

# EARTH'S RADIATION BUDGET



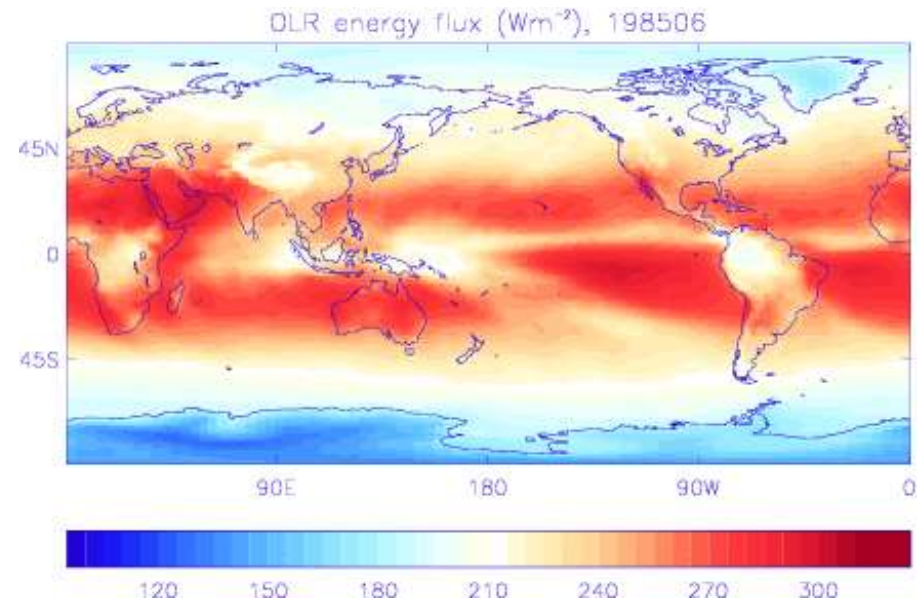
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@rpallanuk



# INTRODUCTION

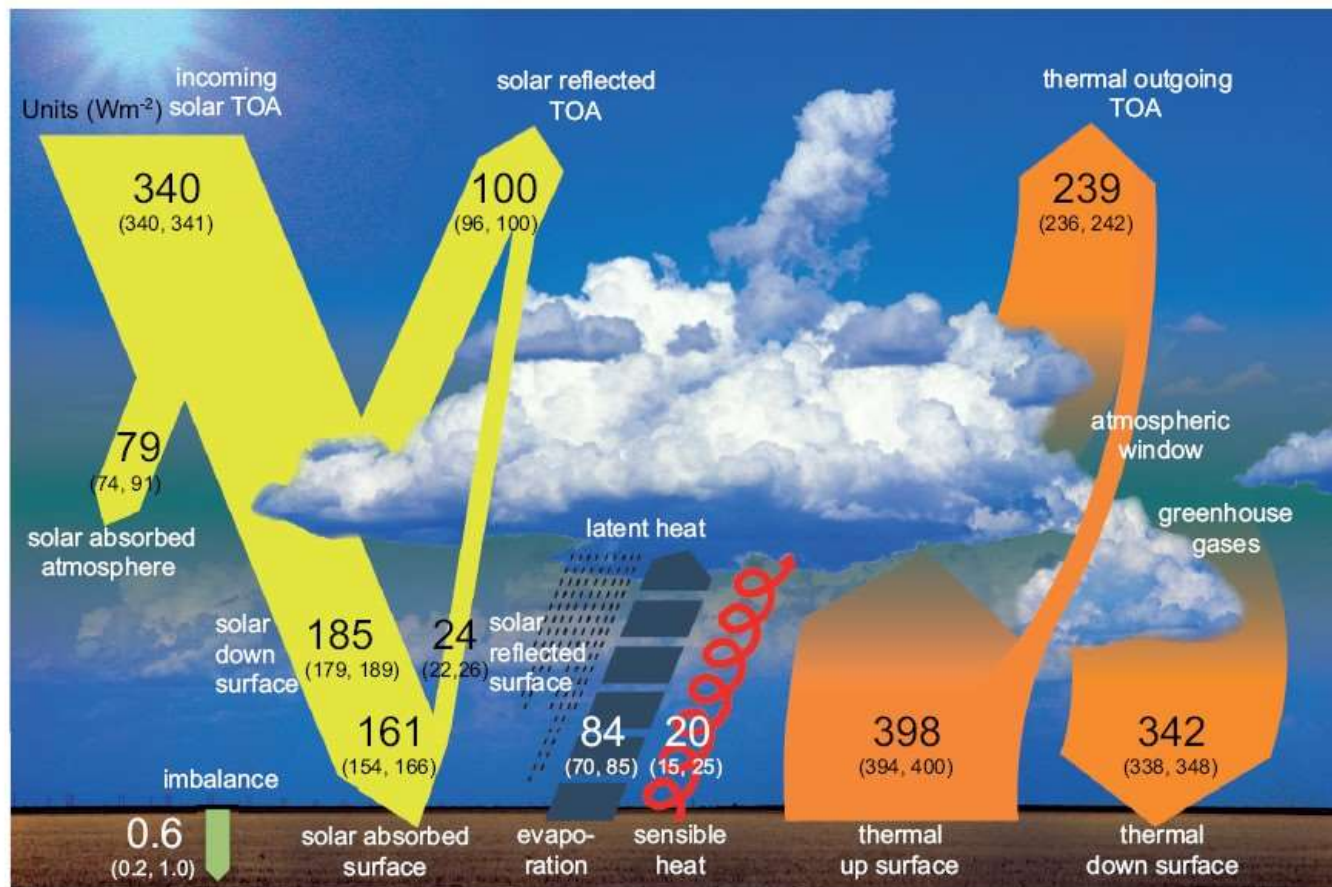


- Earth's energy budget determines trajectory and magnitude of climate change
- Both a powerful constraint on and diagnostic of the water cycle globally and regionally

*Flows of energy and moisture between land and ocean, northern and southern hemispheres and high/low latitudes are fundamental for determining the climate characteristics societies depend upon*

- How is Earth's energy imbalance currently changing and what are the implications for the global water cycle?

# EARTH'S GLOBAL ANNUAL AVERAGE ENERGY BUDGET



**Figure 2.11:** | Global mean energy budget under present-day climate conditions. Numbers state magnitudes of the individual energy fluxes in  $\text{W m}^{-2}$ , adjusted within their uncertainty ranges to close the energy budgets. Numbers in parentheses attached to the energy fluxes cover the range of values in line with observational constraints. (Adapted from Wild et al., 2013.)

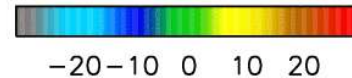
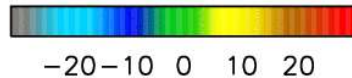
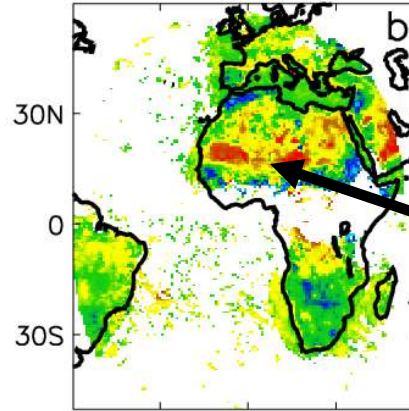
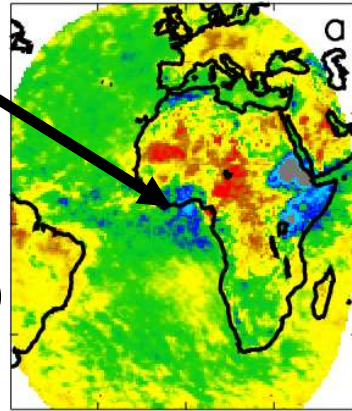


# All-sky

# Clear-sky

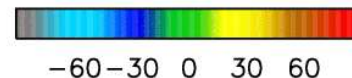
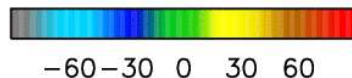
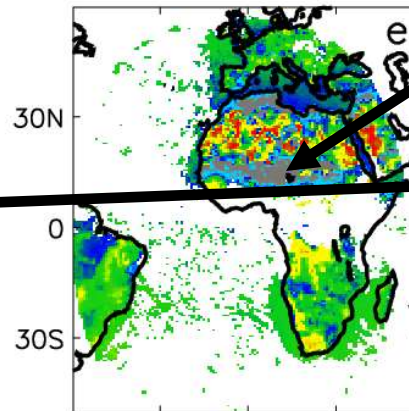
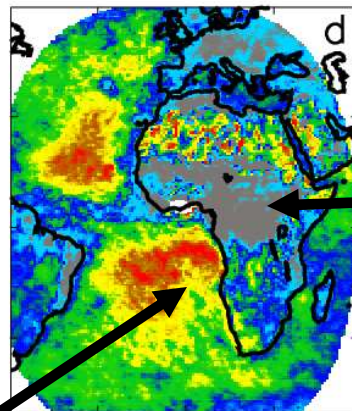
Model-GERB OLR

Model-GERB OLRc



Model-GERB RSW

Model-GERB RSWc



Longwave

Shortwave

Convective outflow

Mineral dust

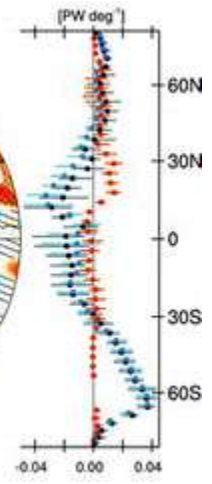
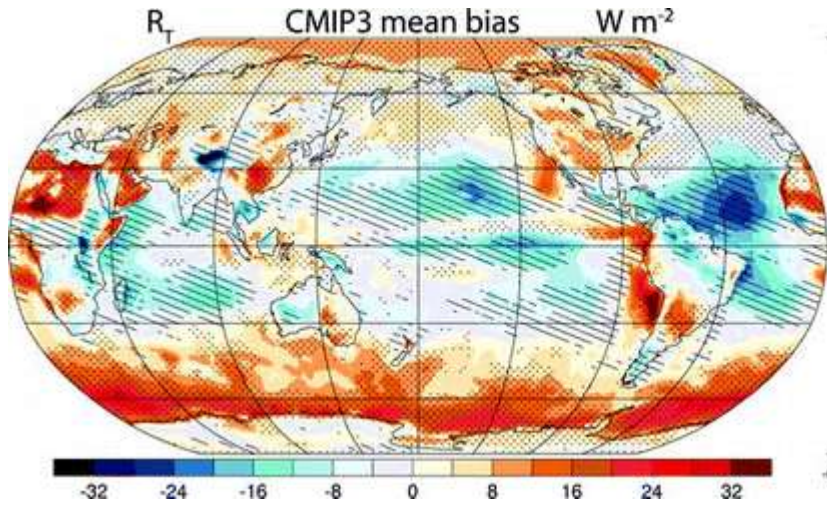
Using GERB data to identify systematic model biases

Surface albedo

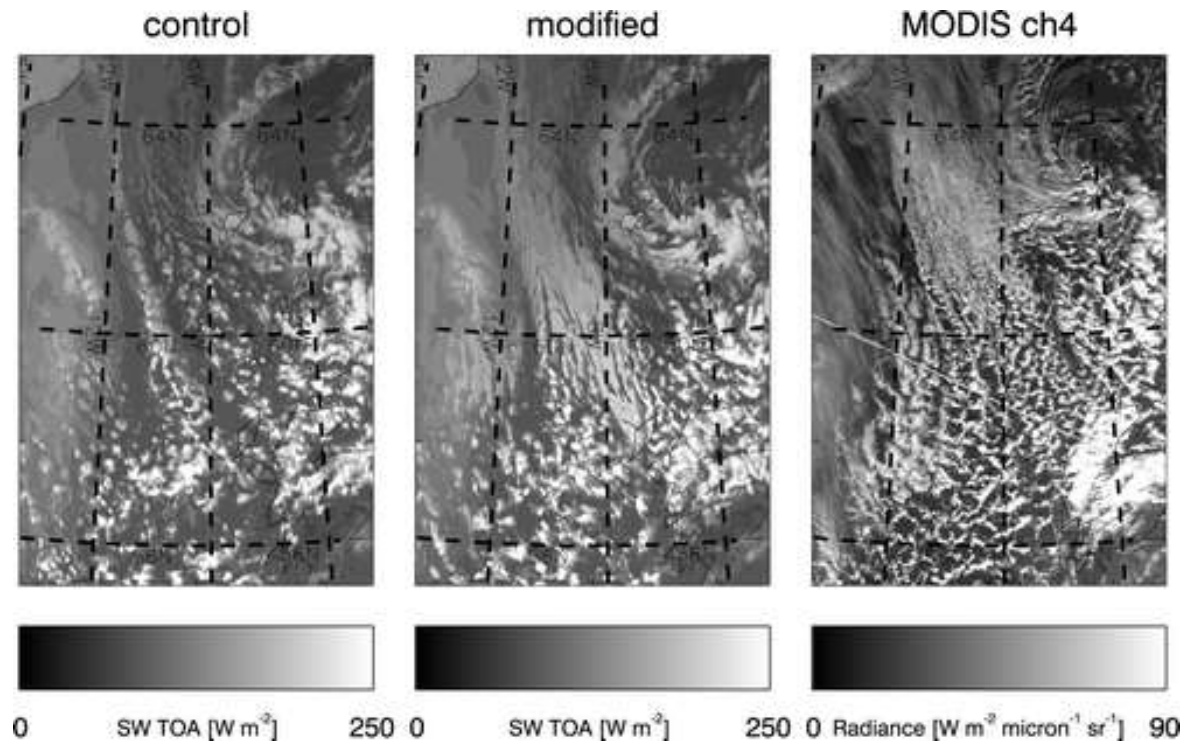
Marine stratocumulus

Convective cloud

Allan et al. (2007) QJRMS



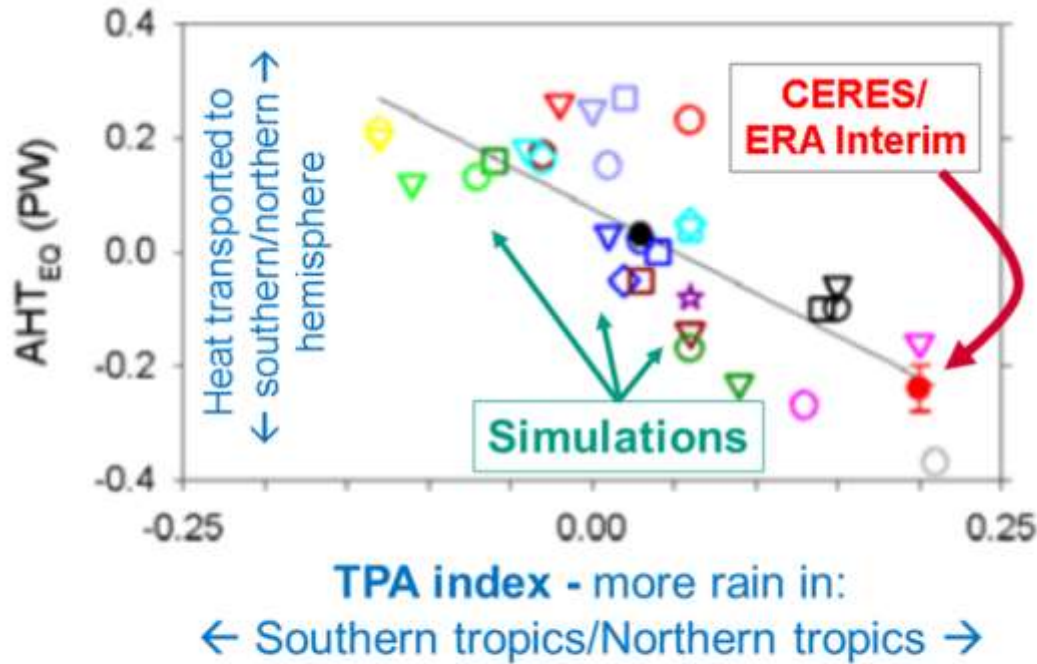
# WHAT CAUSES SYSTEMATIC MODEL BIAS IN SOUTHERN OCEAN?



Assessing cloud properties and radiative forcing relating to cold air outbreaks (e.g. [Trenberth & Fasullo, 2010](#); [Karlsson & Svensson, 2011](#); [Bodas-Salcedo et al., 2012](#); [← Field et al. 2014](#))



# WHAT ARE CAUSES/CONSEQUENCES OF HEMISPHERIC ASYMMETRY IN ENERGY BUDGET?

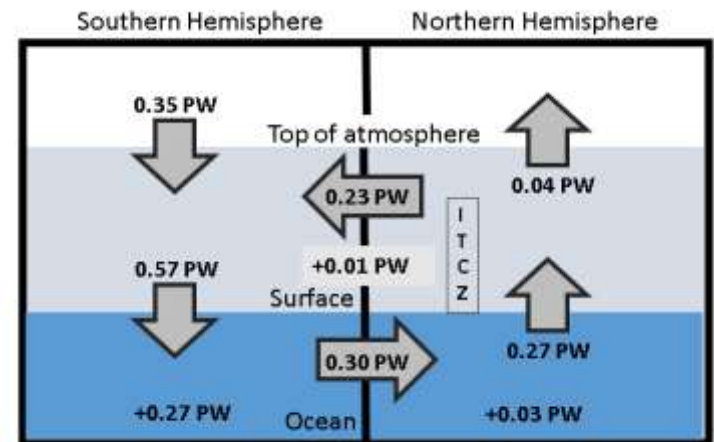


Estimated cross equatorial atmospheric heat transport in peta Watts ( $AHT_{EQ}$ ) against an index of tropical precipitation asymmetry (TPA) between hemispheres in simulations and observations

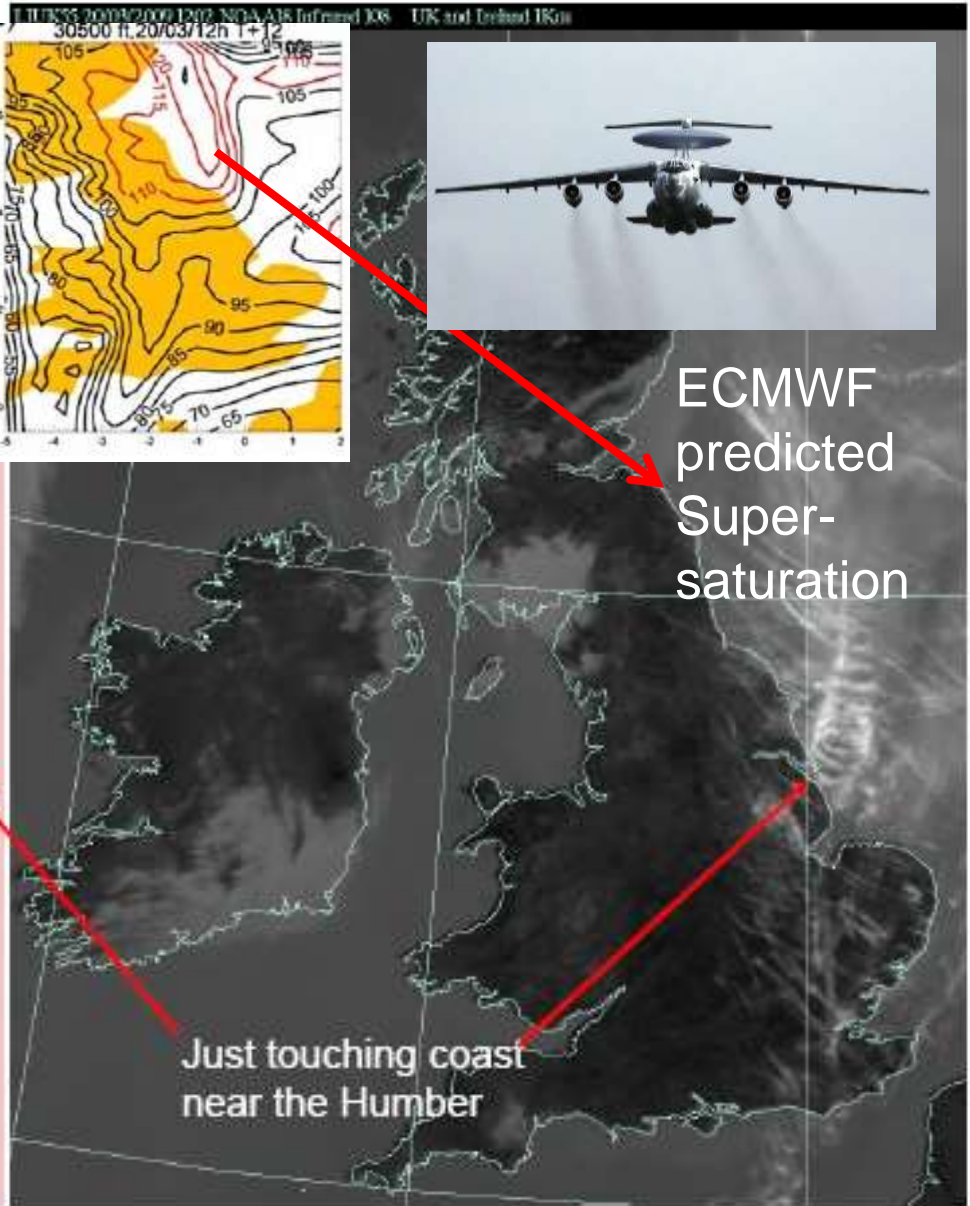
**Above:** [Loeb et al. \(2016\) Clim. Dyn](#)

**Right:** hemispheric energy budget based upon [Liu et al. \(2015\) JGR](#) →

Link between bias in cross-equatorial heat transport by atmosphere and inter-hemispheric precipitation asymmetry; [Frierson et al. \(2013\) Nature Geosci](#); [Haywood et al. \(2016\) GRL](#); [Stephens et al. \(2015\) Rev Geophys](#)



# WHAT IS RADIATIVE FORCING OF CONTRAIL CIRRUS?



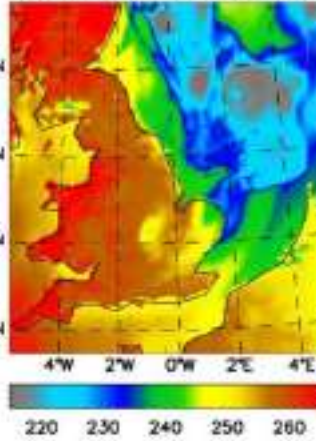
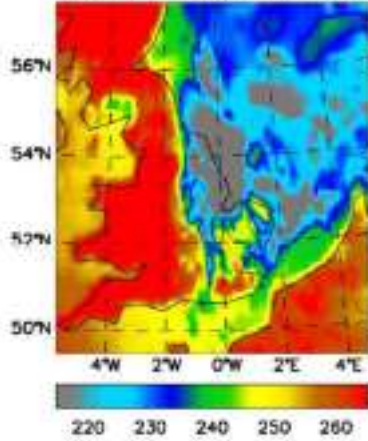
Example at 14:00Z

SEVIRI

UK4

(a) SEVIRI LW ( $Wm^{-2}$ ) 14:00

(b) Model LW ( $Wm^{-2}$ ) 14:00

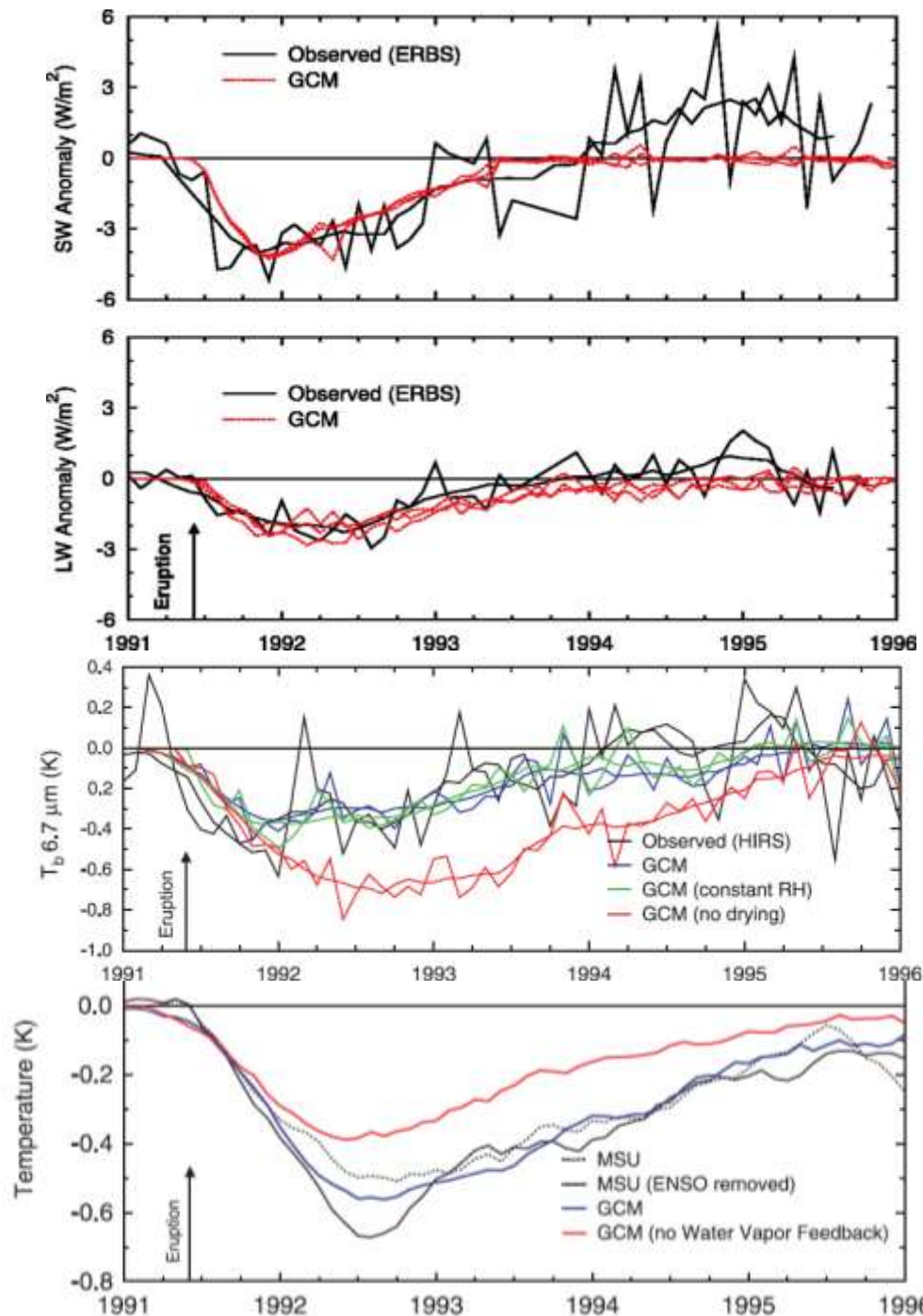


Haywood et al. (2009) JGR

# ARE SIMULATED FORCINGS/FEEDBACKS REALISTIC?

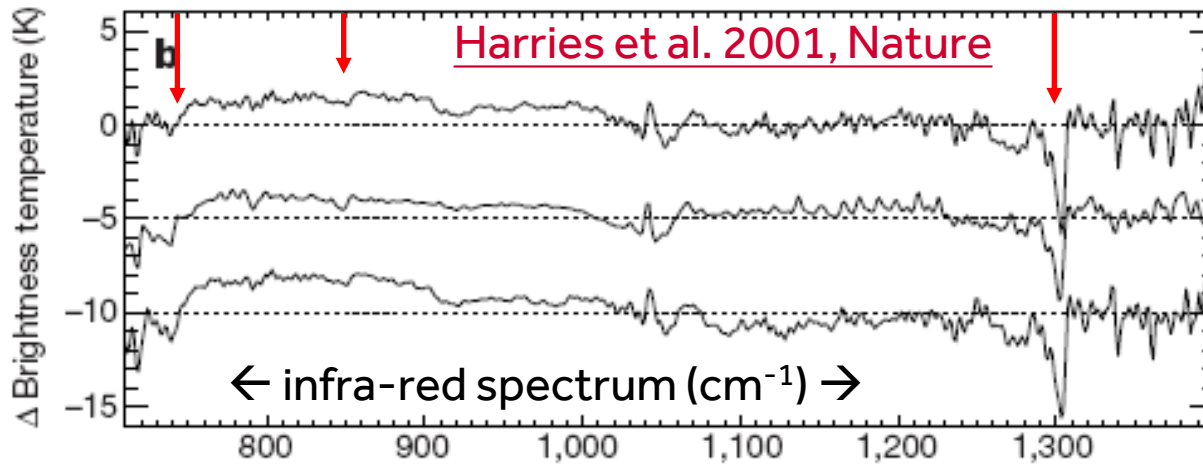
1. Radiative forcing by 1991 eruption of Mt. Pinatubo
2. Resulting cooling drives decreased water vapour in upper troposphere
3. Diminished greenhouse effect amplifies cooling
4. Climate model simulates cooling realistically due to realistic water vapour feedback

[Soden et al. \(2002\) Science](#)

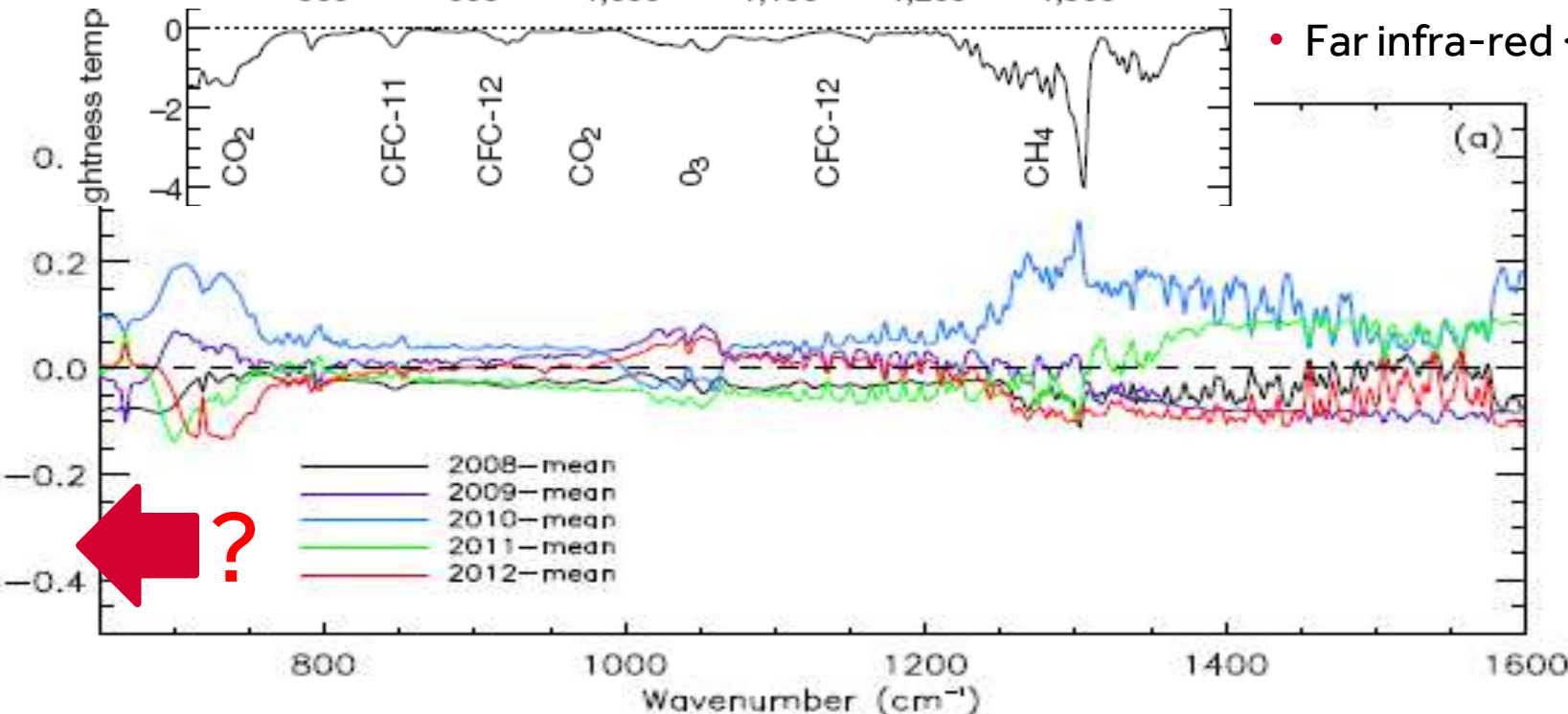




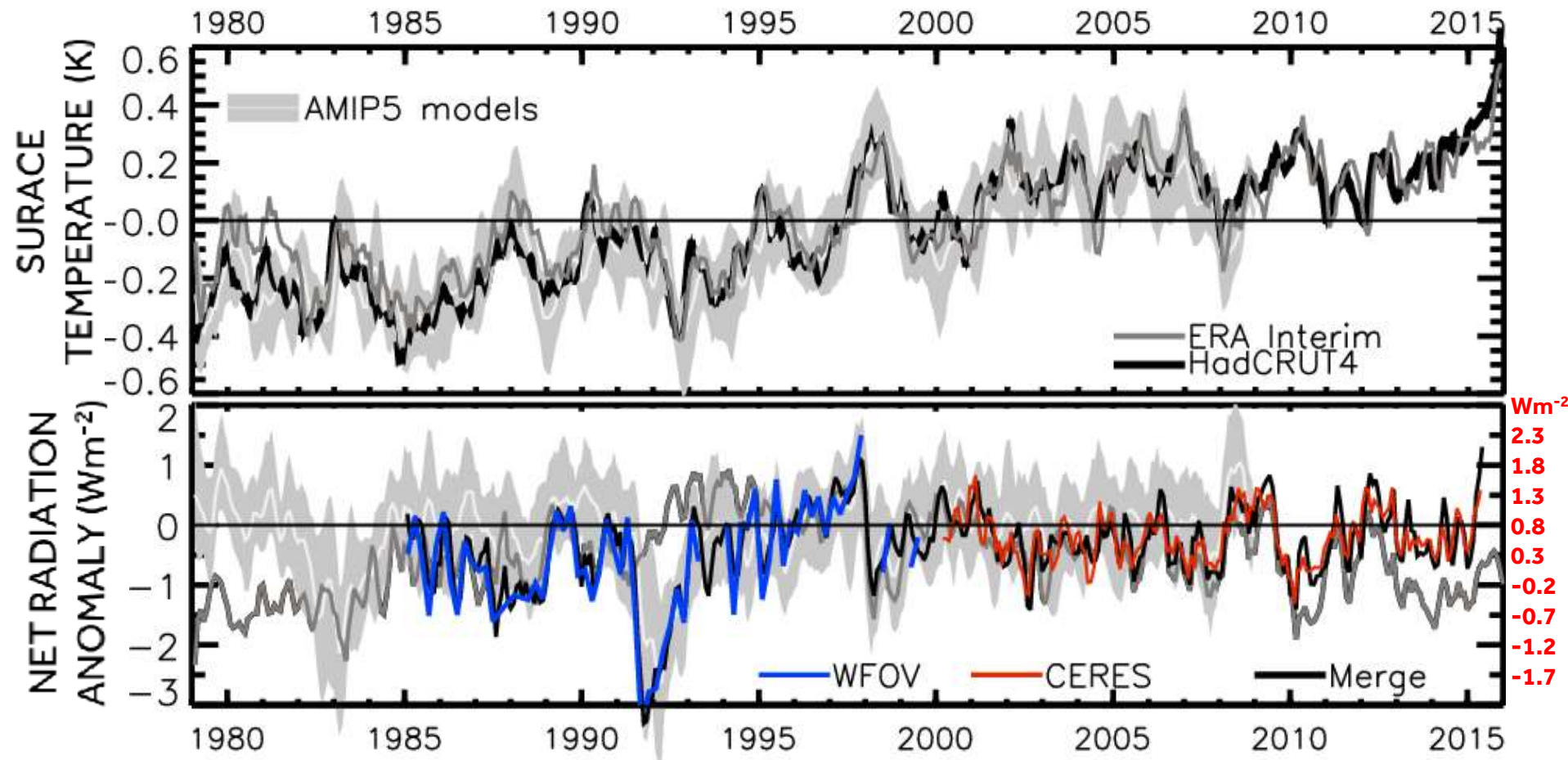
# WHAT IS SPECTRAL SIGNATURE OF CLIMATE CHANGE?



- **Left:** Increased greenhouse gas forcing 1970-97
- **Below:** inter-annual spectral variability from IASI ([Brindley et al. 2015 J. Clim](#))
- Far infra-red  $< 500 \text{ cm}^{-1}$ ?



# HOW IS EARTH'S RADIATION BUDGET & CLIMATE CHANGING?



Update from [Loeb et al. \(2012\) Nature Geoscience](#) & [Allan et al. \(2014\) GRL](#) 10