Examine Climate Models by Using Infrared Spectrum

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Abstract

• *We examine global climate models by comparing the satellite-observed high resolution global infrared spectra with the model-simulated counterpart.*

• *After ensuring consistency in the sampling of the observed and simulated spectra and a proper representation of cloud vertical distribution, the infrared spectra simulated from a state-of-the-art Geophysical Fluid Dynamics Lab climate model are shown to yield a good agreement with those measured by the Atmospheric Infrared Sounder onboard Aqua satellite, in terms of global and regional means.*

• *The radiance discrepancies, however, do exist and are consistent with the model biases in geophysical variables (temperature, water vapor concentration, etc.).*

• *An examination of the seasonal covariations of the infrared spectra and surface temperatures demonstrates the need and a method to use spectrally resolved radiance to understand and constrain model sensitivity.*

• *This study shows that infrared spectrum forms an advantageous means for climate model validation. The study also provides an example of the climatic applications using spectroscopic observations and the molecular absorption database.*

I. Infrared Radiances – a Diagnostic Proxy

• The outgoing radiation at any frequency is sensitive to the temperature and atmospheric composition at the level where the radiation mainly emerges from – a good tool to diagnose model simulation.

[Huang, Ramaswamy and Soden, 2007; Huang and Ramaswamy, 2007]

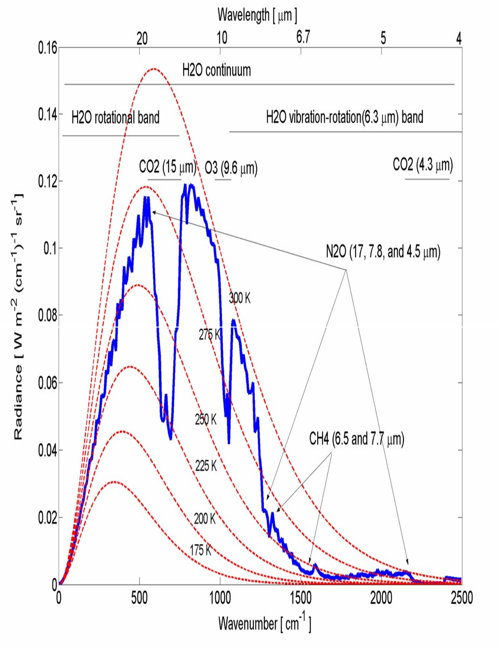


Fig 1. Outgoing Longwave Radiation (OLR) spectrum

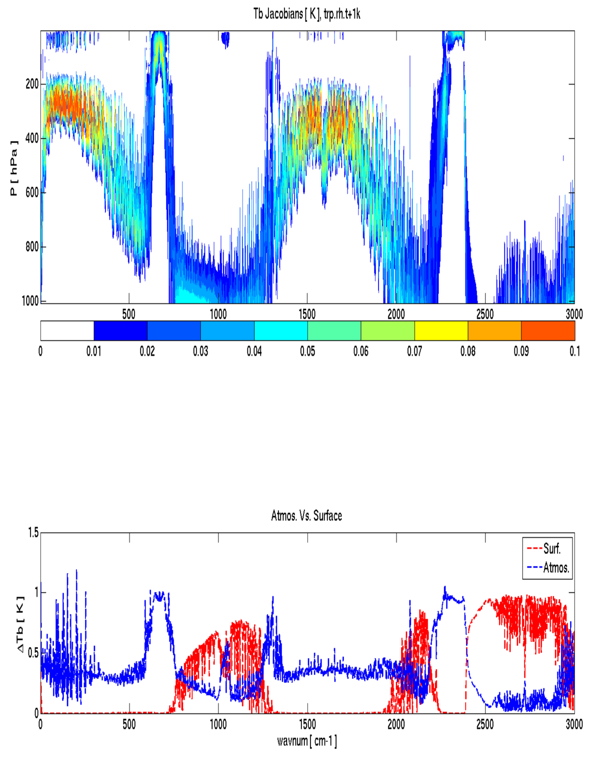


Fig 2. Radiative Jacobians – the sensitivity of outgoing radiances to atmospheric and surface temperatures

II. Model and Observation Data

•GCM

– GCM: GFDL General Circulation Models

– 25-level (up to ~ 3hPa) temperature/moisture/cloud profiles output 3 hourly at each model grid

– To ensure sampling consistency: satellite tracking

•MODTRAN

– "Mod4v3r1", HITRAN 2000 with 2001 update, CKD2.4

– Resolution: 2 cm^{-1}

– 5 extra levels (up to 100 km) of standard atmosphere patched atop the GCM generated profiles

– Random overlapping clouds (realized offline)

•AIRS

– Atmospheric Infrared Sounder **o**nboard Aqua satellite (polar orbital; 1:30 equator crossing time)

– Operational since Aug 31, 2002: ~6 billion spectra collected

– Resolution: $\nu/\Delta\nu$=1200

– Spectral range: 650 to 2665 cm^{-1}

III. Results

• Good agreement in general

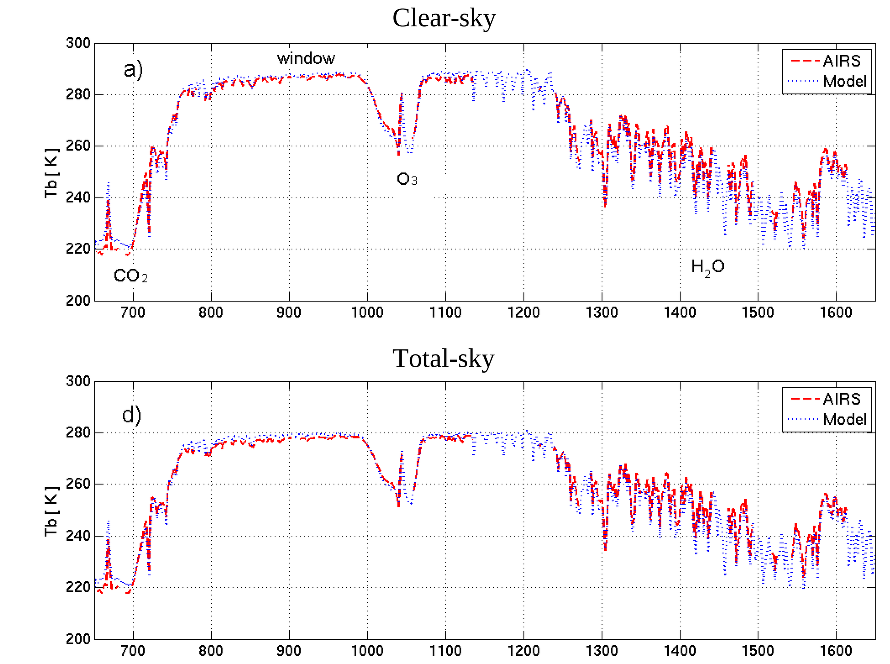
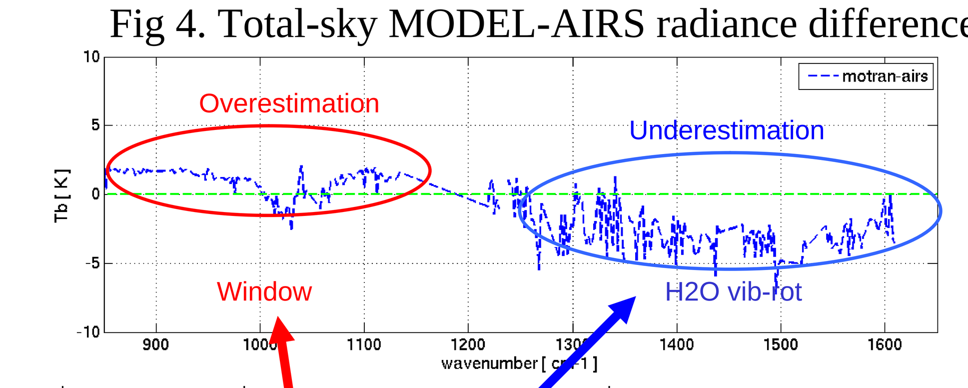


Fig 3. Global mean radiance (Tb)

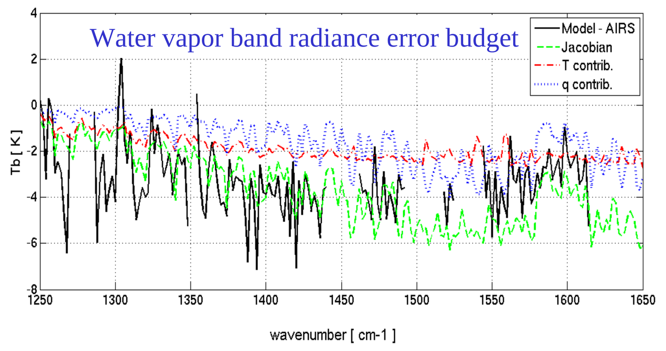
• Compensating spectral errors [Huang et al., 2007]

Fig 4. Total-sky MODEL-AIRS radiance difference



Unit: W m^{-2}	OLR		Window band	
	Total sky	Clear sky	Total sky	Clear sky
CERES	241.73	275.87	66.94	83.28
GCM	240.63	263.43	73.99	87.56
GCM-CERES	-1.10	-12.44	7.05	4.28

$$\Delta R = \frac{\partial R}{\partial T_s}\Delta T_s + \sum_i \frac{\partial R}{\partial T_a^i}\Delta T_a^i + \sum_i \frac{\partial R}{\partial H_2O^i}\Delta H_2O^i$$



• Climate sensitivity: R-Ts relationship [Huang & Ramaswamy, 2008]

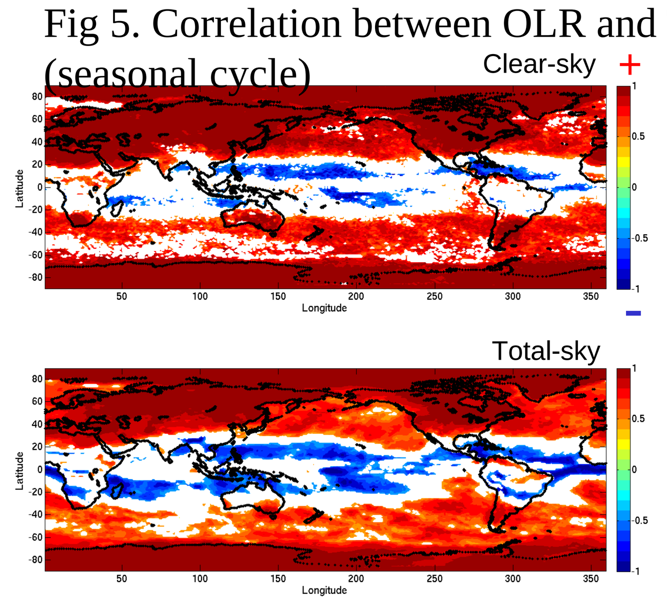
Sensitivity

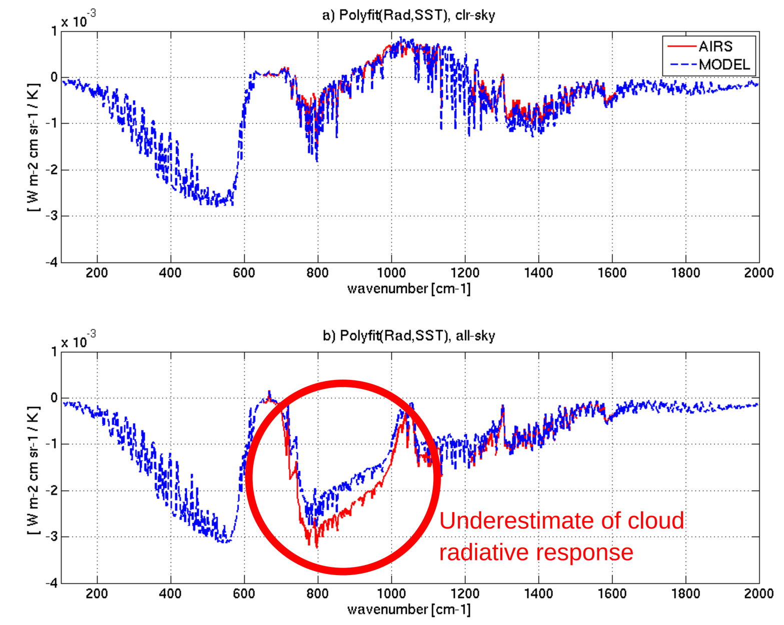
$$\Delta Ts = \Delta R \cdot \left(\Gamma + \sum \frac{\partial R}{\partial Xi}\frac{\partial Xi}{\partial Ts}\right)^{-1}$$

Surface T Tendency; TOA Radiation Imbalance; Planck Damping; Feed-backs

Manabe and Wetherald [1988]

Fig 5. Correlation between OLR and T_s (seasonal cycle)





Clear-sky $\delta OLR/\delta T$ = -2.3 (CERES) -2.1 (MODEL) [W m^{-2} / K]

Total-sky $\delta OLR/\delta T$ = -7.2 (CERES) -6.1 (MODEL) [W m^{-2} / K]

Fig 6. Spectral decomposition of OLR-Ts relationship

IV. References

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