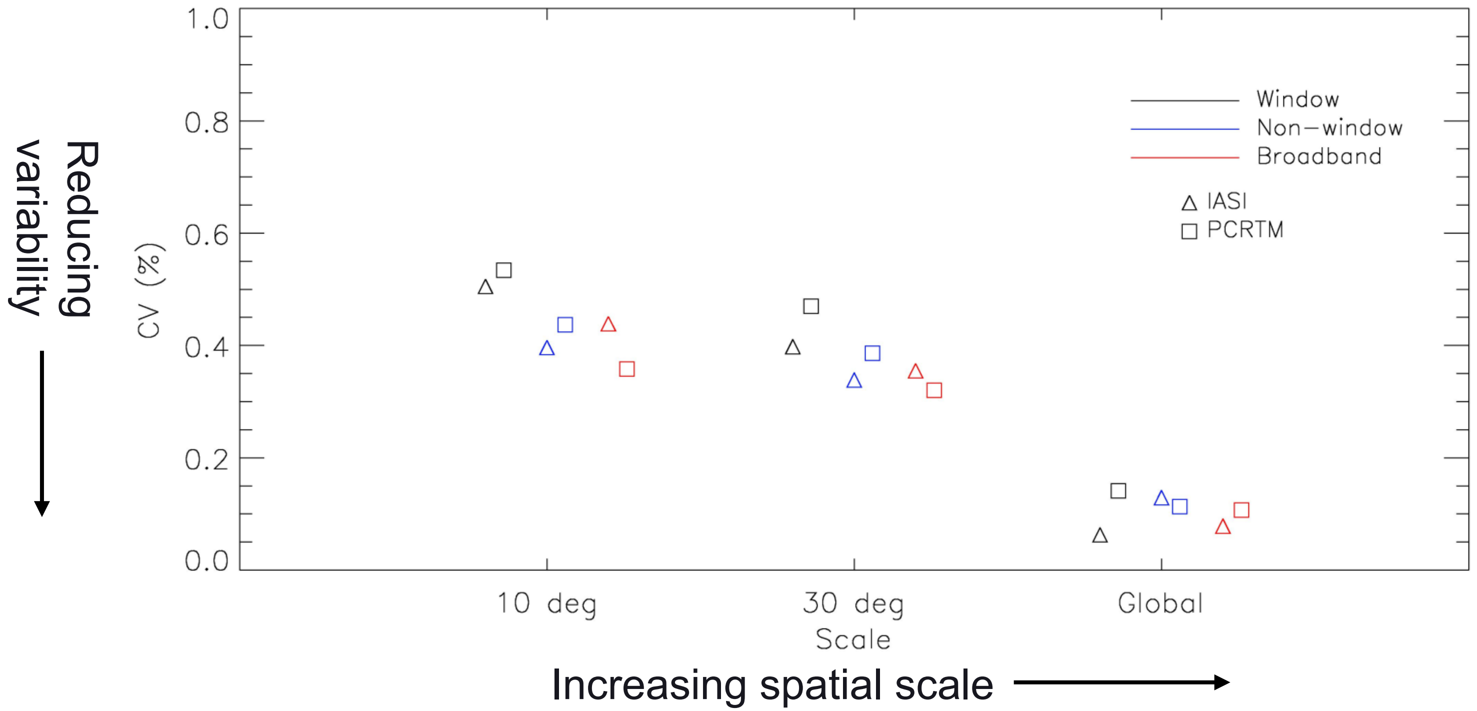








Consistency with Reanalyses?



- Window inter-annual variability reduces most rapidly with increasing scale

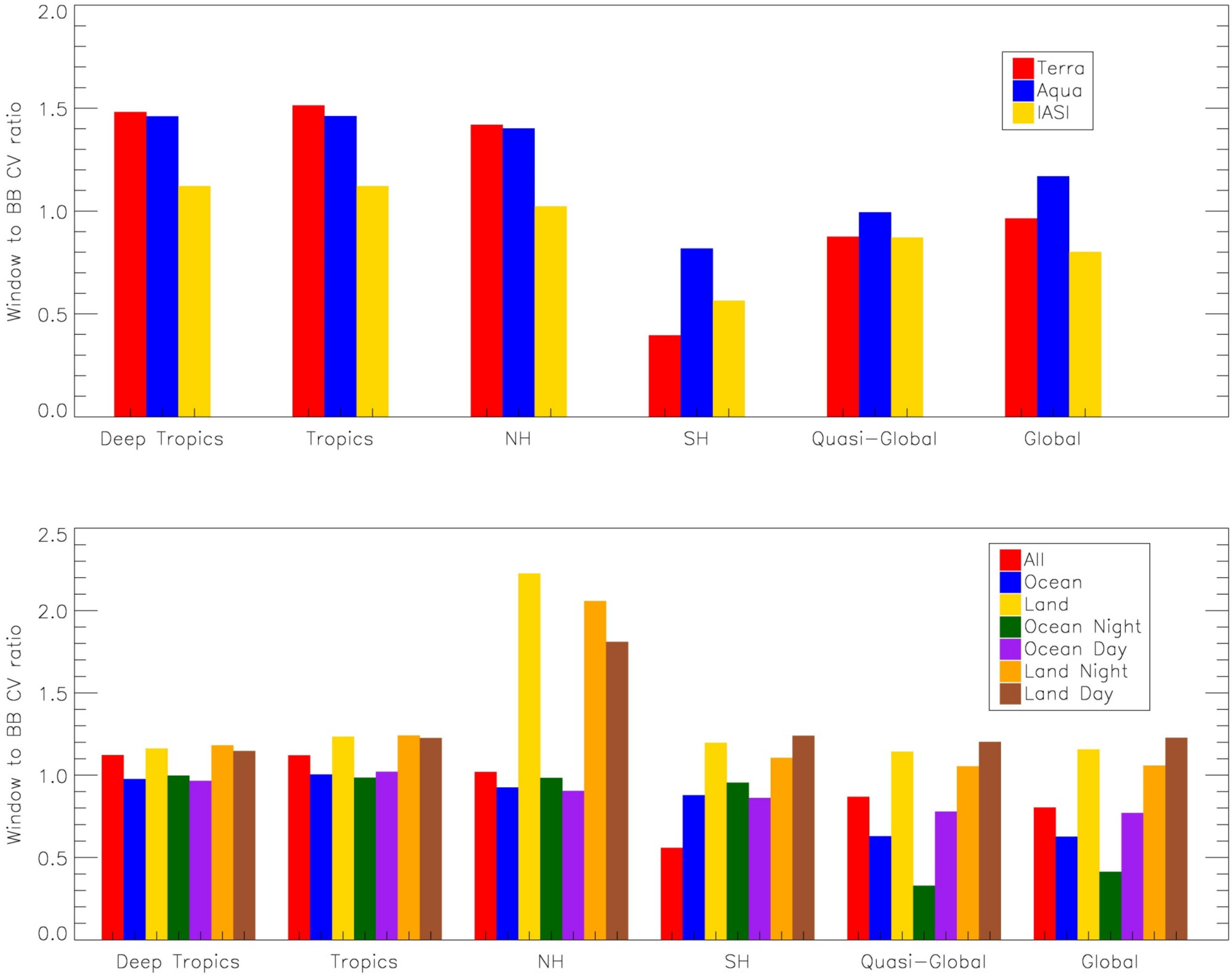
  Simulations show the same behaviour but reduction in window is not as rapid. Non-window variability exceeds broadband at all scales and seems to show a faster rate of change with scale than observations

- Results in non-window variability becoming dominant at global scale

  Window variability still dominates at global scale

- Spectrally, global inter-annual variability < 0.17 K, < 0.05 K across window

  Variability < 0.15 K but up to 0.08 K within window



Window to BB CV ratio
Terra
Aqua
IASI
2.0
1.5
1.0
0.5
0.0
Deep Tropics
Tropics
NH
SH
Quasi-Global
Global
Window to BB CV ratio
All
Ocean
Land
Ocean Night
Ocean Day
Land Night
Land Day
2.5
2.0
1.5
1.0
0.5
0.0
Deep Tropics
Tropics
NH
SH
Quasi-Global
Global