# Future Directions for Radiative Transfer: *Prospective Capabilities and Diagnostics*

Bill Collins
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- Current status
- Science opportunities
- New physics
- New diagnostics
- New process coupling

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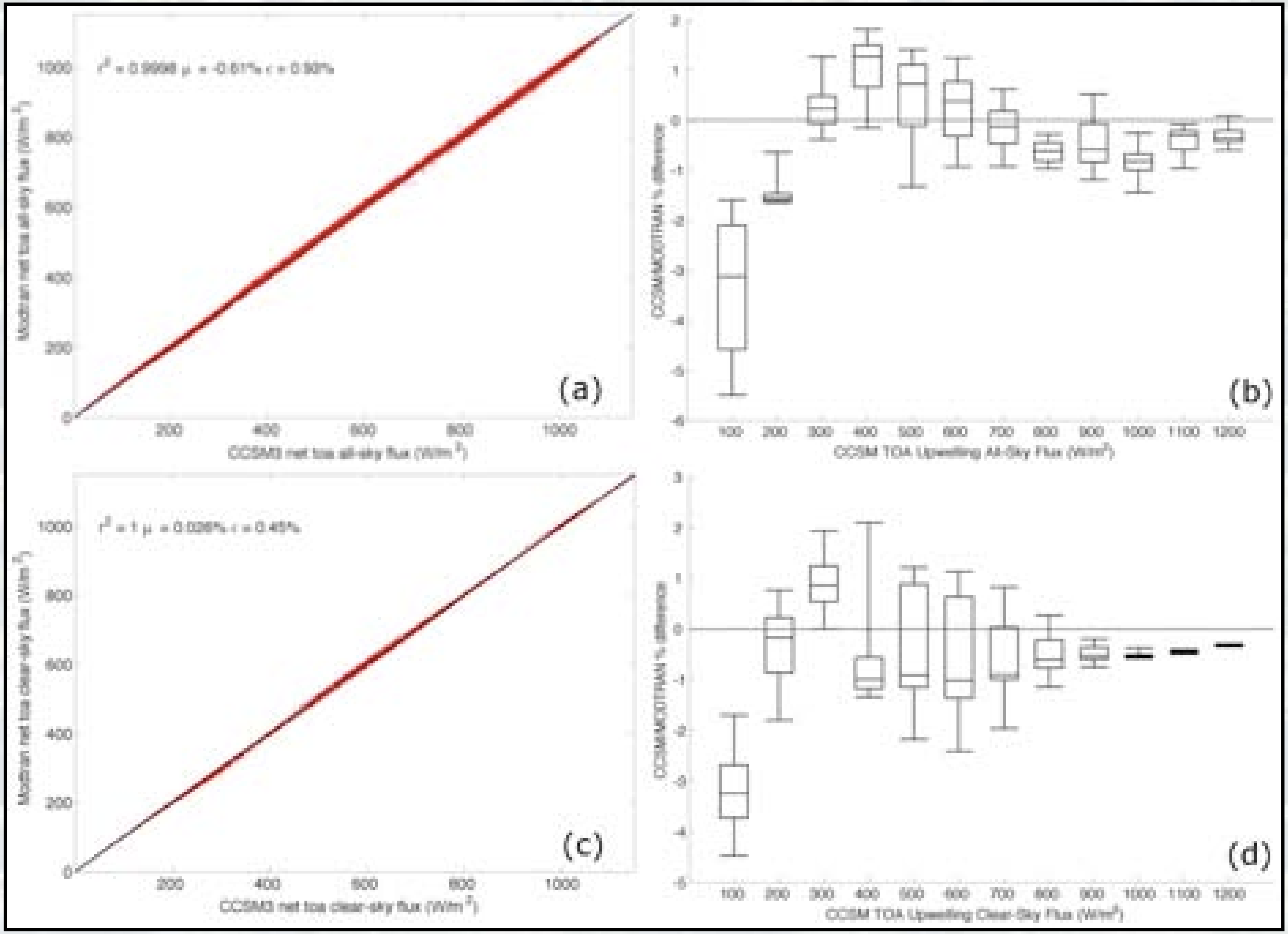
# Current status

- As of CESM1, we transitioned to the Rapid Radiative Transfer Method (RRTMG).
- Advantages:
  - Gas properties are current with modern spectroscopy.
  - RRTMG is based upon and tested against line-by-line codes.
  - RRTMG is continuously tested against field observations.

# Sufficient Accuracy of CAM RT and RRTMG(?)




AMWG Meeting
Boulder, Feb. 14-13, 2011

Feldman and Collins, 2011

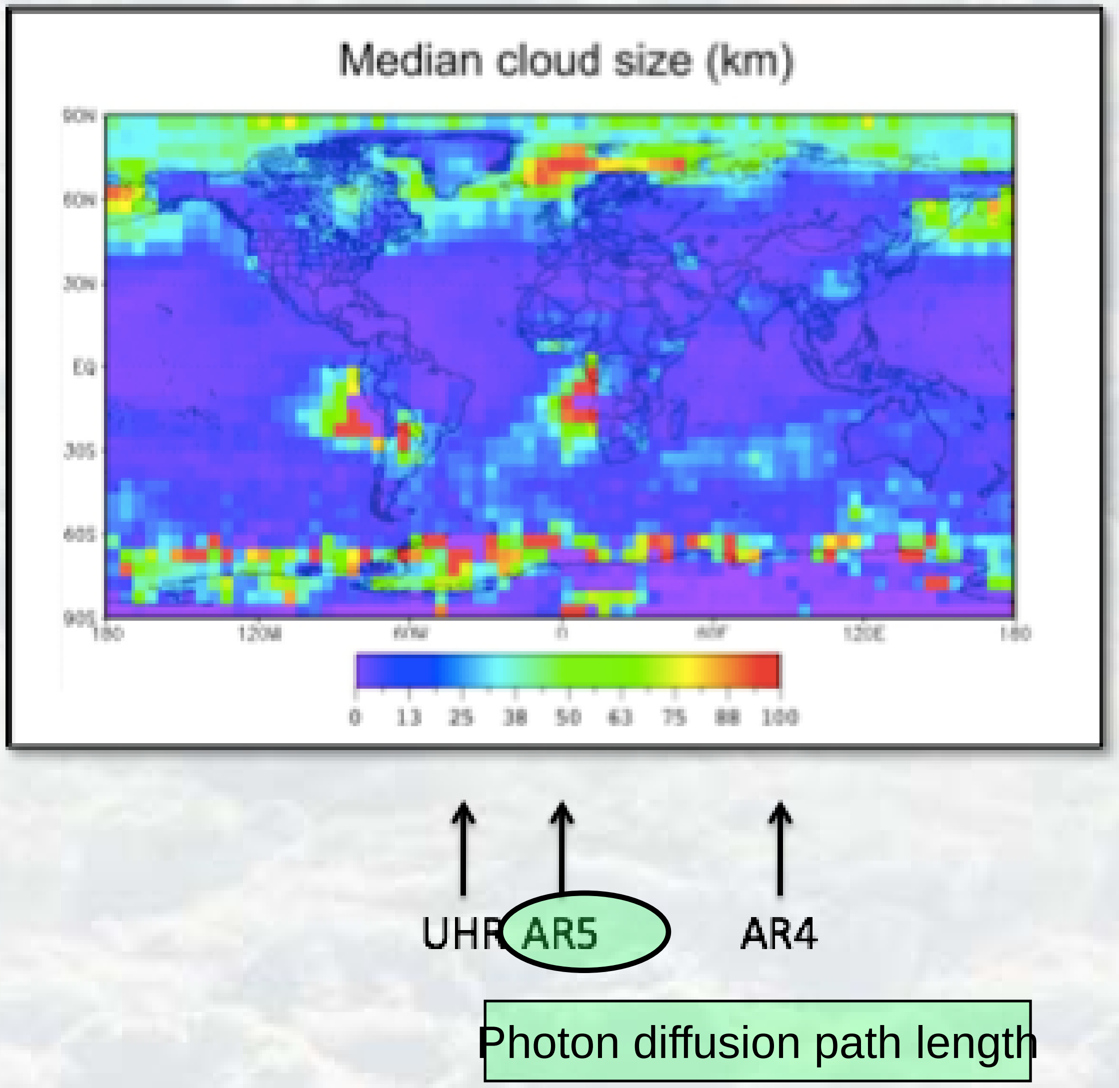
# Focal Areas for Radiative Transfer

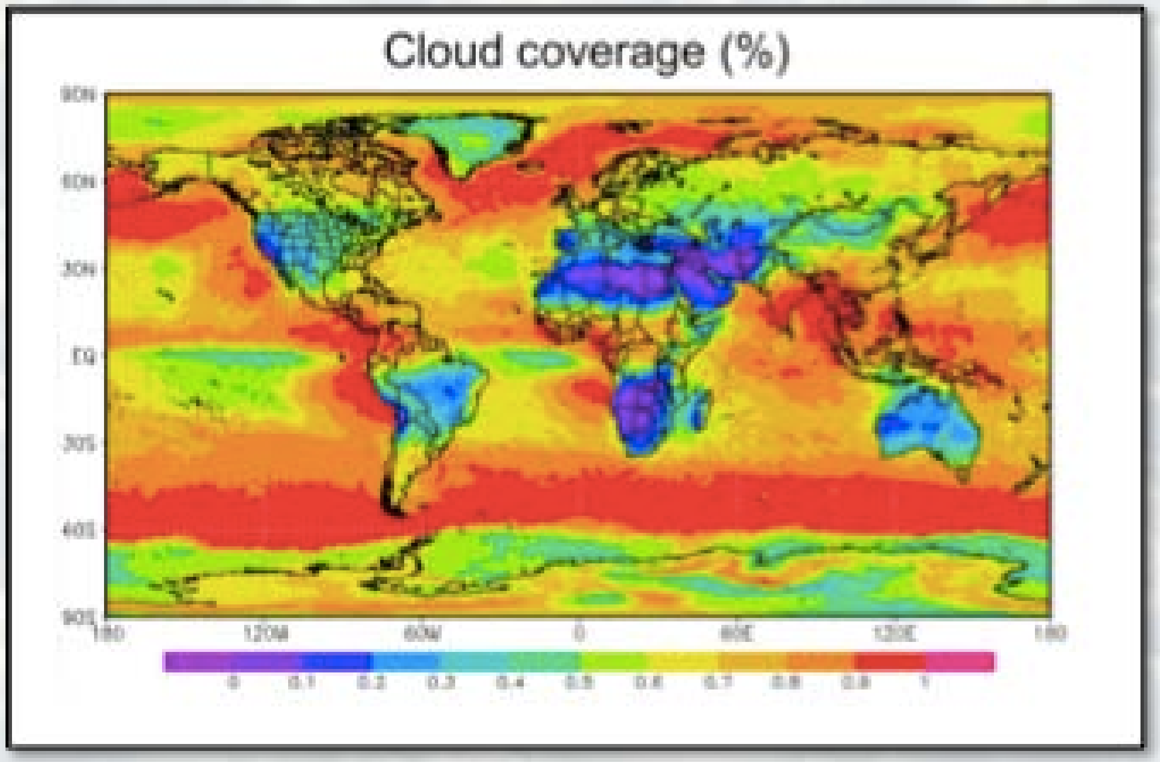
- Possible areas for major advances:
  - New radiative physics
  - New radiative diagnostics
  - New interactions with Earth-system processes

# New Radiative Physics

- Physics to be added:
  - 3D radiative transfer
  - Missing radiatively active gases
  - Correction to RT in near-IR
  - Accuracy under deep paleoclimate conditions

# 3D Radiative Transfer



# Addition of radiative species

**Table 1.** Atmospheric Budget Lifetimes of Fluorinated Gases From UCI CTM With and Without $O(^1D)$ Reactions Compared With IPCC[a]

Prather and Hsu, 2008

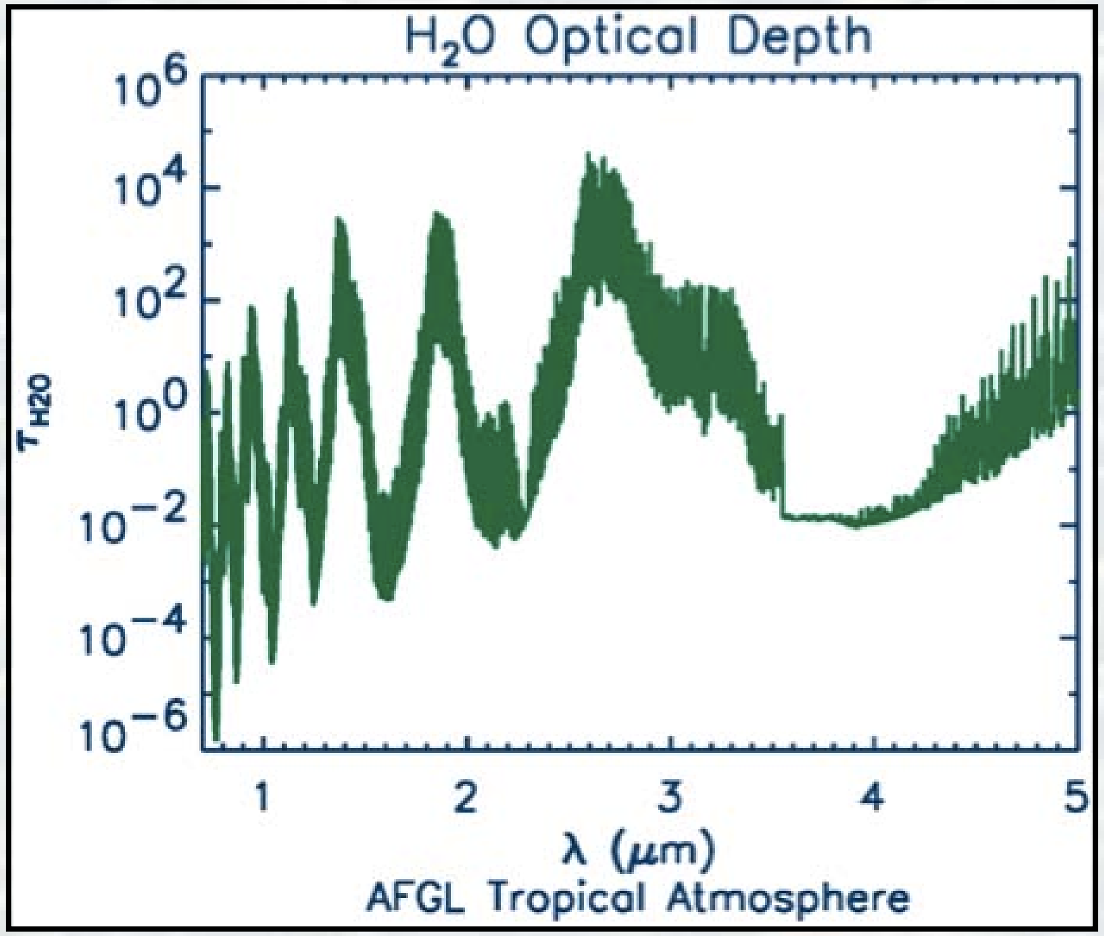
| Gas | UCI Without $O(^1D)$ | UCI With $O(^1D)$ | IPCC |
|---|---|---|---|
| $NF_3$ | 640 | 550 | 740 |
| CFC-11 ($CFCl_3$) | 48 | 47 | 45 |
| CFC-12 ($CF_2Cl_2$) | 100 | 96 | 100 |
| CFC-113 ($CF_2ClCFCl_2$) | 82 | 80 | 85 |
| CFC-114 ($CF_2ClCF_2Cl$) | 230 | 180 | 300 |
| CFC-115 ($CF_3CF_2Cl$) | 1650 | 540 | 1700 |

[a]Source: *Forster et al.* [2007]. Lifetimes are given in years.

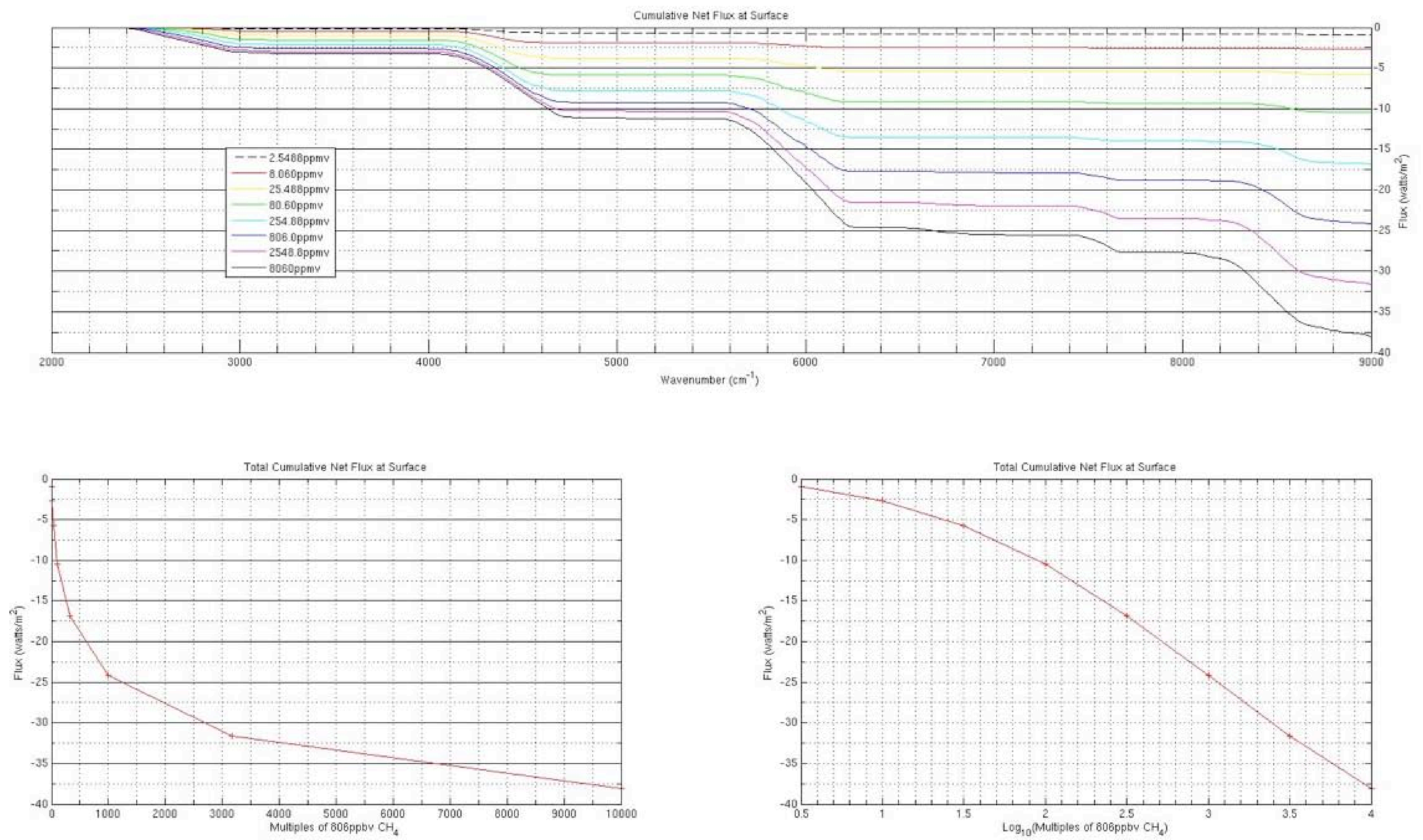
- $NF_3$ has a GWP exceeded only by that of $SF_6$.
- $NF_3$ is not treated in any existing radiative code.
- Warming could exceed that of PFCs or $SF_6$.

# Radiative transfer in near-IR

- The near-IR is a highly absorbing spectral region.
- However, we are using Mie theory for aerosols and droplets imbedded in a non-absorptive medium.
  - Physically correct for visible.
  - Physically incorrect for near-IR.
- We know how to implement correct physics.

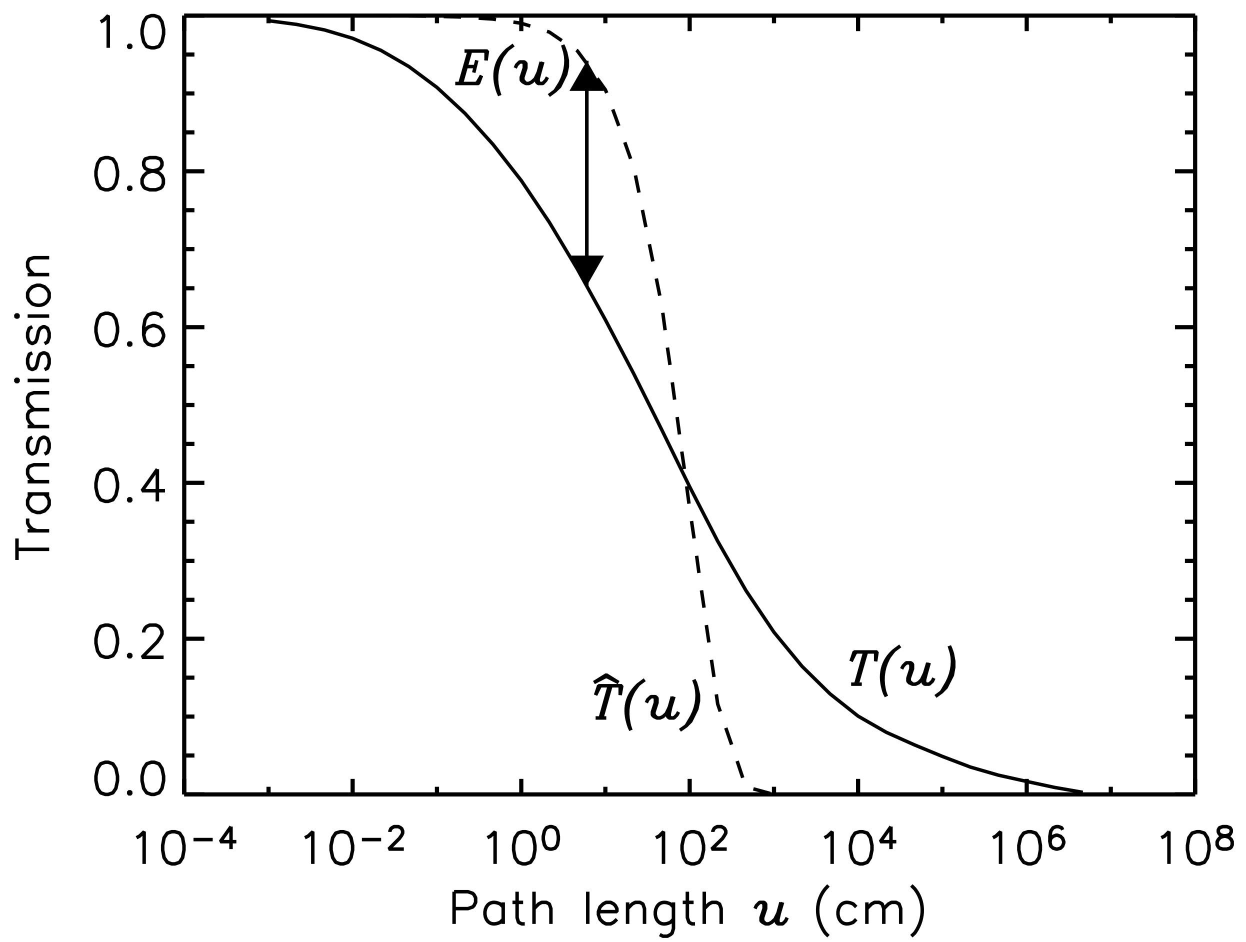


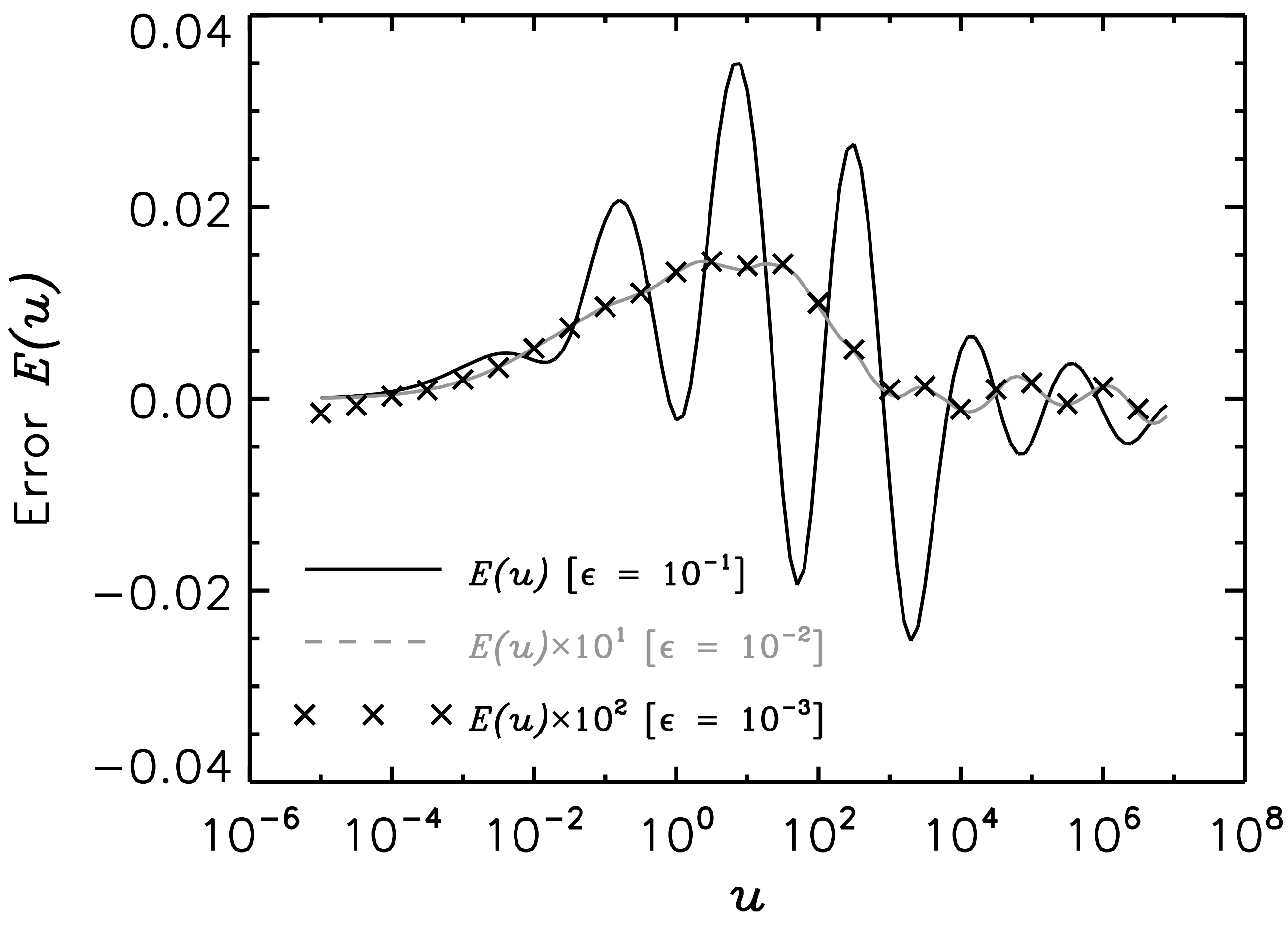
# Application to deep paleoclimate




- At Permian-Triassic boundary, $CH_4$ was $O(10^3)$X PD.
- Large SW forcing has been not been properly treated (to date).

# New methods for robust RT in the asymptotic limit

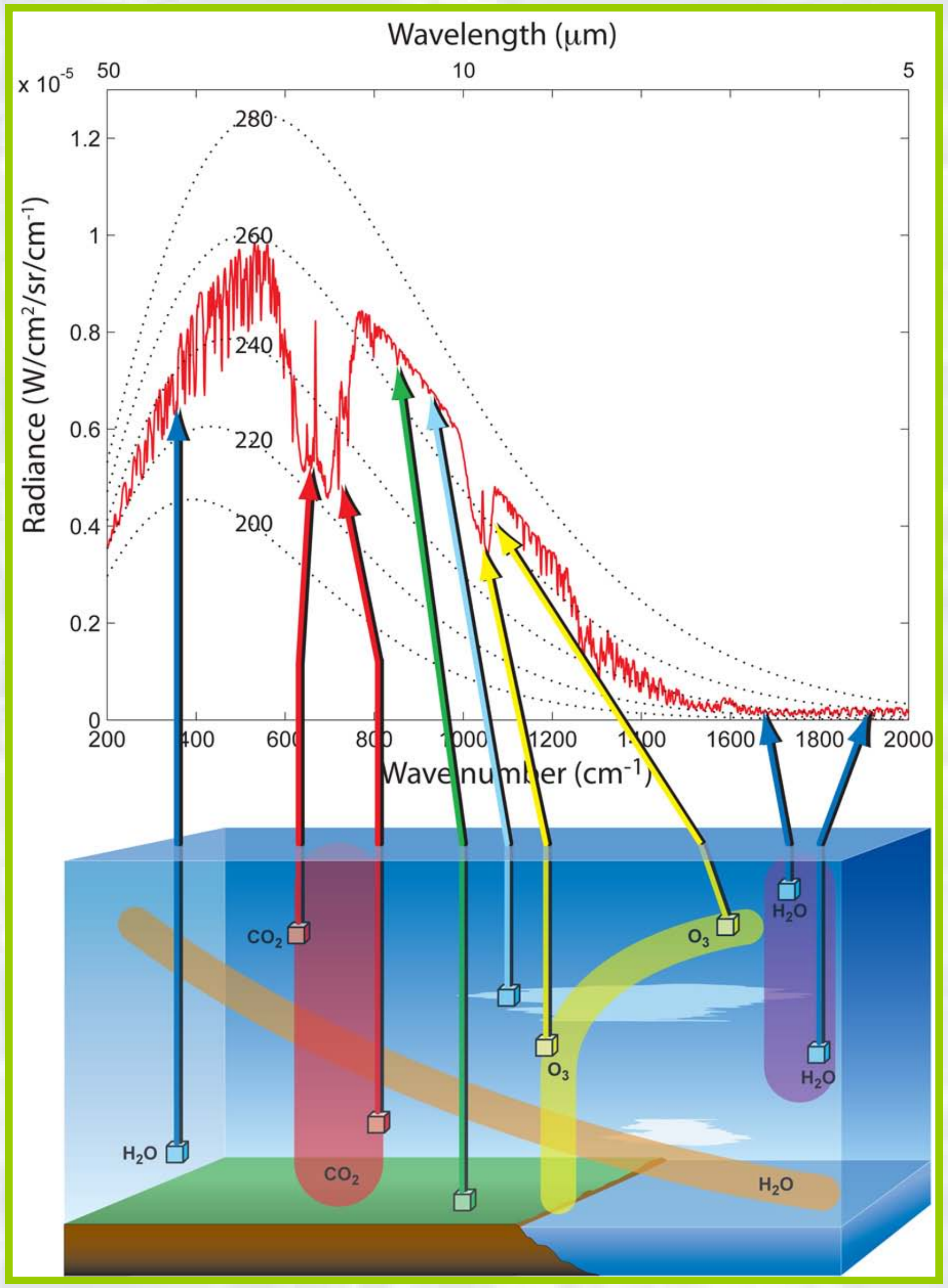


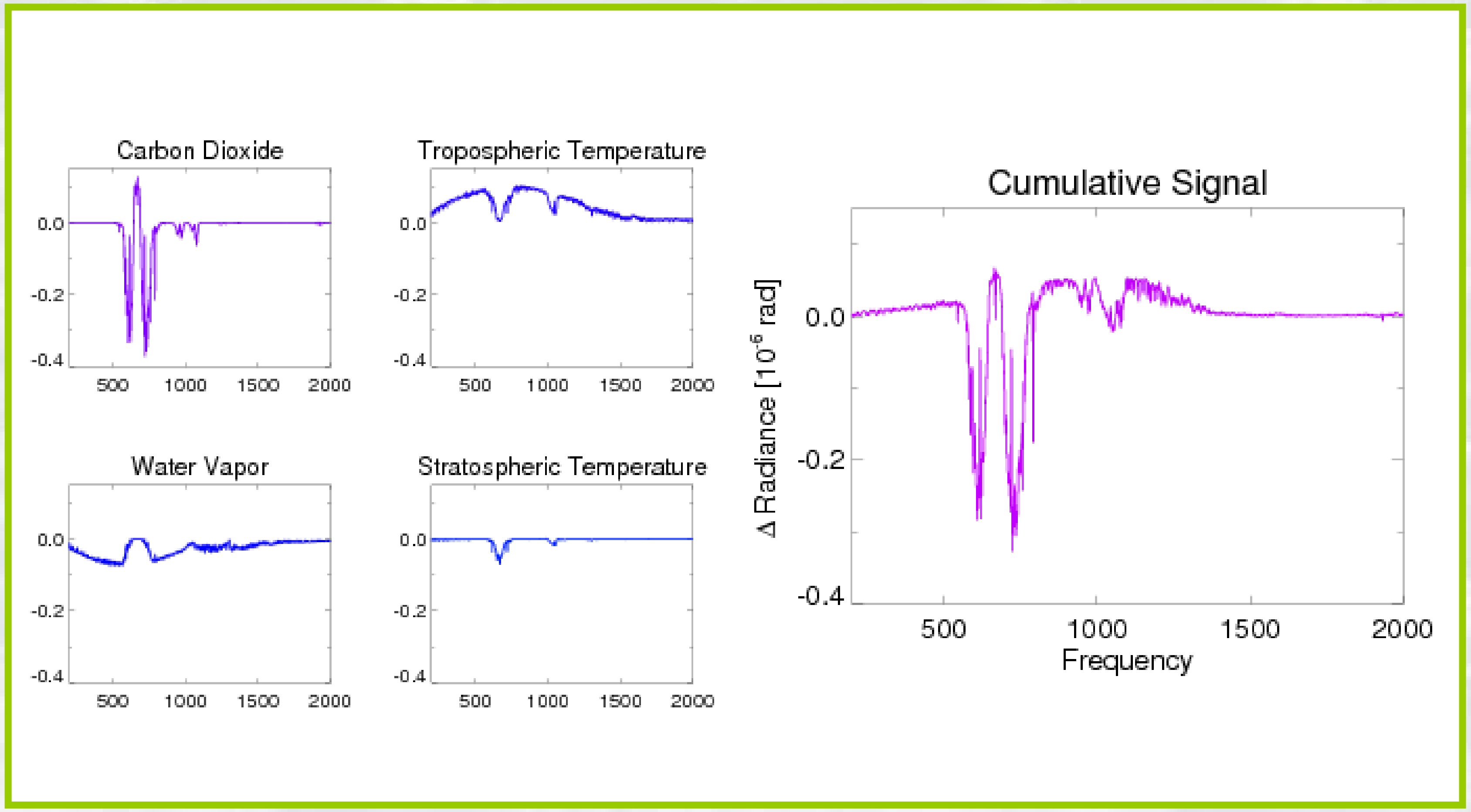




Collins and Conley, 2011

- We have developed new mathematical methods for RT.
- These methods *guarantee* bounded errors at *all* path lengths.

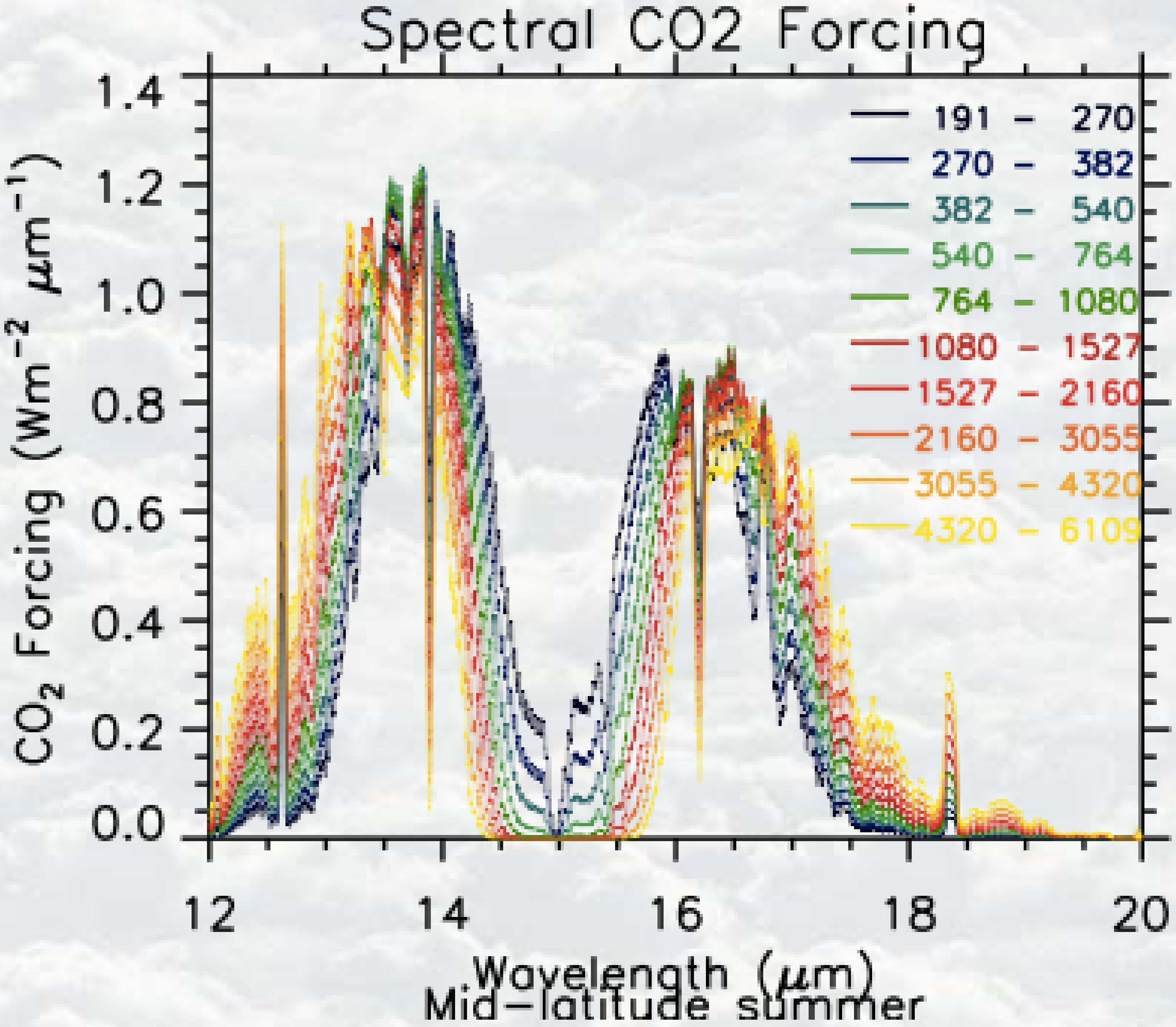
# Utility of spectra for attribution of forcings and feedbacks




Leroy et al, 2008

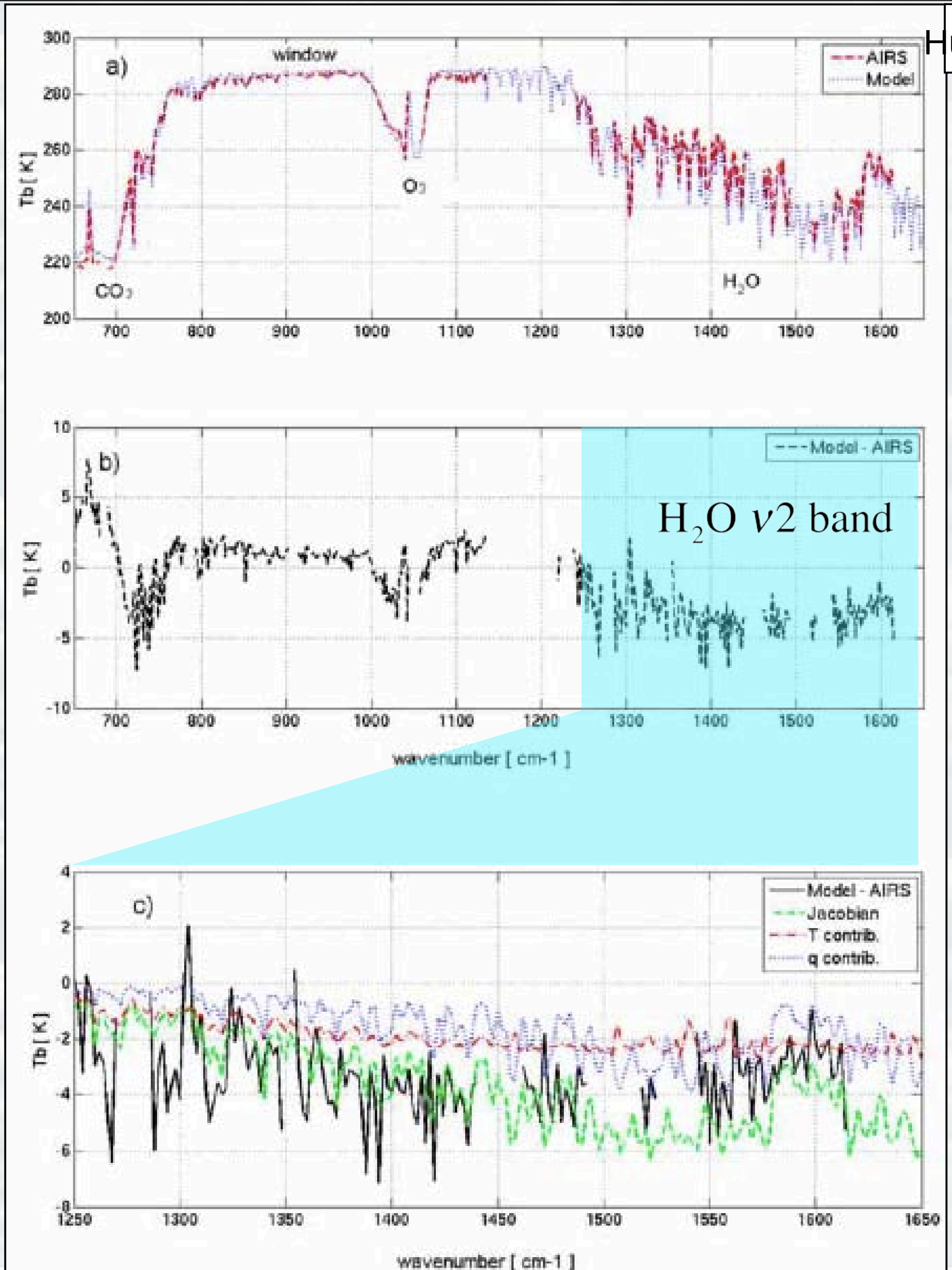
# Example: Forcing by Carbon Dioxide




Collins and Algieri, 2011

# Utility of spectra for error detection

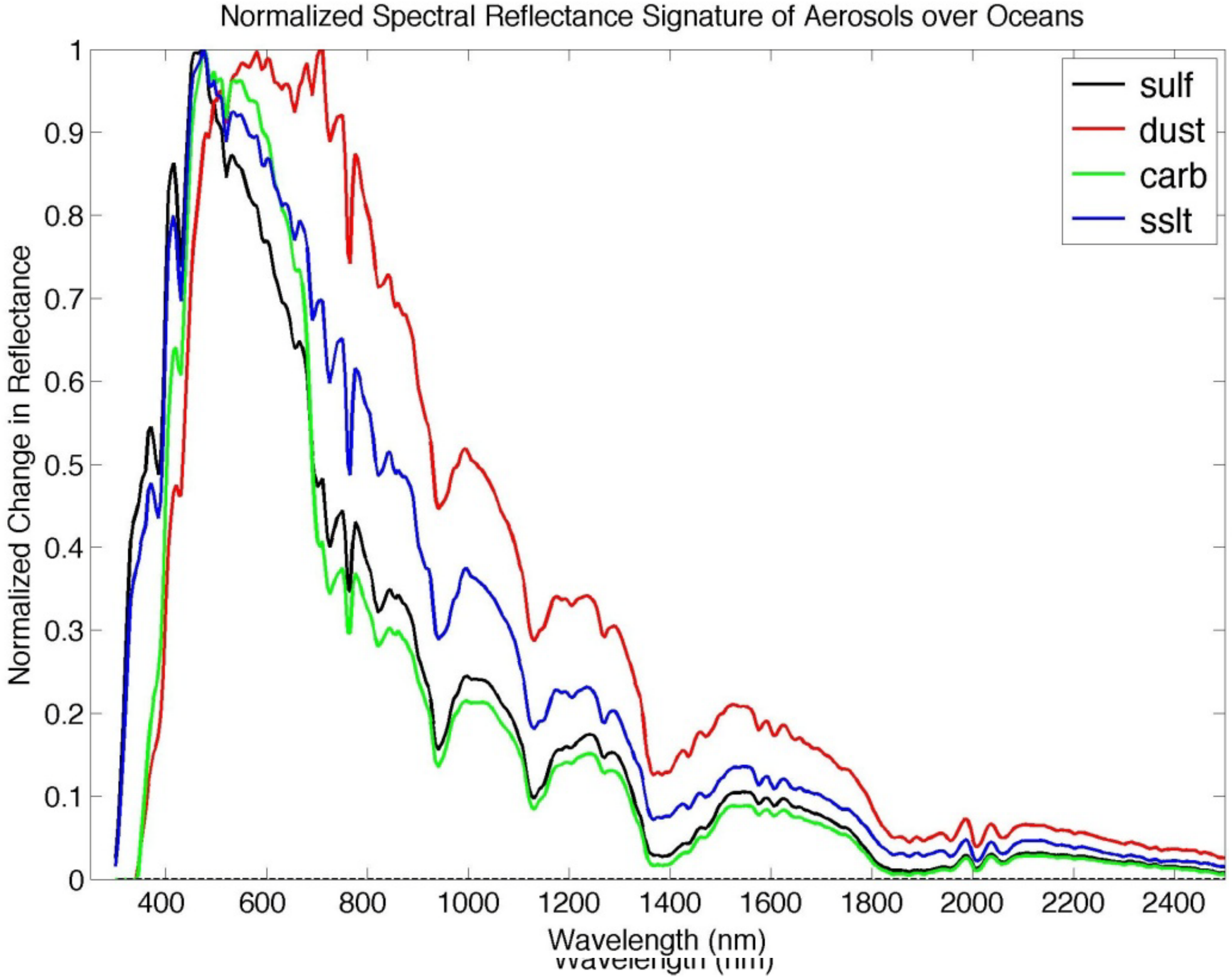
Huang and Ramaswamy, 2007

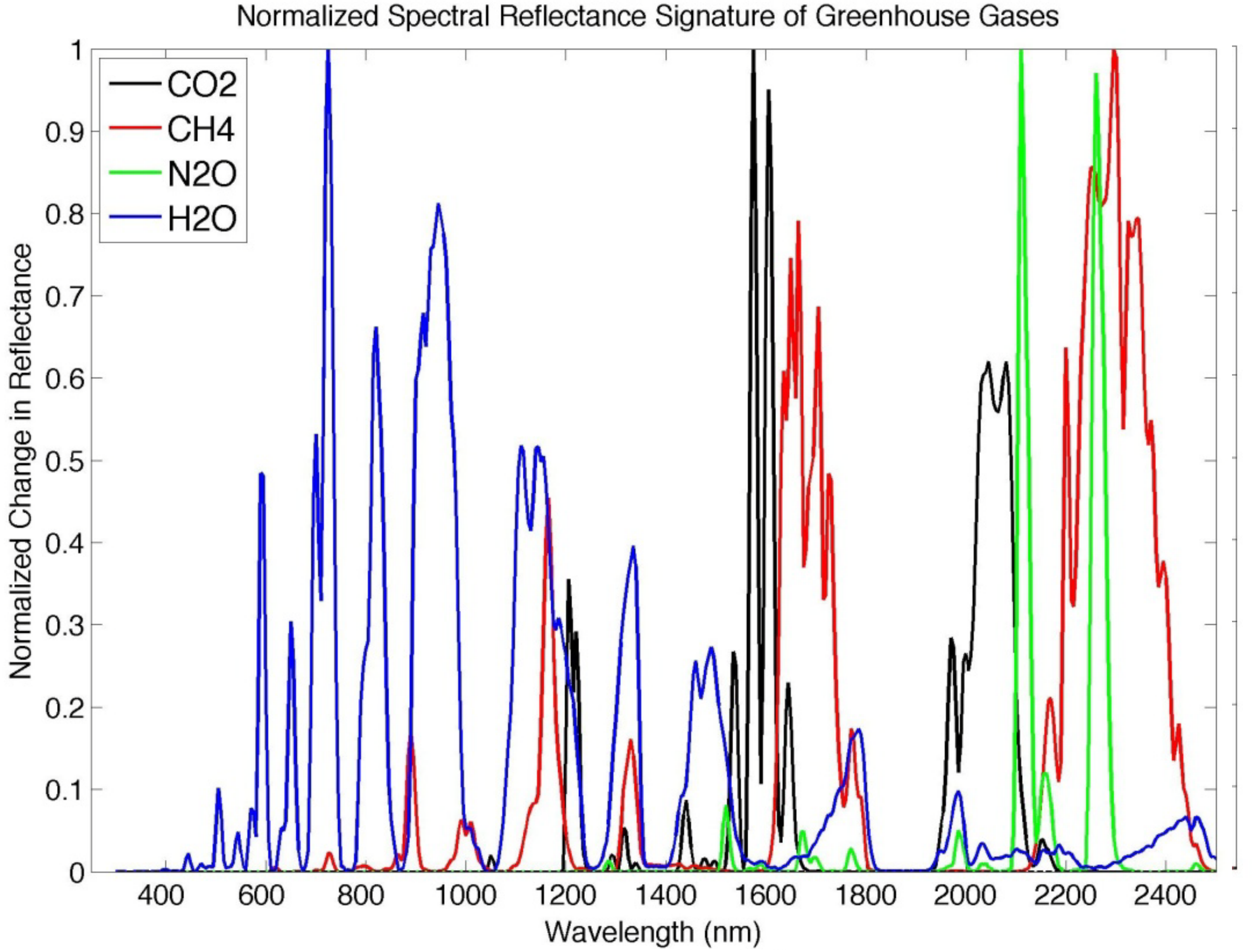


# Spectral Signatures of Forcings & Feedbacks

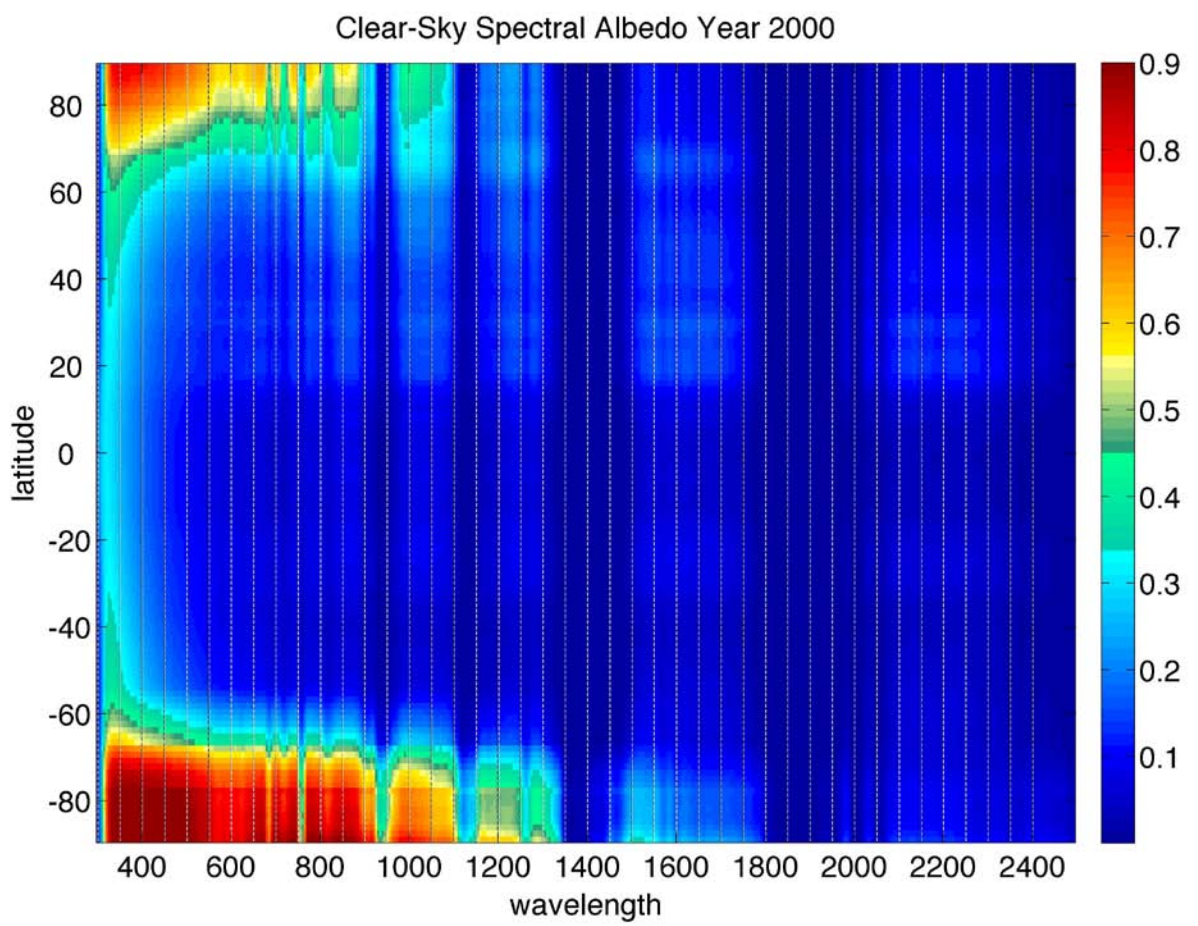
- GHG′s: small signals but have sharp and separable signature features.
- Aerosols: broadband signatures with some separability by Angstrom exponent.
- Clouds: broadband signatures with $H_2O$ lines indicative of cloud height.

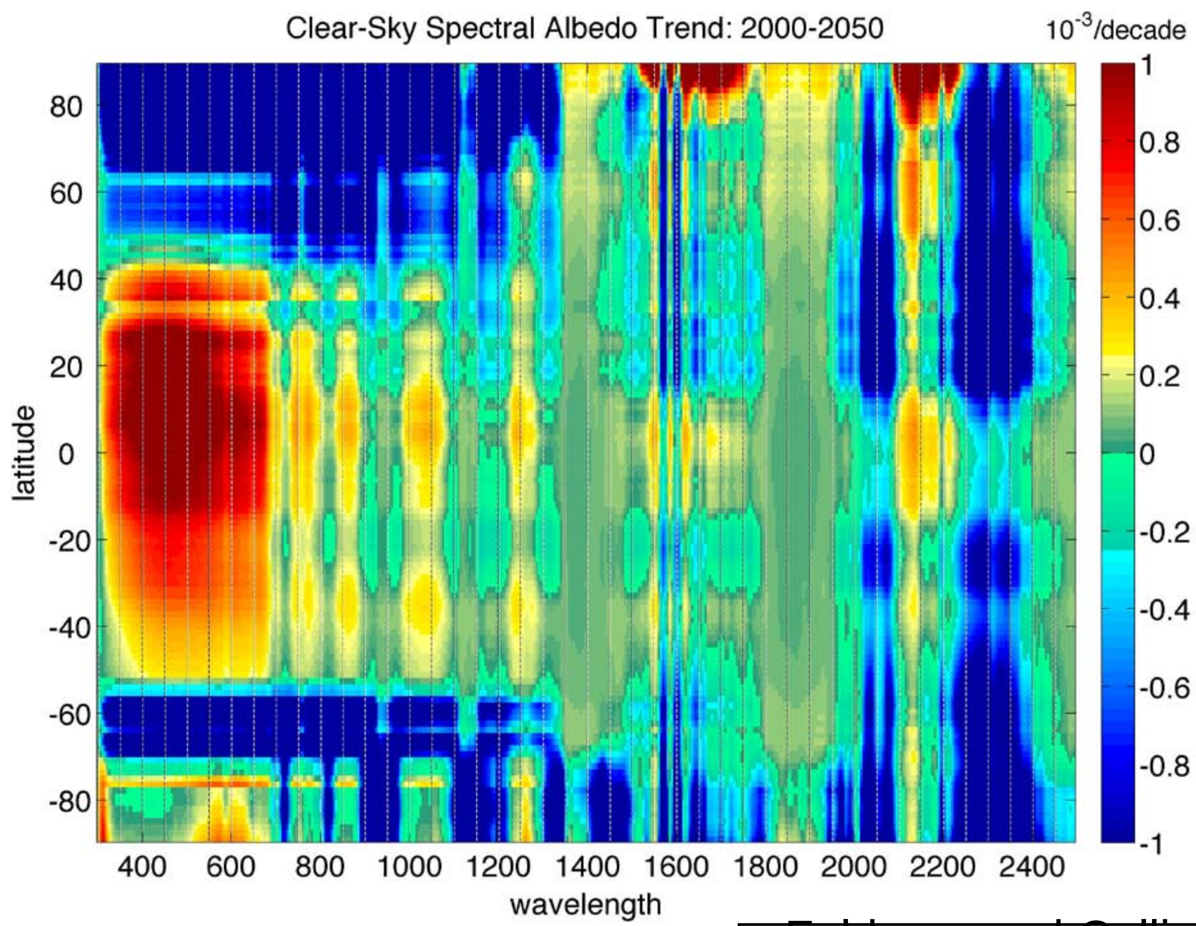
Feldman and Collins, 2011



# Δ Clear-sky spectral albedo: Trend

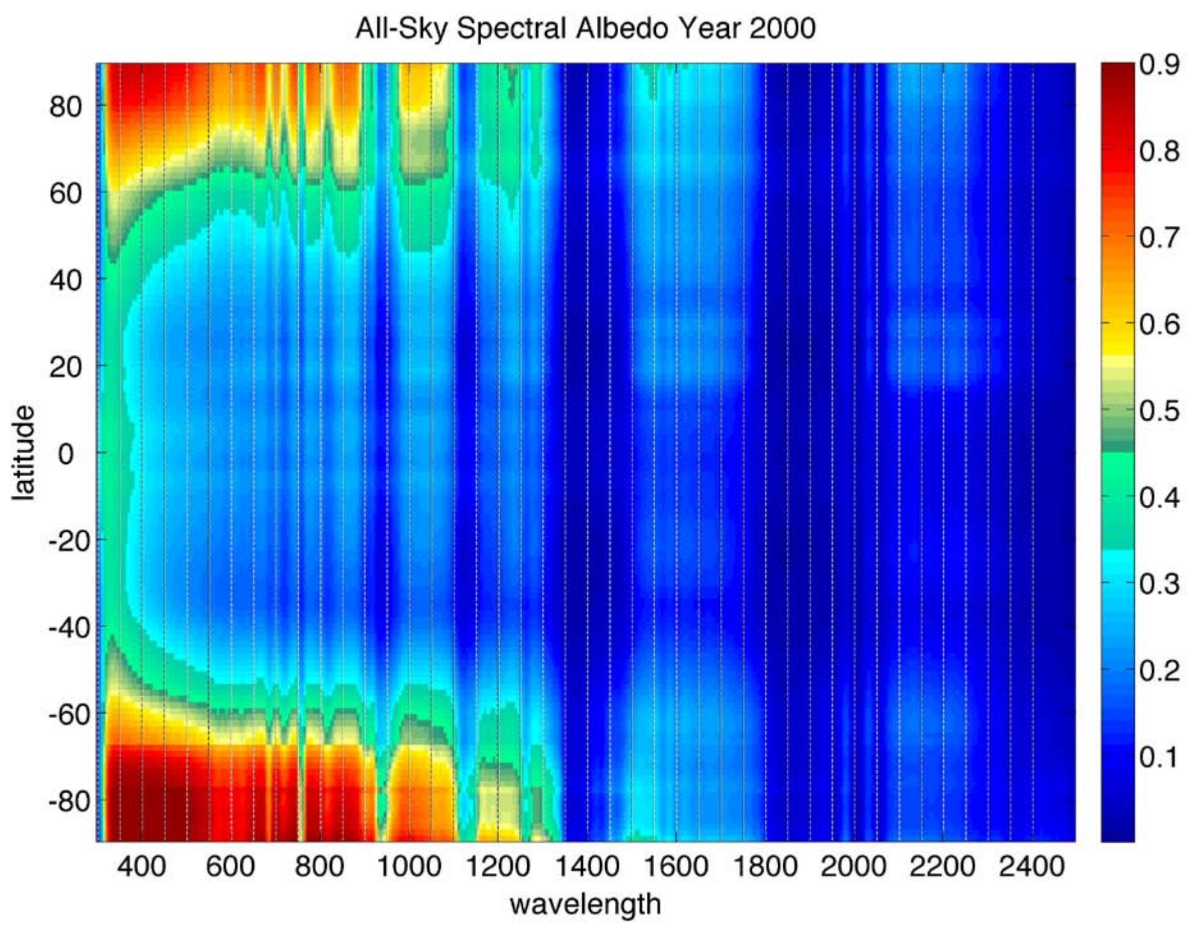


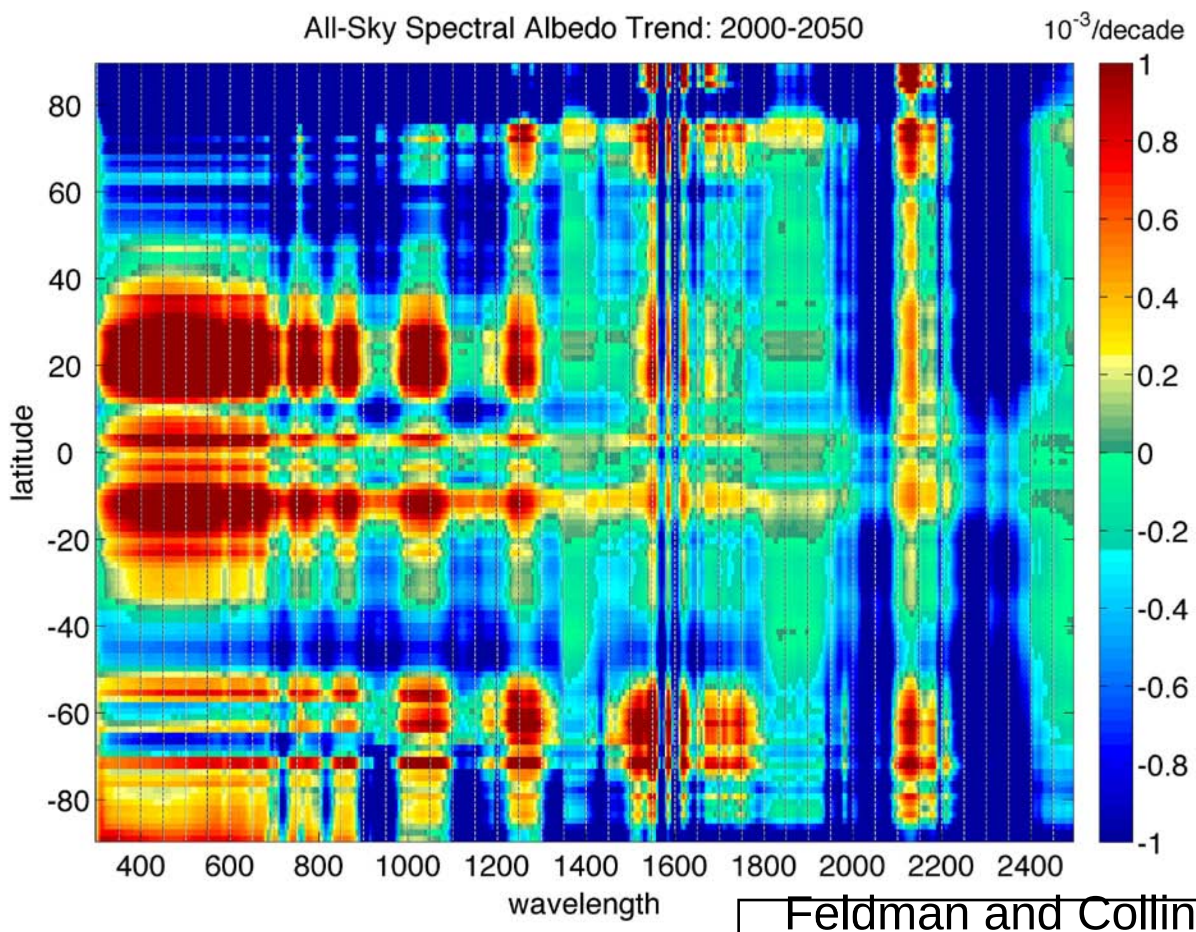




Feldman and Collins, 2011

Largest spectral trends occur in the
- Tropics and subtropics due to aerosols
- Arctic region due to snow and sea ice

# Δ All-sky spectral albedo: Trend




Feldman and Collins, 2011

Largest spectral trends occur in the tropics, subtropics, and polar regions.

# Questions?