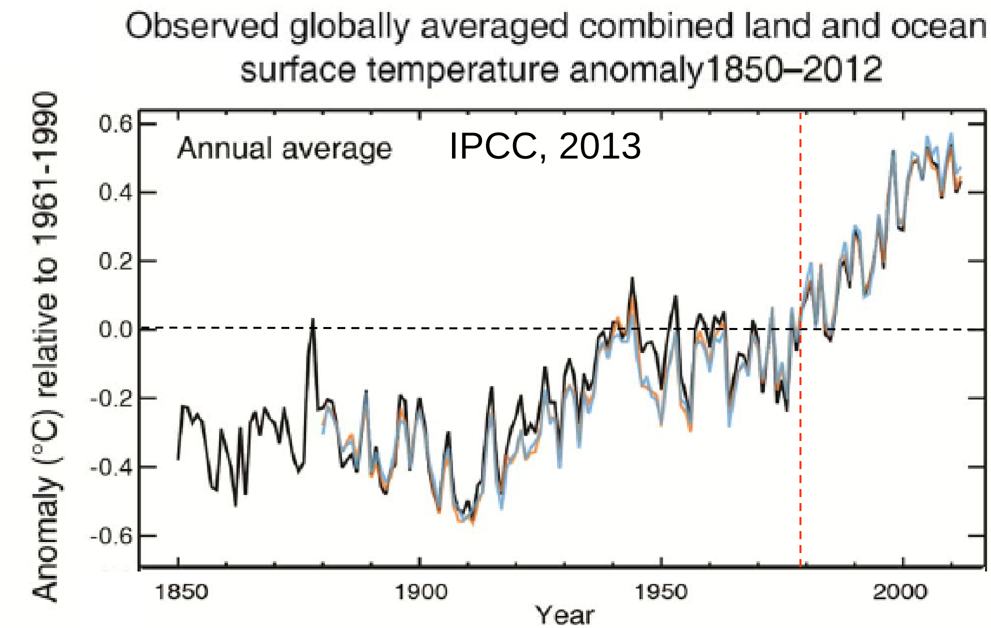
Spectral variability in the Earth's Outgoing Longwave Radiation

Richard Bantges, Helen Brindley, Jacqui Russell, Jon Murray, Claudio Belotti, Christopher Dancel, John Harries and the CLARREO Science Definition Team

Key Questions:

- What is the short-term (5 year) variability seen in observed outgoing longwave radiance spectra?
- How do these signals compare to
  - broadband observations?
  - model simulations and what can this tell us about the representation of the processes driving variability/change?
- Are observed long-term change signals robust?

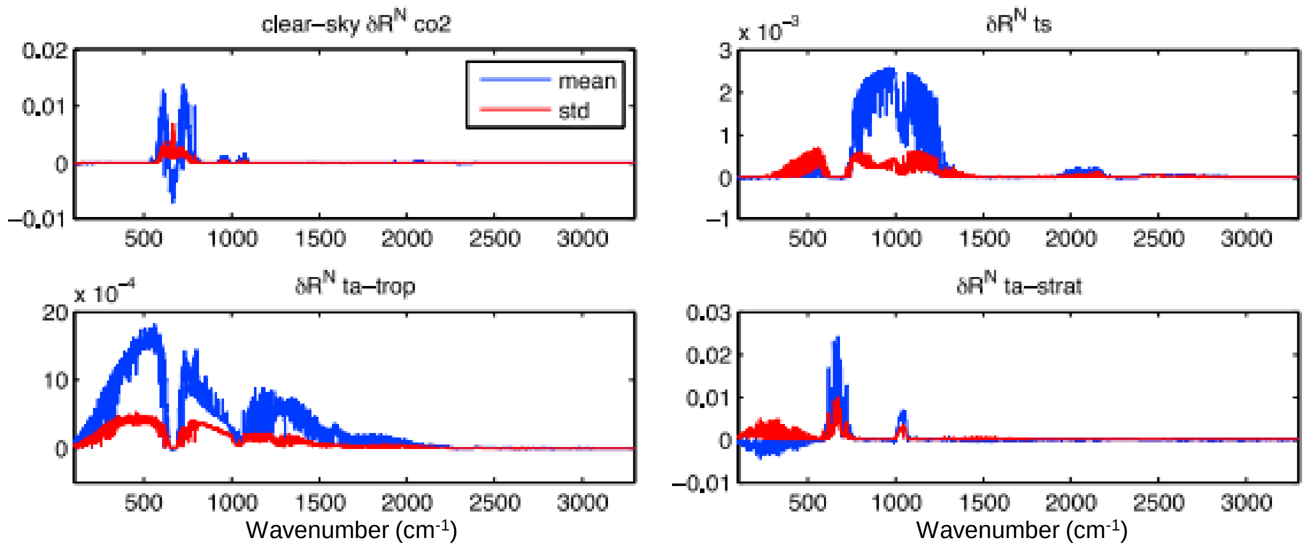
Some key issues to consider



Climate change signals are *in general* relatively small and superposed on a large *background* variability

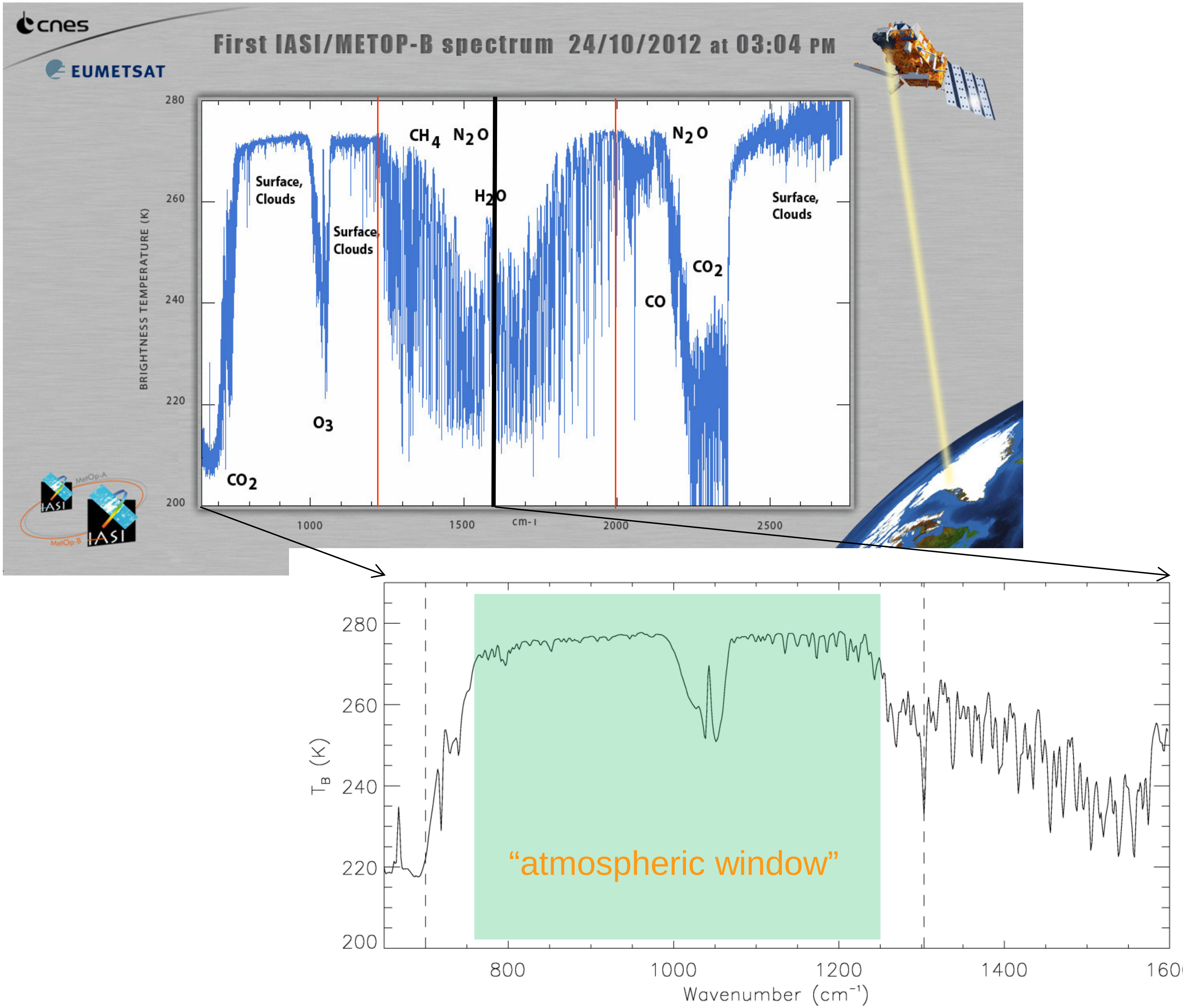
Theoretical (model) signatures of spectrally resolved normalised radiance changes at TOA in response to $2xCO_2$

Huang et al. 2010



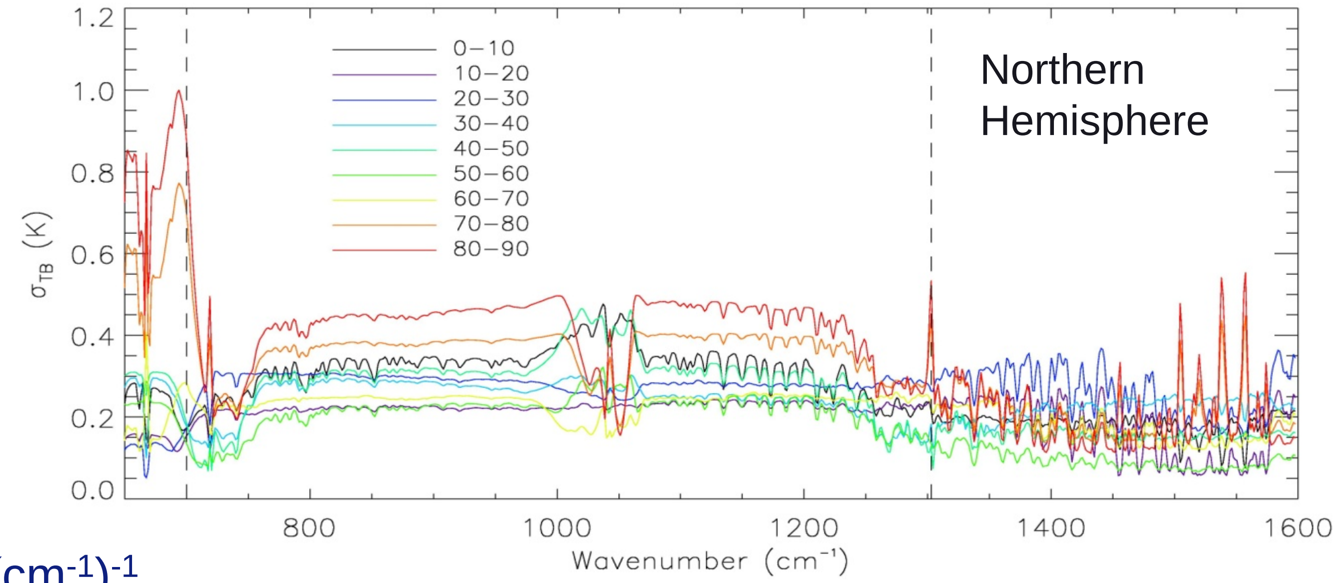
Infrared Atmospheric Sounding Interferometer (IASI)

- EPS programme:
  Metop-A launched Oct. 2006, B launched Sep. 2012 and C due for launch in 2017 (nominal 5 yr lifetime)
- IASI: 645-2760cm^{-1} (3 bands), 0.5cm^{-1}, 2x2 pixels 12km at nadir, <0.5K @ 280K
- Study employs 5 years L1c radiance data from IASI on Metop-A (2008 to 2012), 50TB
- Data reduction: spectral & spatial resolution, ‘nadir’ obs. only

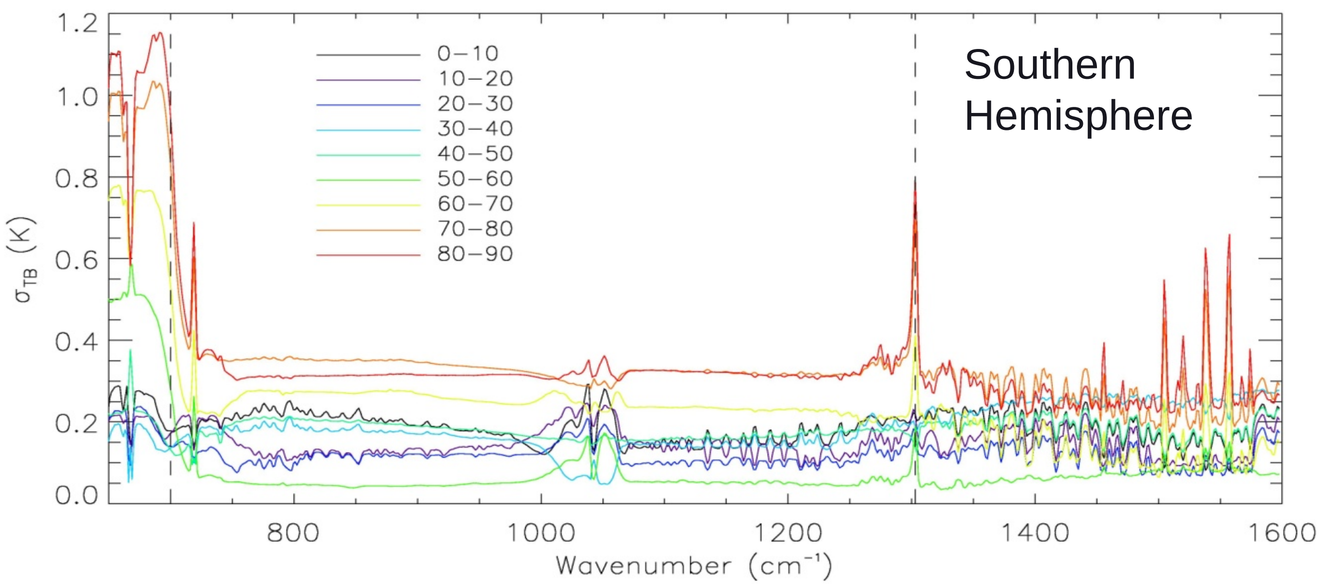

cnes
EUMETSAT
First IASI/METOP-B spectrum 24/10/2012 at 03:04 PM
BRIGHTNESS TEMPERATURE (K)
280
260
240
220
200
Surface, Clouds
Surface, Clouds
CH4 N2O
H2O
N2O
CO2
CO
Surface, Clouds
O3
CO2
1000
1500
cm-1
2000
2500
MetOp-A
IASI
MetOp-B
IASI
TB (K)
280
260
240
220
200
“atmospheric window”
800
1000
1200
1400
1600
Wavenumber (cm⁻¹)

Interannual spectral variability (2008 to 2012)

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

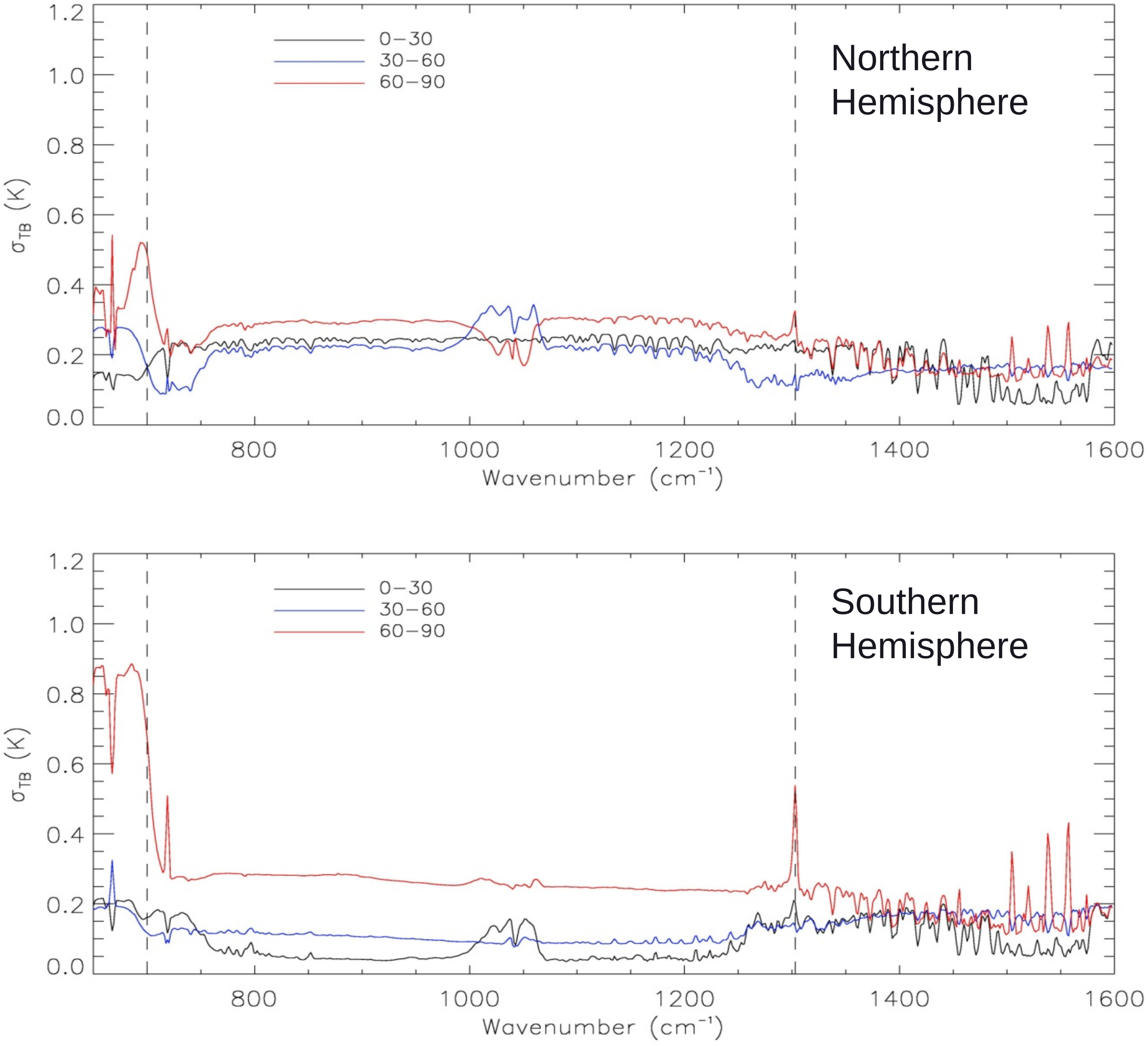


1 K ~ 1 mW m^{-2} sr^{-1} (cm^{-1})$^{-1}$



Interannual spectral variability (2008 to 2012)

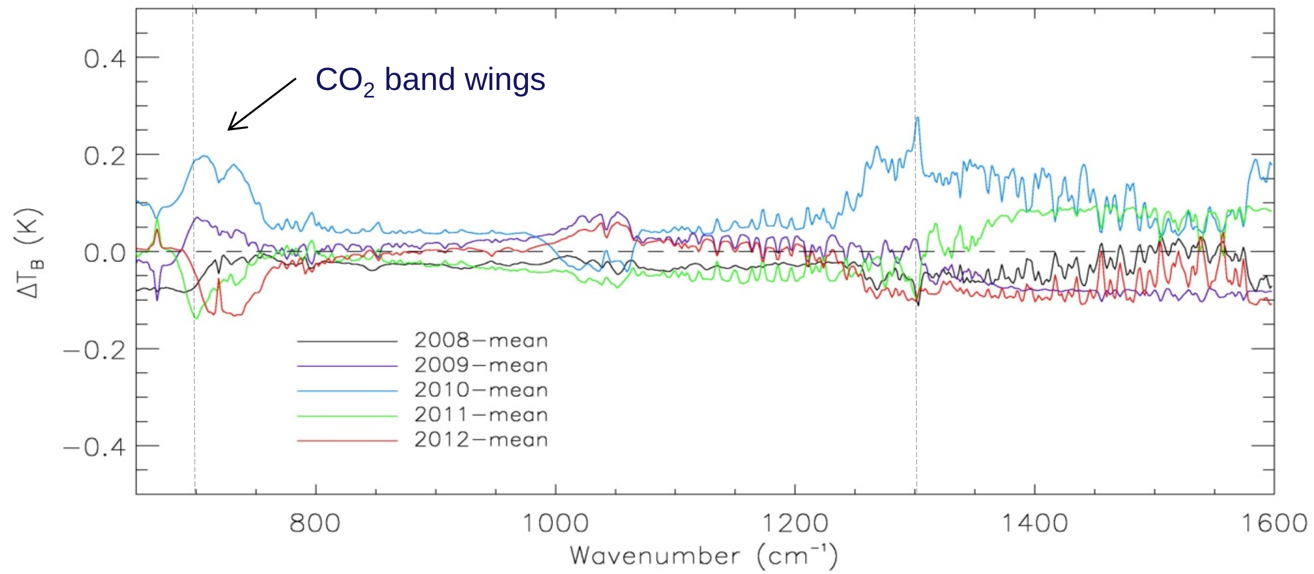
Standard deviation in **<u>30° latitude band</u>** annual means



Interannual spectral variability (2008 to 2012)

Deviation from overall global annual mean for each year

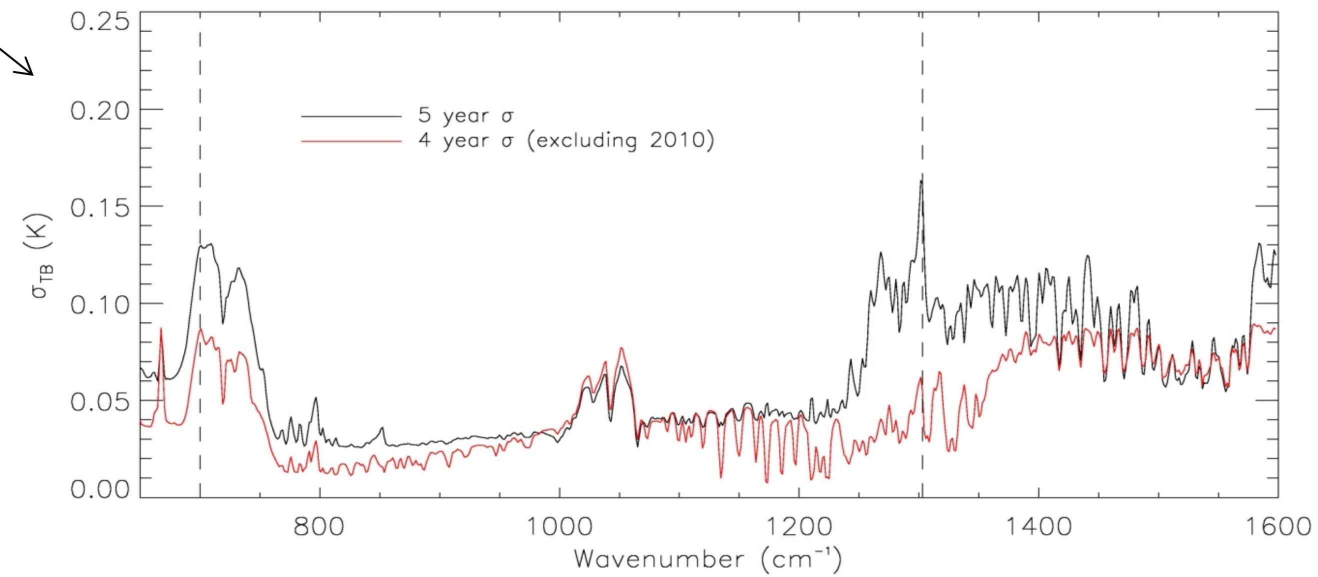
- <0.3K year-year



Note change in scale

Standard deviation in global annual means

- <0.17K σ
- Min^m σ 'window'
- UT conditions dominate – not cloud or T_s

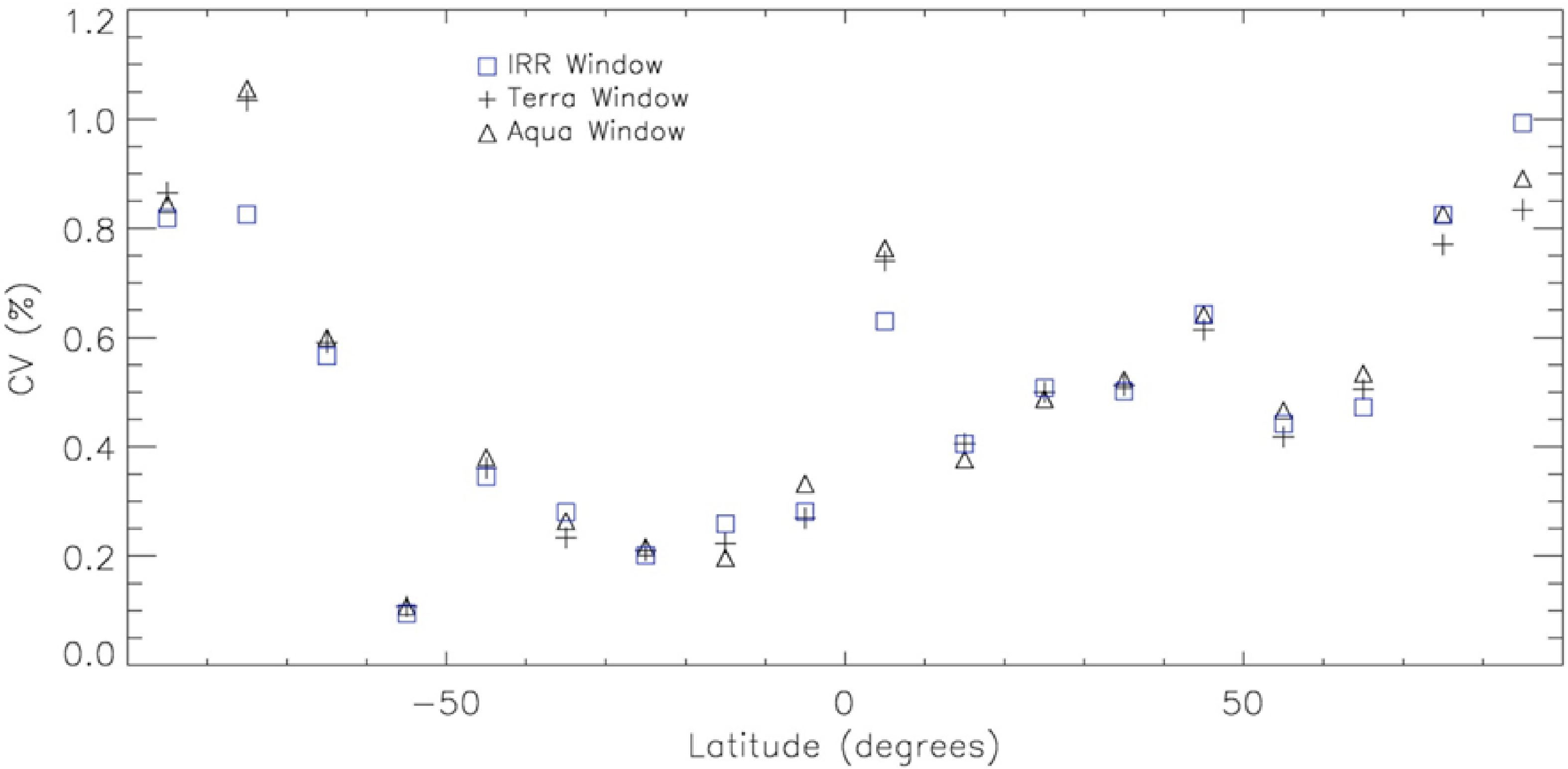


Consistency with broadband measurements?

CERES SSF: broadband and window ***fluxes***

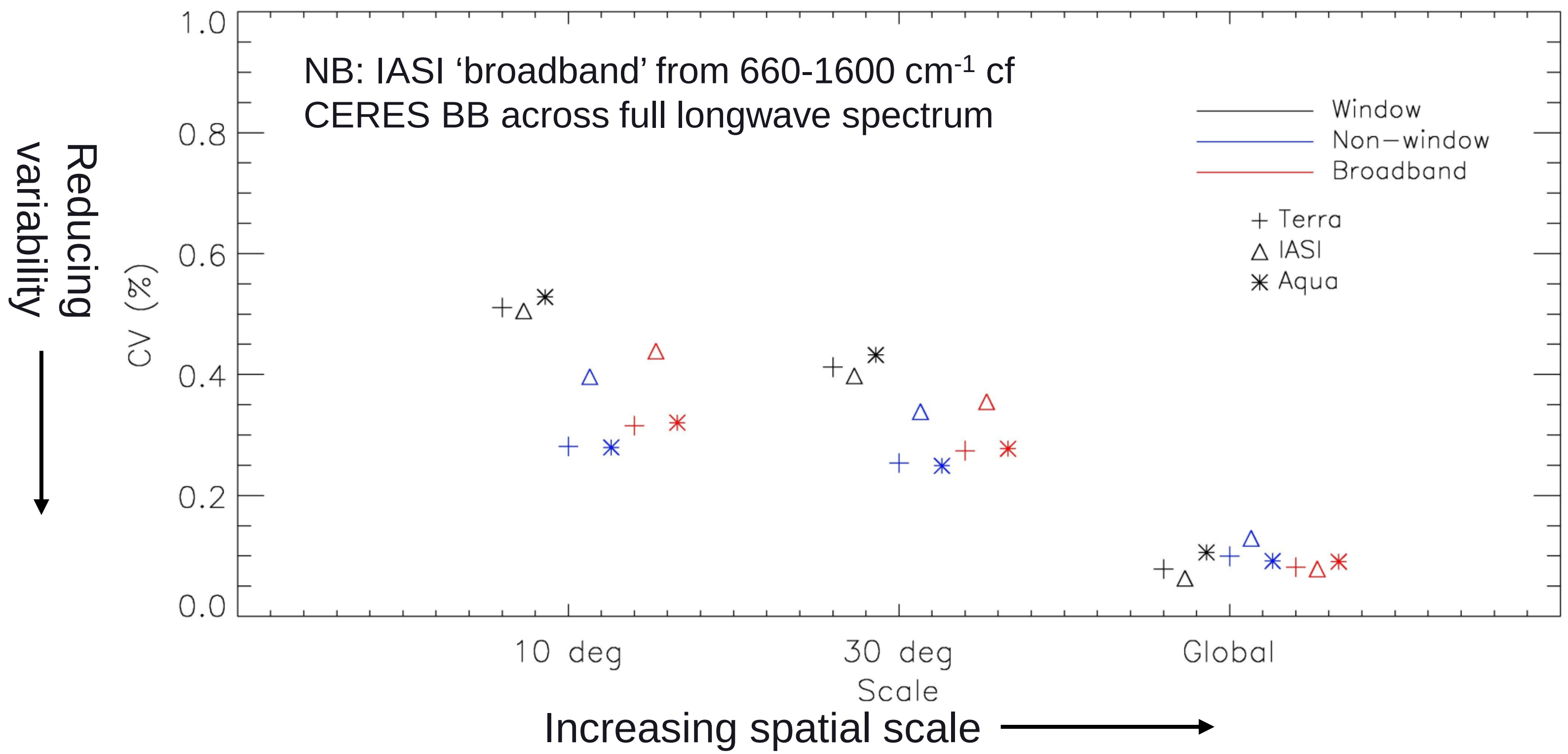
Different measurement scales so use ***coefficient of variation, CV = σ / μ***

Broadband 'window' comparison (833-1250cm^{-1})



- Variability about mean < 1% (most latitude bands)
- Similar latitudinal pattern – sampling characteristics have only small impact

Consistency with broadband measurements?



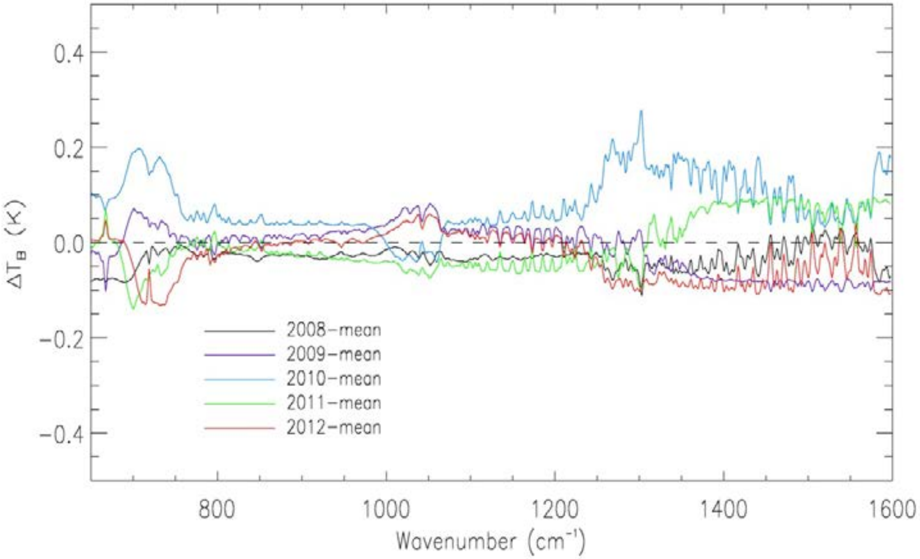
- Window inter-annual variability reduces most rapidly with increasing scale
- Results in non-window variability becoming dominant at global scale
- Difference between IASI BB and CERES BB behaviour suggests an important role for the far infra-red in determining all-sky inter-annual variability at the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

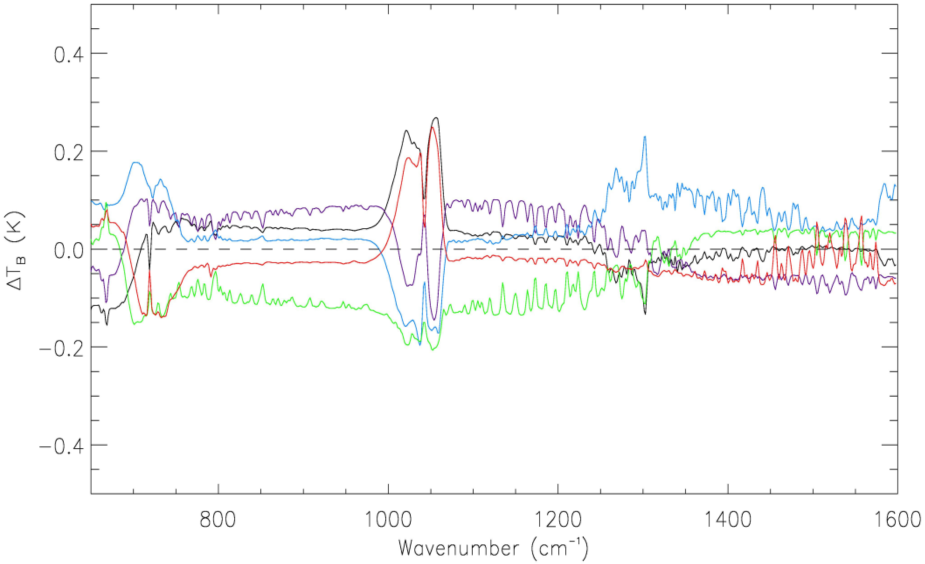
Consistency with Reanalyses?

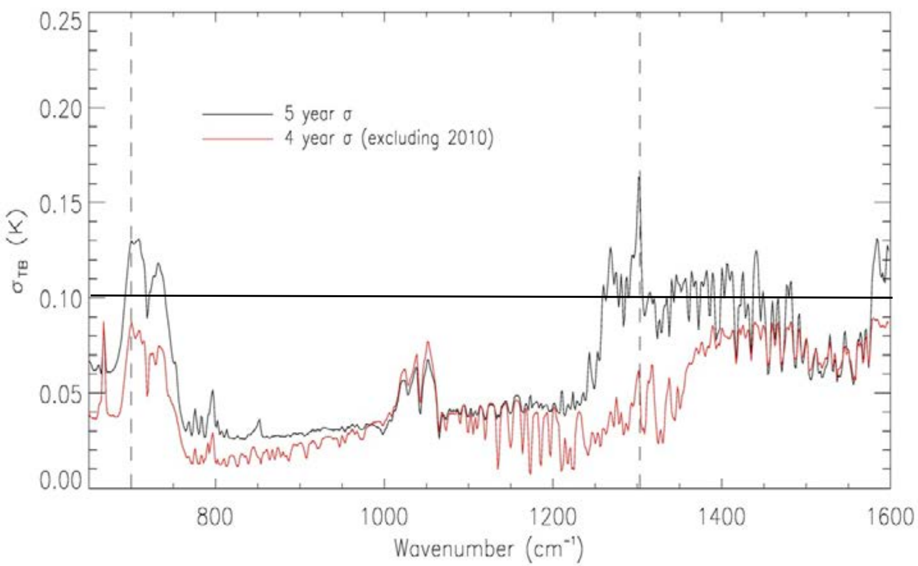
Global

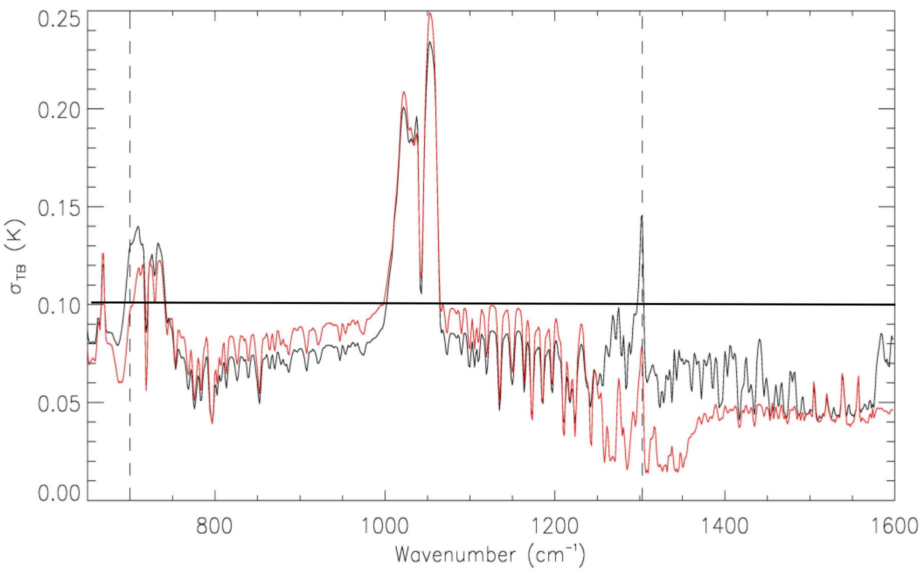
OBSERVATIONS

SIMULATIONS (10^6 spectra)







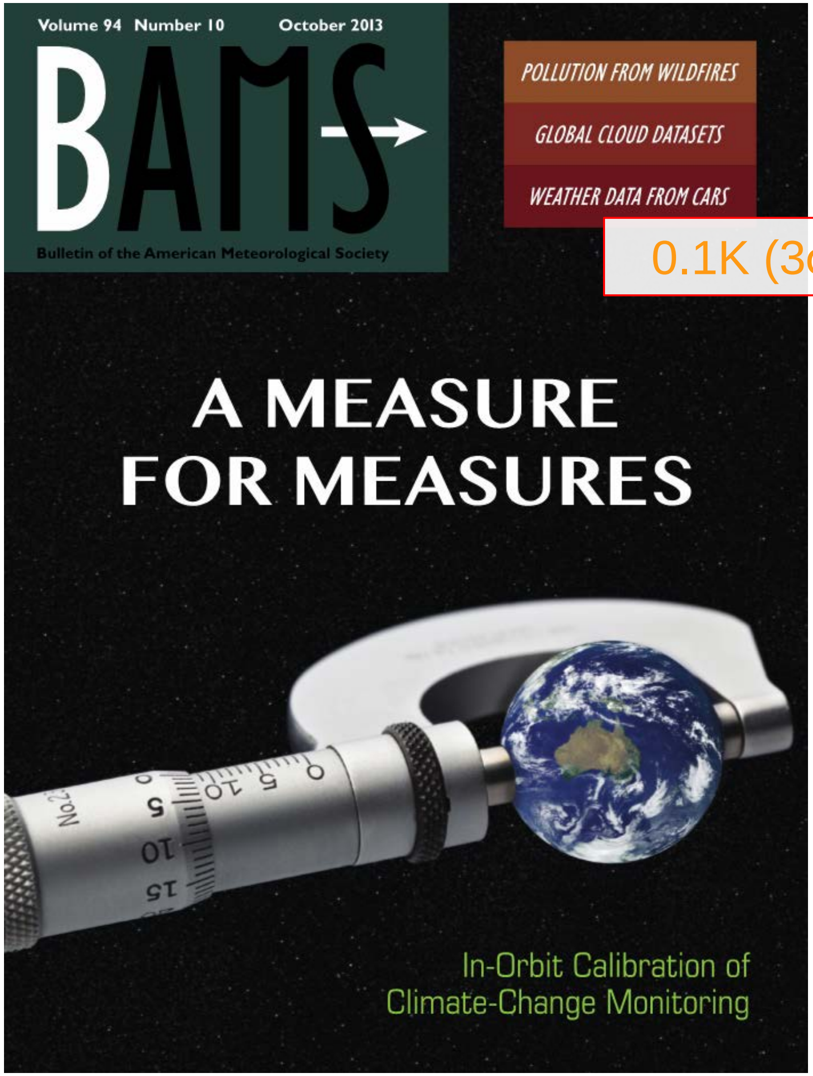


Summary

- 5 years of IASI data have be used to probe how the emission to space varies spectrally on interannual timescales.
- The maximum variability is observed at high latitudes across 15µm CO_2 band: >1K at the smallest spatial scales (10°), (cf <0.5K window)
- The variability reduces with increasing spatial scale across the spectrum, although the rate of change varies with wavenumber; a more noticeable reduction is seen in the 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 5 year period and imply that at the largest spatial scales fluctuations in mid-upper tropospheric temperatures and water vapour, and **not cloud or surface temperature**, play the dominant role in determining the level of inter-annual all-sky OLR variability.
- Although simulations from reanalysis show an encouraging level of agreement in general, they do not replicate this scaling behaviour.
- The levels of variability seen are very small and current satellite observing systems are still not optimised for climate studies.

CLARREO Status

0.1K (3σ) decade^{-1}



ACHIEVING CLIMATE CHANGE ABSOLUTE ACCURACY IN ORBIT

BY BRUCE A. WIELICKI, D. F. YOUNG, M. G. MLYNCZAK, K. J. THOME, S. LEROY, J. CORLISS, … G. ANDERSON, C. O. AO, R. BANTGES, F. BEST, K. BOWMAN, H. BRI…DLEY, J. J. BUTLER, W. COLLINS, J. A. DYKEMA, D. R. DOELLING, D. R. FELDMAN, N. FOX, … Y. HUANG, Z. JIN, D. JENNINGS, D. G. JOHNSON, K. JUCKS, S. KATO, D. B. KIRK-DAVIDOFF, … G. KO…PP, D. P. KRATZ, X. LIU, C. LUKASHIN, A. J. MANNUCCI, N. PHOJANAMONGKOLKIJ, P. PILEWSKIE, … REVERCOMB, J. RICE, Y. ROBERTS, C. M. ROITHMAYR, F. ROSE, S. SANDFORD, E. L. SHIRLEY, W. L. SMITH SR., B. SODEN, P. W. SPETH, W. SUN, P. C. TAYLOR, D. TOBIN, AND X. XIONG

With its unprecedented accuracy, the Climate Absolute Radiance and Refractivity Observatory substantially shortens the time to detect the magnitude of climate change at the high confidence level that decision makers need.

THE CLARREO VISION FROM THE NATIONAL RESEARCH COUNCIL DECADAL SURVEY. A critical issue for climate change observations is that their absolute accuracy is insufficient to confidently observe decadal climate change signals (NRC 2007; Trenberth et al. 2013; Trenberth and Fasullo 2010; Ohring et al. 2005; Ohring 2007). Observing decadal climate change is critical to assessing the accuracy of climate model projections (Solomon et al. 2007; Masson and Knutti 2011; Stott and Kettleborough 2002) as well as to attributing climate change to various sources (Solomon et al. 2007). Sound policymaking requires high confidence in climate predictions verified against decadal change observations with rigorously known accuracy. The need to improve satellite data accuracy has been expressed in ▶

Detail of CLARREO (red orbit track) obtaining matched data to serve as reference intercalibration for instruments on a polar orbiting weather satellite (green track). For more information see Fig. 6.

Economic Value of Climate Observations

Springer Link

Environment Systems and Decisions
Formerly The Environmentalist

10.1007/s10669-013-9451-8

Value of information for climate observing systems

Roger Cooke [1], Bruce A. Wielicki [2], David F. Young [2] and Martin G. Mlynczak [2]

(1) Resources for the Future, Washington, DC, USA
(2) NASA Langley Research Center, Hampton, VA, USA

Roger Cooke
Email: Cooke@rff.org

Published online: 23 July 2013

Abstract

The Interagency Working Group Memo on the social cost of carbon is used to compute the value of information (VOI) of climate observing systems. A generic decision context is posited in which society switches from a business as usual (BAU) emissions path to a reduced emissions path upon achieving sufficient confidence that a trigger variable exceeds a stipulated critical value. Using assessments of natural variability and uncertainty of measuring instruments, it is possible to compute the time at which the required confidence would be reached under the current and under a new observing system, if indeed the critical value is reached. Economic damages (worldwide) from carbon emissions are computed with an integrated assessment model. The more accurate observing system acquires the required confidence earlier and switches sooner to the reduced emissions path, thereby avoiding more damages which would otherwise be incurred by BAU emissions. The difference in expected net present value of averted damages under the two observing systems is the VOI of the new observing system relative to the existing system. As illustration, the VOI for the proposed space-borne CLARREO system relative to current space-borne systems is computed. Depending on details of the decision context, the VOI ranges from 2 to 30 trillion US dollars.

Electronic supplementary material

The online version of this article (doi:10.1007/s10669-013-9451-8) contains supplementary material, which is available to authorized users.

Keywords Value of information – Climate observing system – Social cost of carbon – DICE – CLARREO

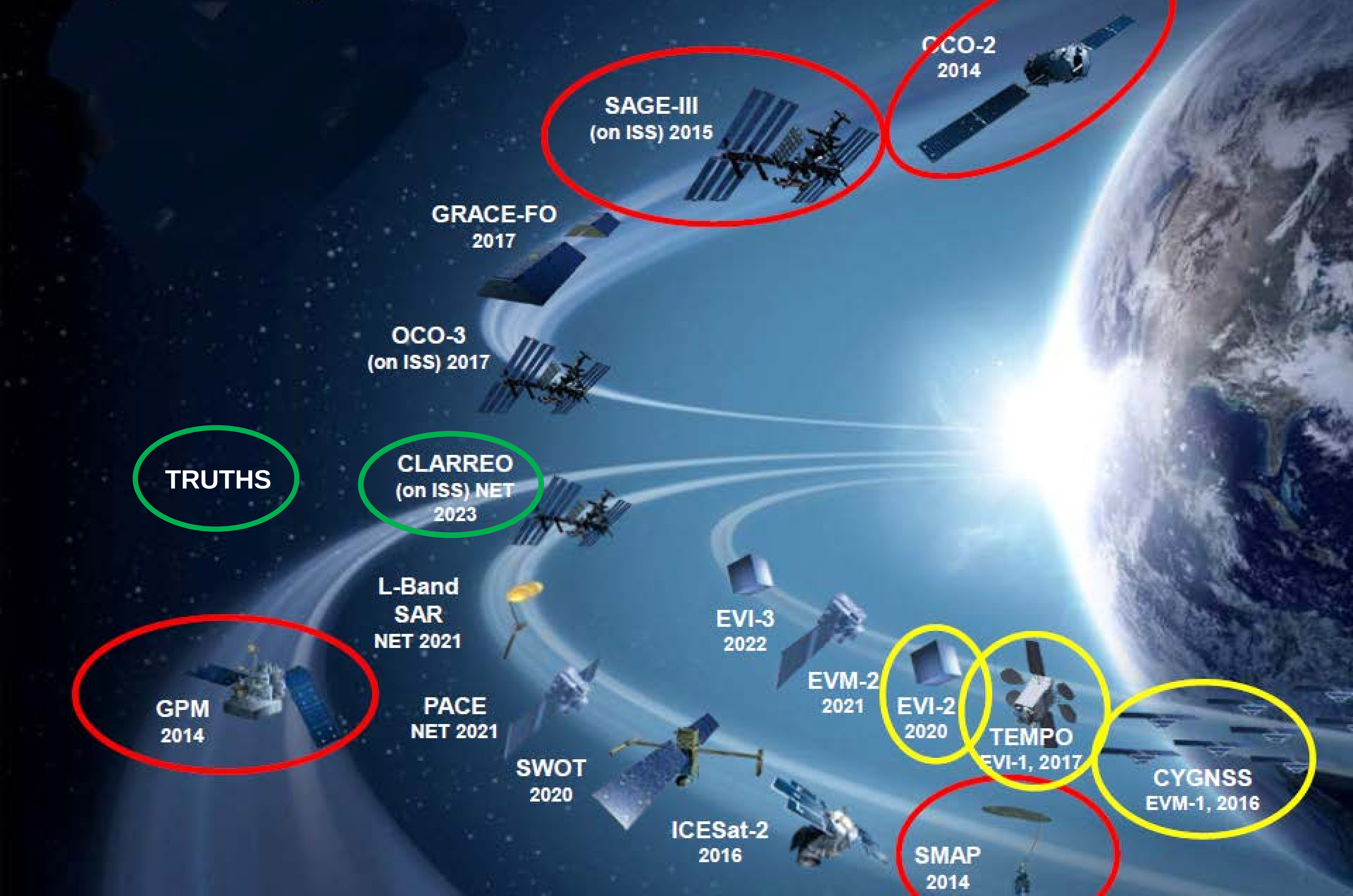
Journal of Environment, Systems, and Decisions

Cooke et al., 2013

Available free and open access online @ http://link.springer.com /article/10.1007%2Fs10669-013-9451-8

$12 Trillion economic value

Upcoming Orbital Missions

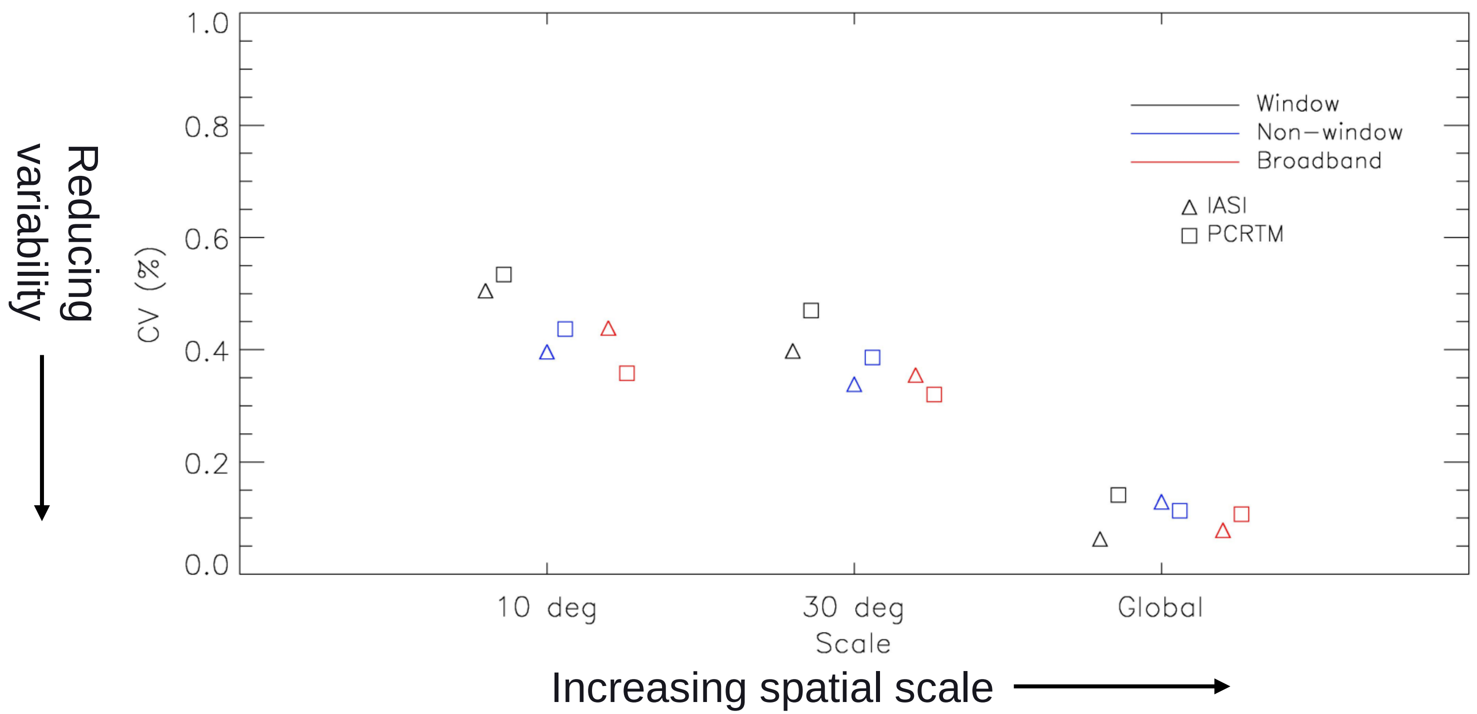


EXTRA SLIDES

CLARREO Mission Status

- Current NASA launch schedule for CLARREO is 2023
- CLARREO continues science studies and risk reduction activities in pre-phase A.
  - 26 journal papers published in 2013, including BAMS mission overview, and paper on the $12 Trillion economic value of higher accuracy.
  - IR calibration demonstration system at NASA Langley continuing development and NIST verification tests.
  - IR instrument at U. Wisconsin reaches TRL-6 environmental testing
  - RS calibration demonstration system at NASA Goddard continuing development and NIST verification tests.
  - RS instrument at Univ of Colorado completes high altitude balloon flight (30km altitude) in Sept 2013, second in Sept 2014.
  - Continued studies on smaller instruments, refining requirements, climate model OSSEs,CLARREO related Venture Class proposals
  - RS instrument proposed to NASA Venture Instrument AO
  - ISS remains the least expensive option to fly CLARREO

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

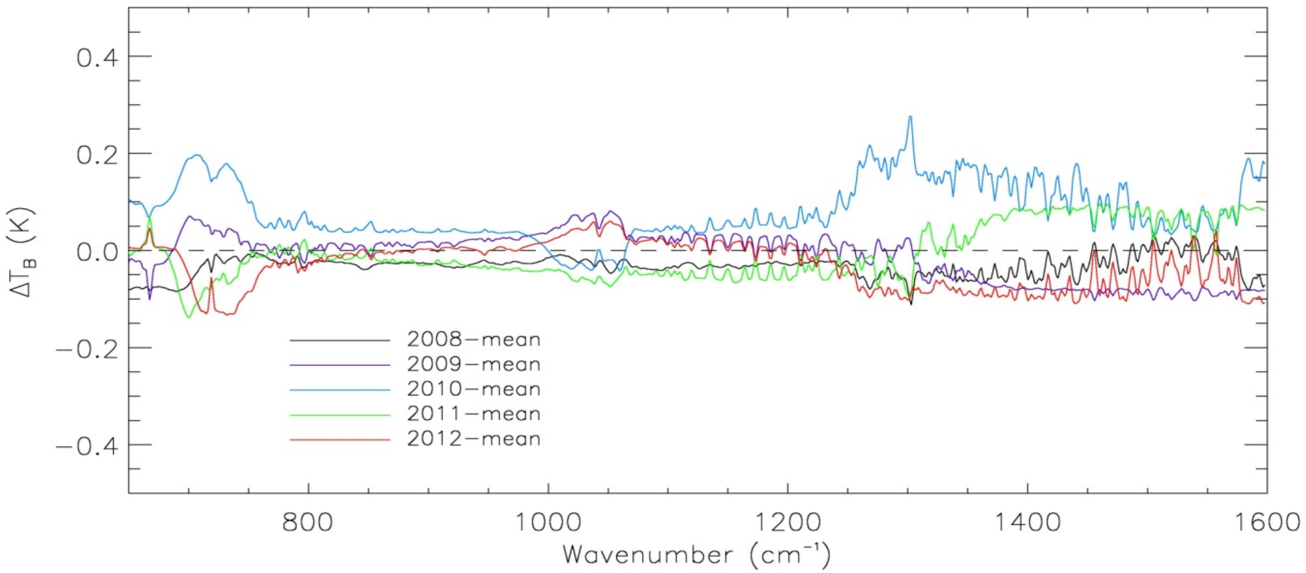
  Window variability still dominates at global scale

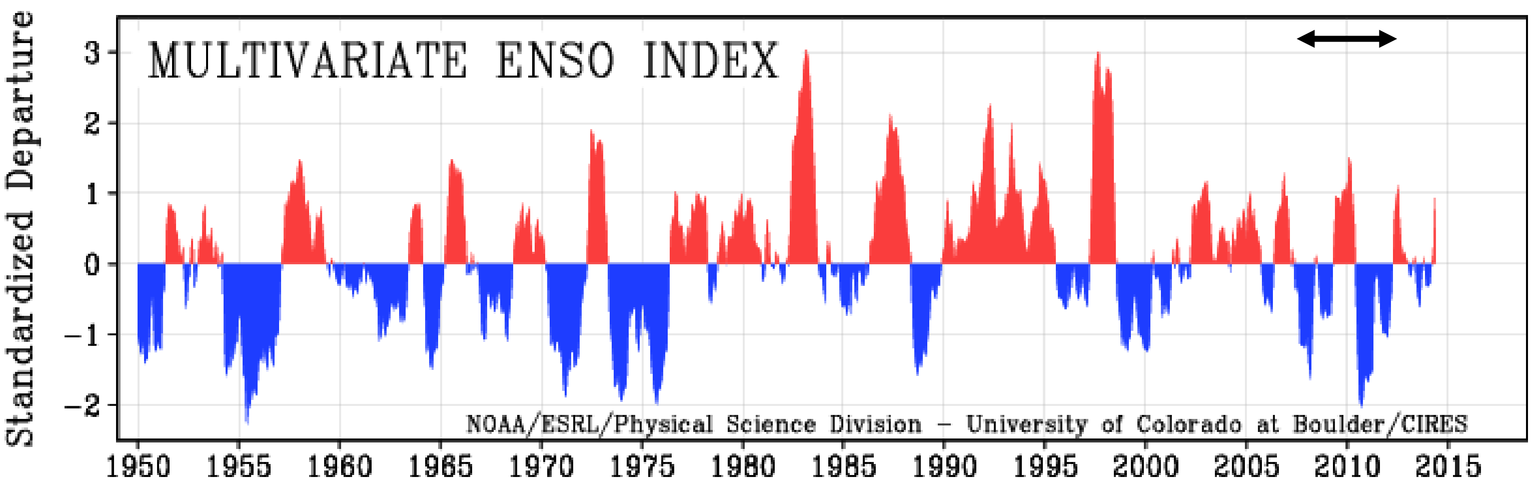
- Spectrally, global inter-annual variability < 0.17 K, < 0.05 K across window

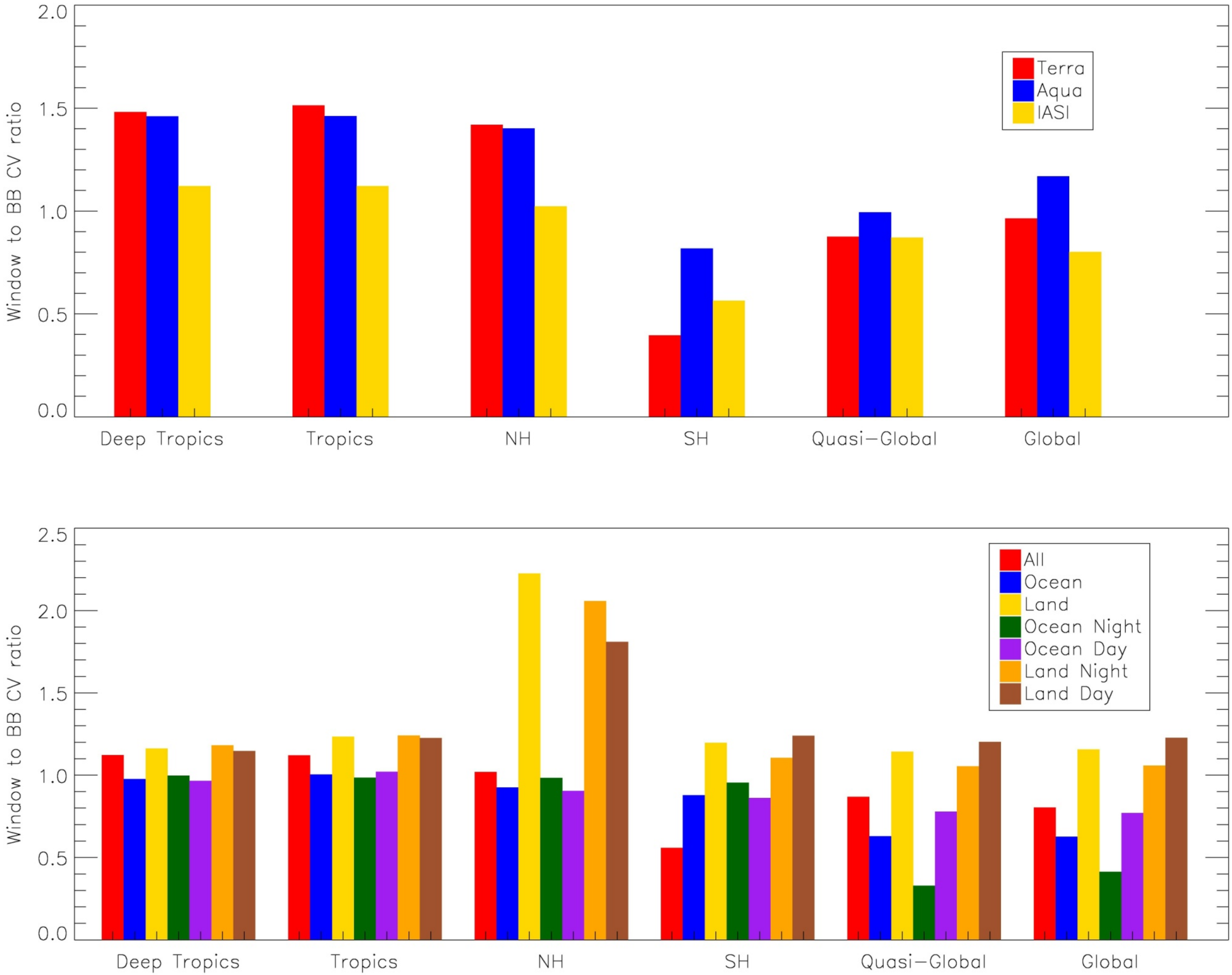
  Variability < 0.15 K but up to 0.08 K within window

Interannual spectral variability (2008 to 2012)

Deviation from overall **global** annual mean for each year

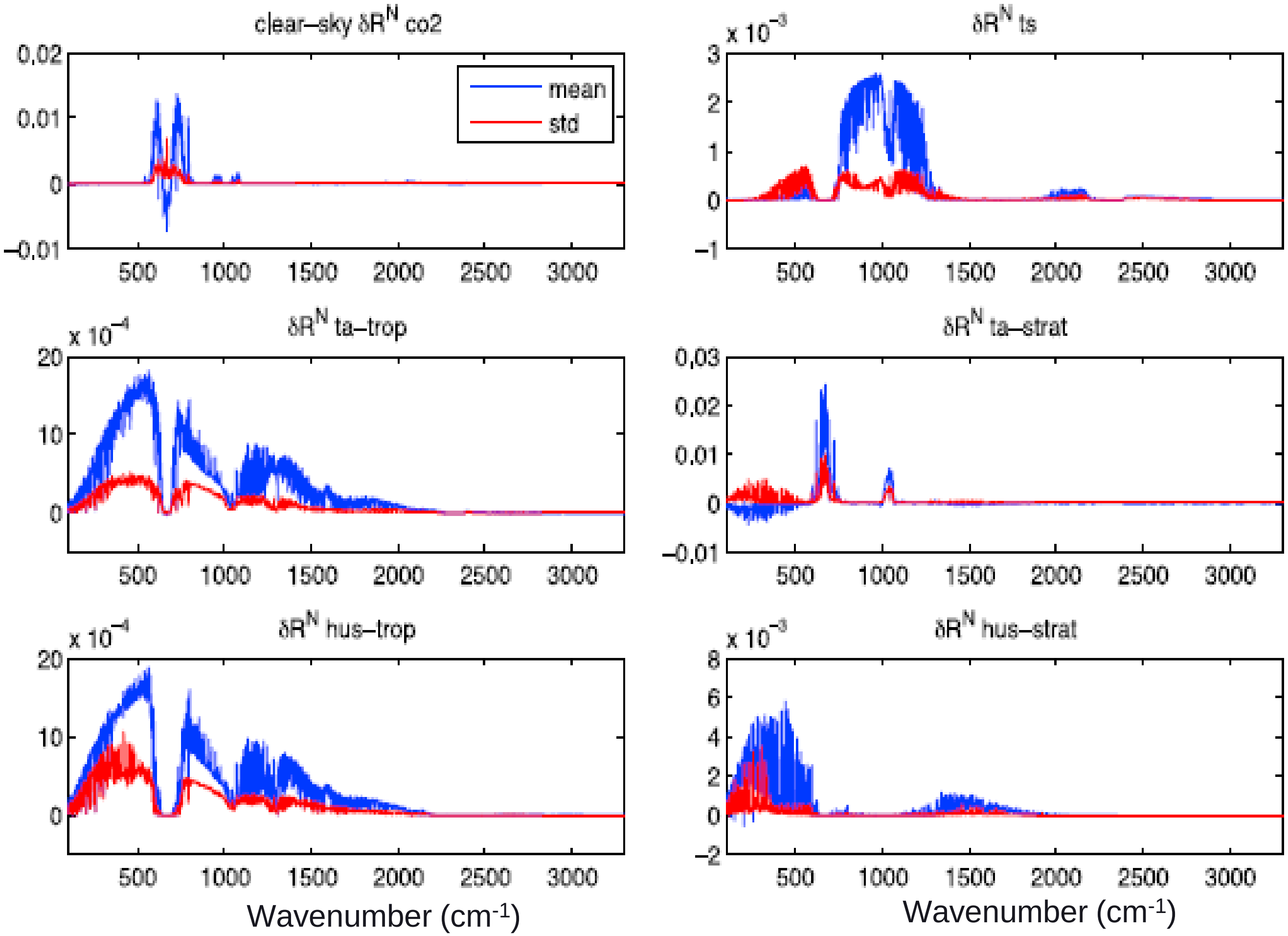






Window to BB CV ratio
2.0
1.5
1.0
0.5
0.0
Terra
Aqua
IASI
Deep Tropics
Tropics
NH
SH
Quasi−Global
Global
Window to BB CV ratio
2.5
2.0
1.5
1.0
0.5
0.0
All
Ocean
Land
Ocean Night
Ocean Day
Land Night
Land Day
Deep Tropics
Tropics
NH
SH
Quasi−Global
Global

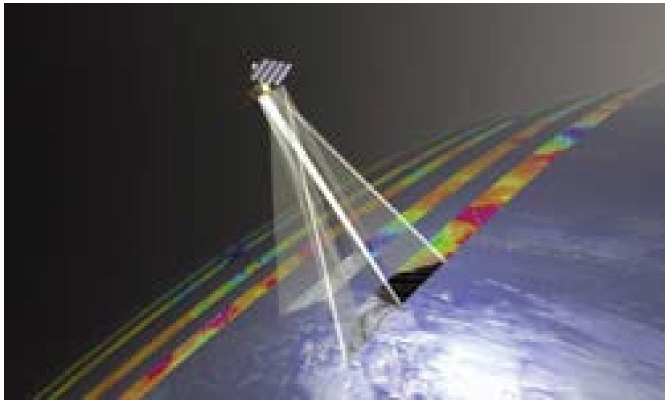
But in principle...

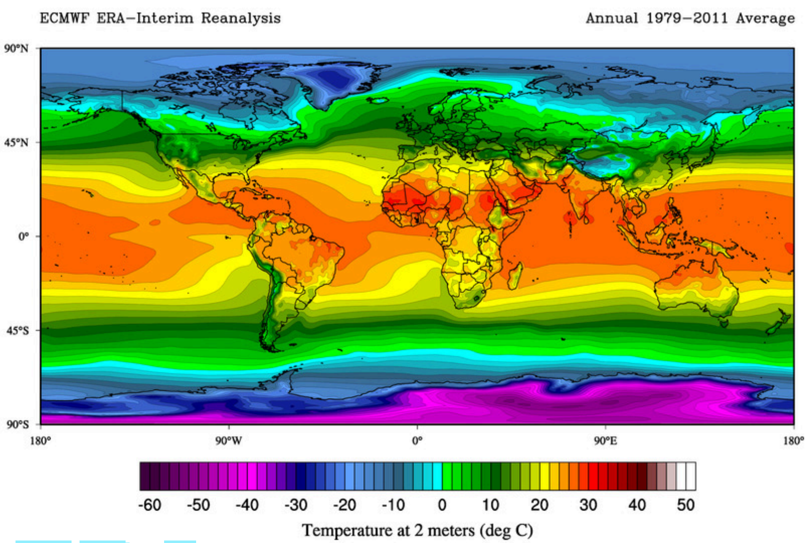


Theoretical signatures of spectrally resolved normalised radiance changes at TOA in response to $2xCO_2$

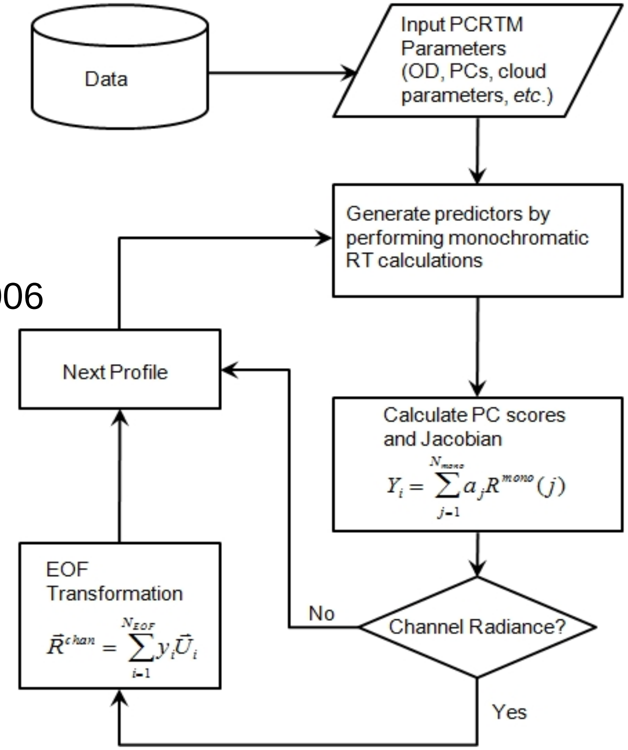
Huang *et al*., 2010

Consistency with Reanalyses?





PCRTM
Liu *et al.*, 2006

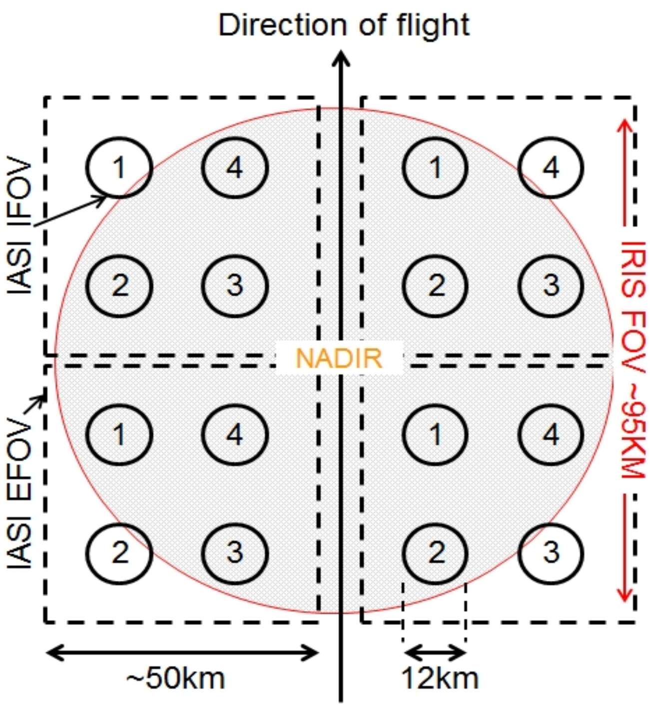


X. Huang, University of Michigan

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

Ensure instruments 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