An Assessment of Radiative Forcing from CMIP5 Models

CMIP3

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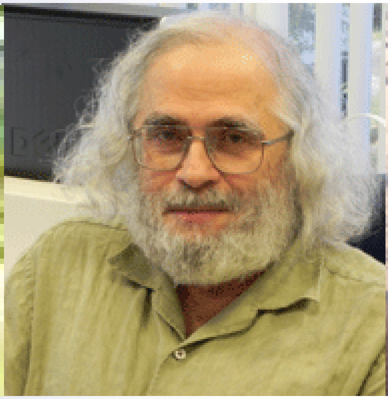

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Take Home Points

Dominant sources of uncertainty in CMIP3 climate projections :

(1) Direct radiative forcing from aerosols

(2) Low (stratocumulus/cumulus) cloud feedback

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Motivation

- **Most modeling centers do not provide (calculate?) the radiative forcing for different emission scenarios.**
- **Those that do calculate the radiative forcing usually do so differently from one group to the next.**
- **This leads to attempts to estimate the radiative forcing from available output (e.g., “Gregory Method”)**
- **We use “radiative kernels” (Soden et al., 2008) to estimate clear-sky radiative forcing.**

Estimating Radiative Forcing using "Kernels"

Consider the Change in Net Clear-sky Flux at TOA: ***dR***

$$dR = \left(\frac{\delta R}{\delta T}\frac{dT}{dT_s} + \frac{\delta R}{\delta W}\frac{dW}{dT_s} + \frac{\delta R}{\delta \alpha}\frac{d\alpha}{dT_s}\right)dT_s \quad + G \quad + \ldots$$

Temperature Feedback | **Water Vapor Feedback** | **Sfc Albedo FeedbacK**

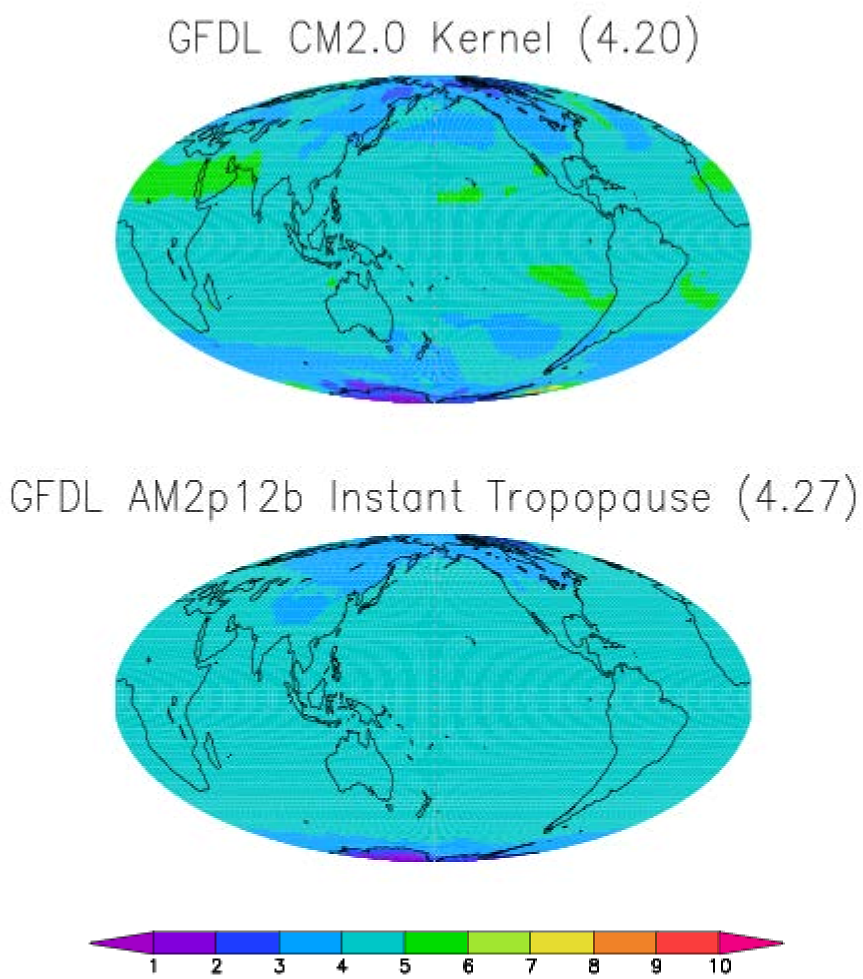
GCM Output (→ dR)

Linear response of radiative flux to feedbacks (computed from kernels)

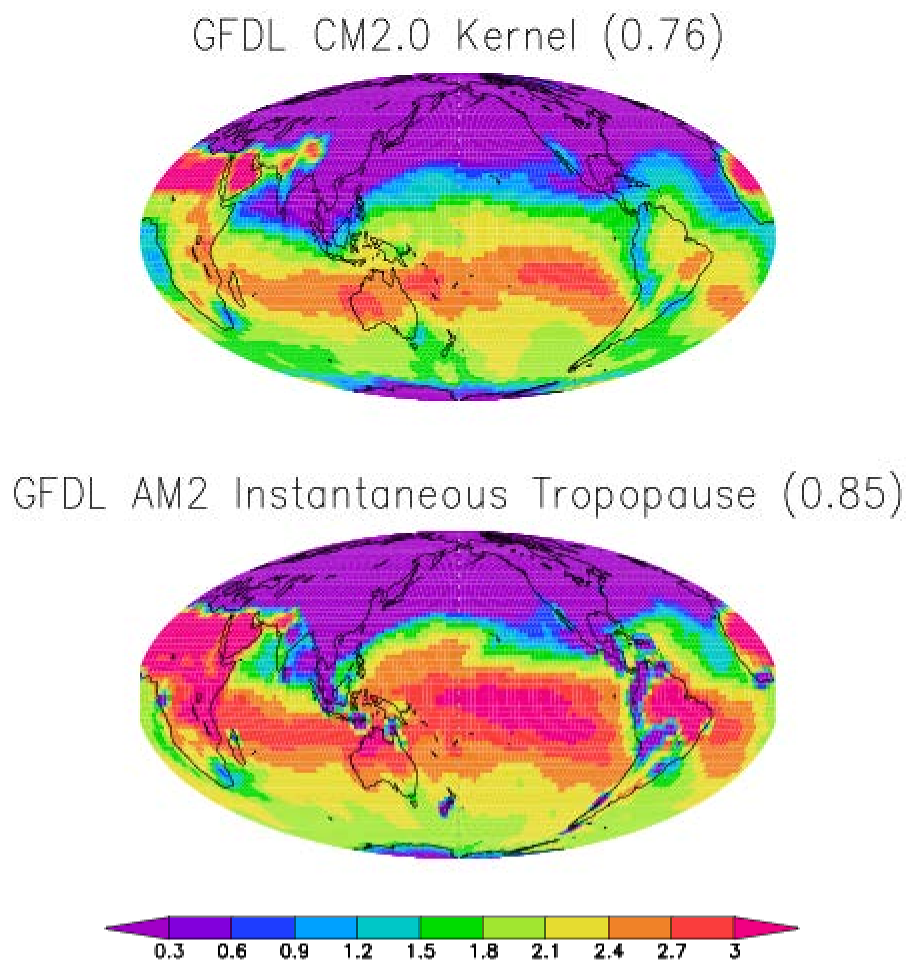
Clear-Sky Radiative Forcing (→ G)

Radiative Forcing: Kernel vs. Direct Calculation

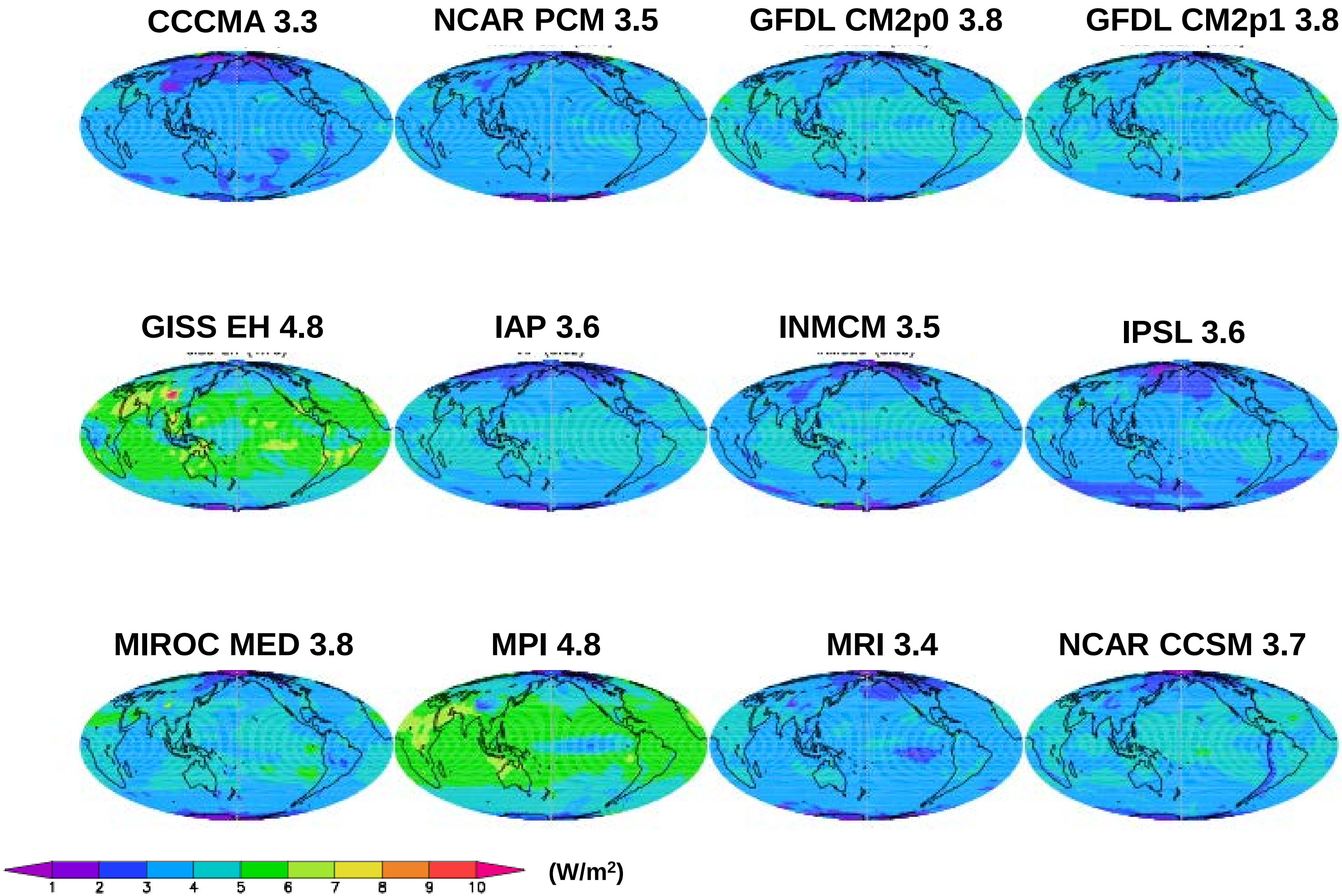
2x CO2



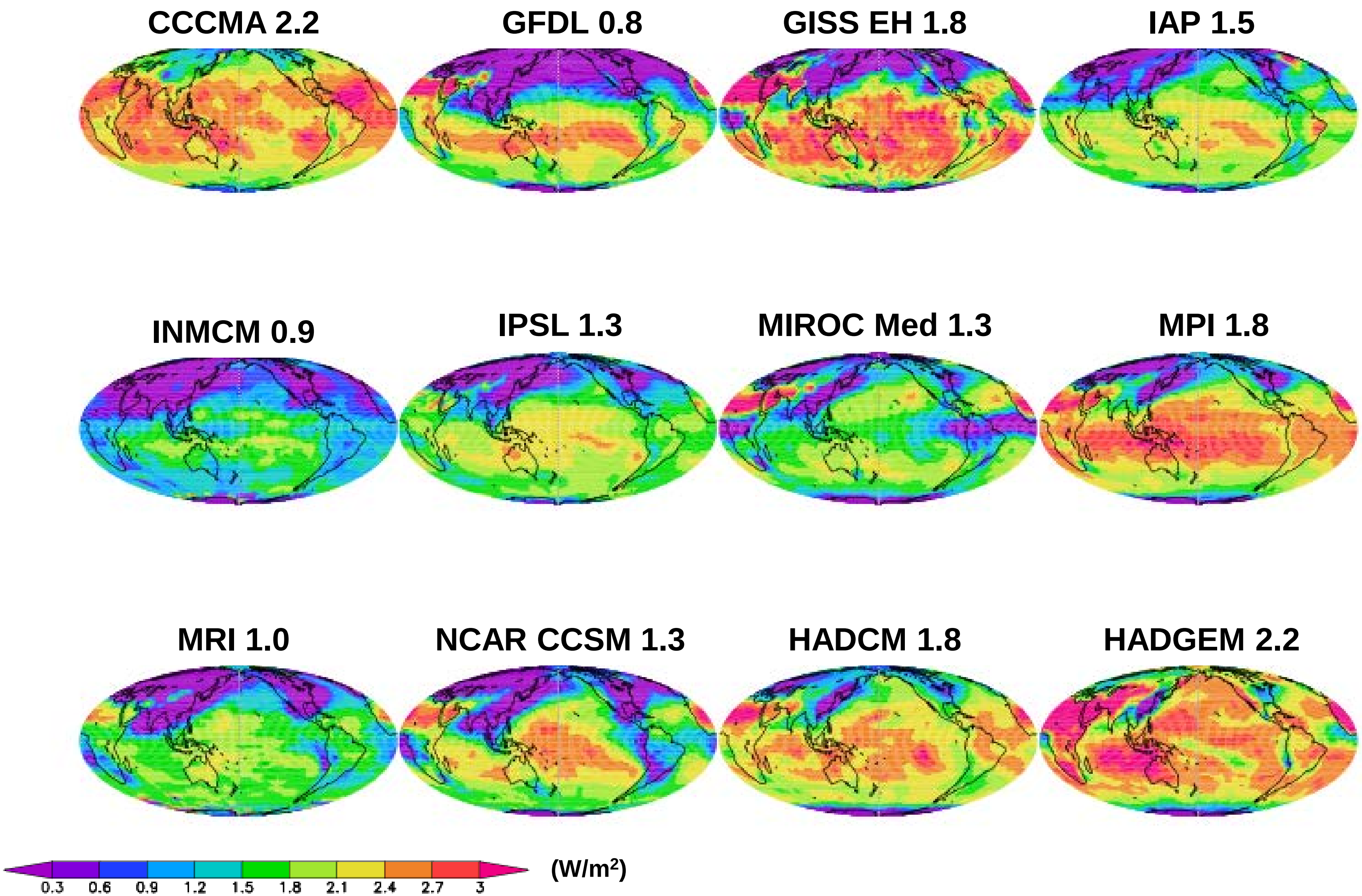
20C3M



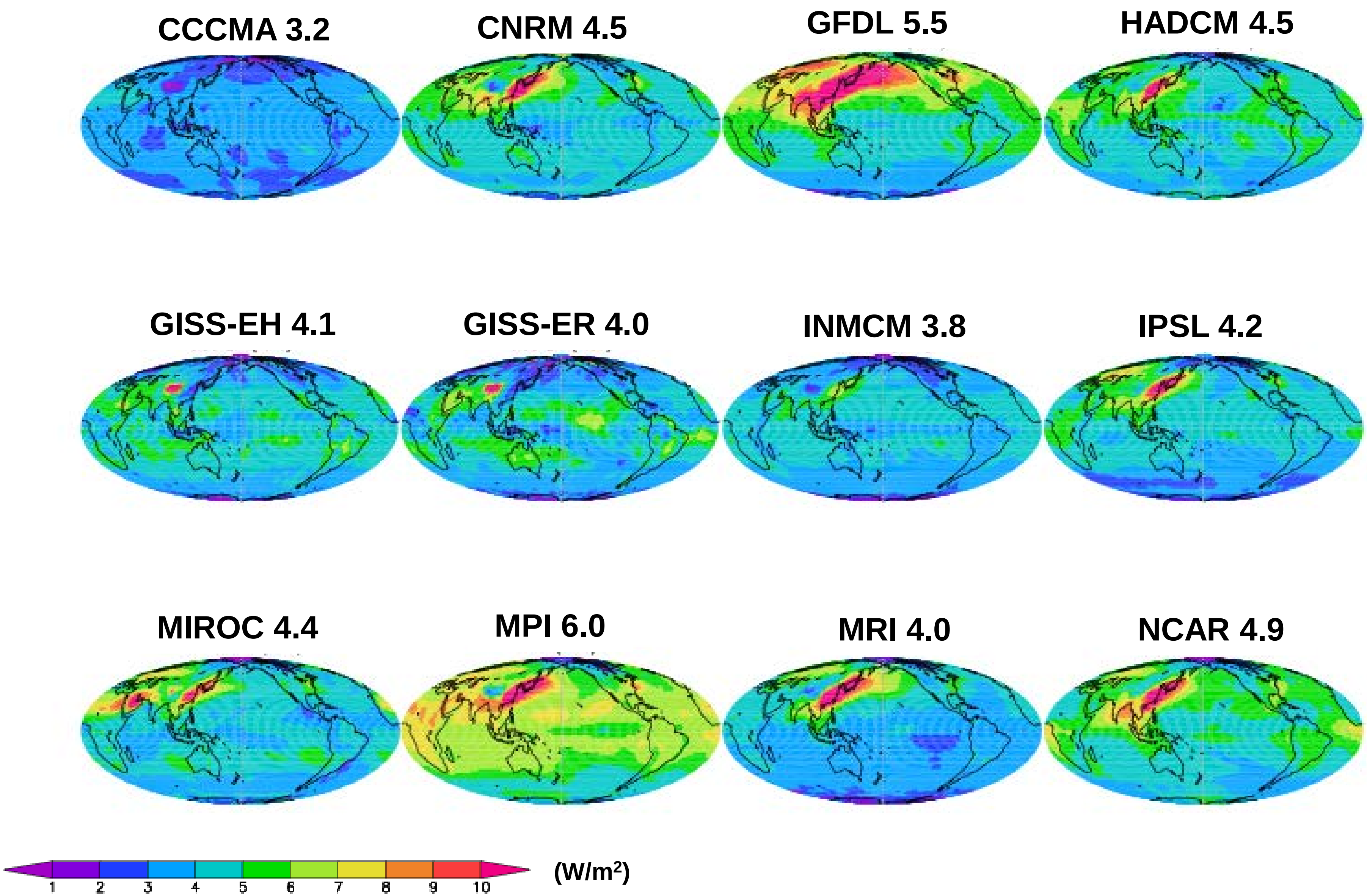
Clear-sky Radiative Forcing: IPCC AR4 2xCO2



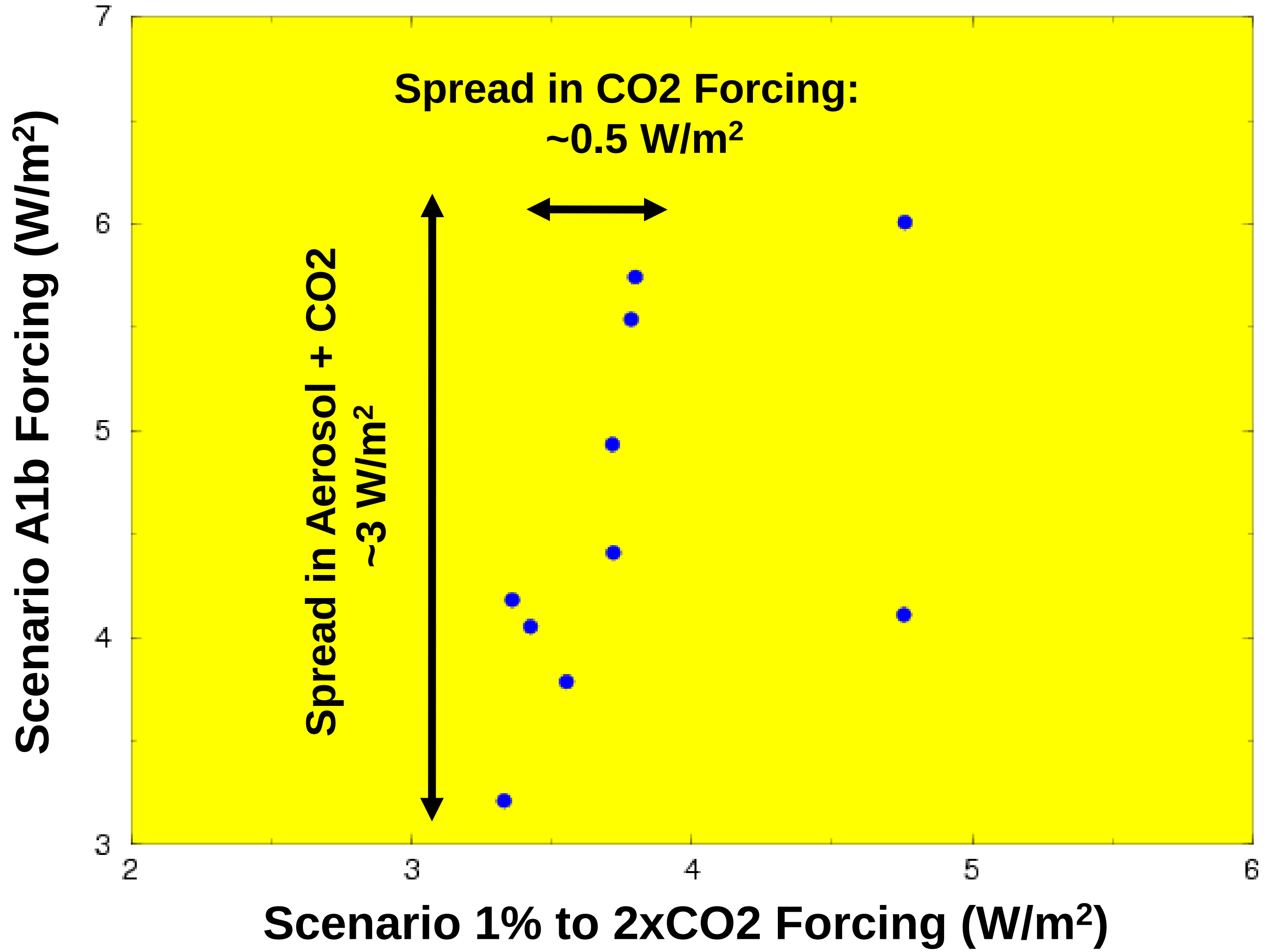
Clear-sky Radiative Forcing: IPCC AR4 20C3M



Clear-sky Radiative Forcing: IPCC AR4 A1b



Clear-sky Radiative Forcing: 2xCO2 vs. A1b



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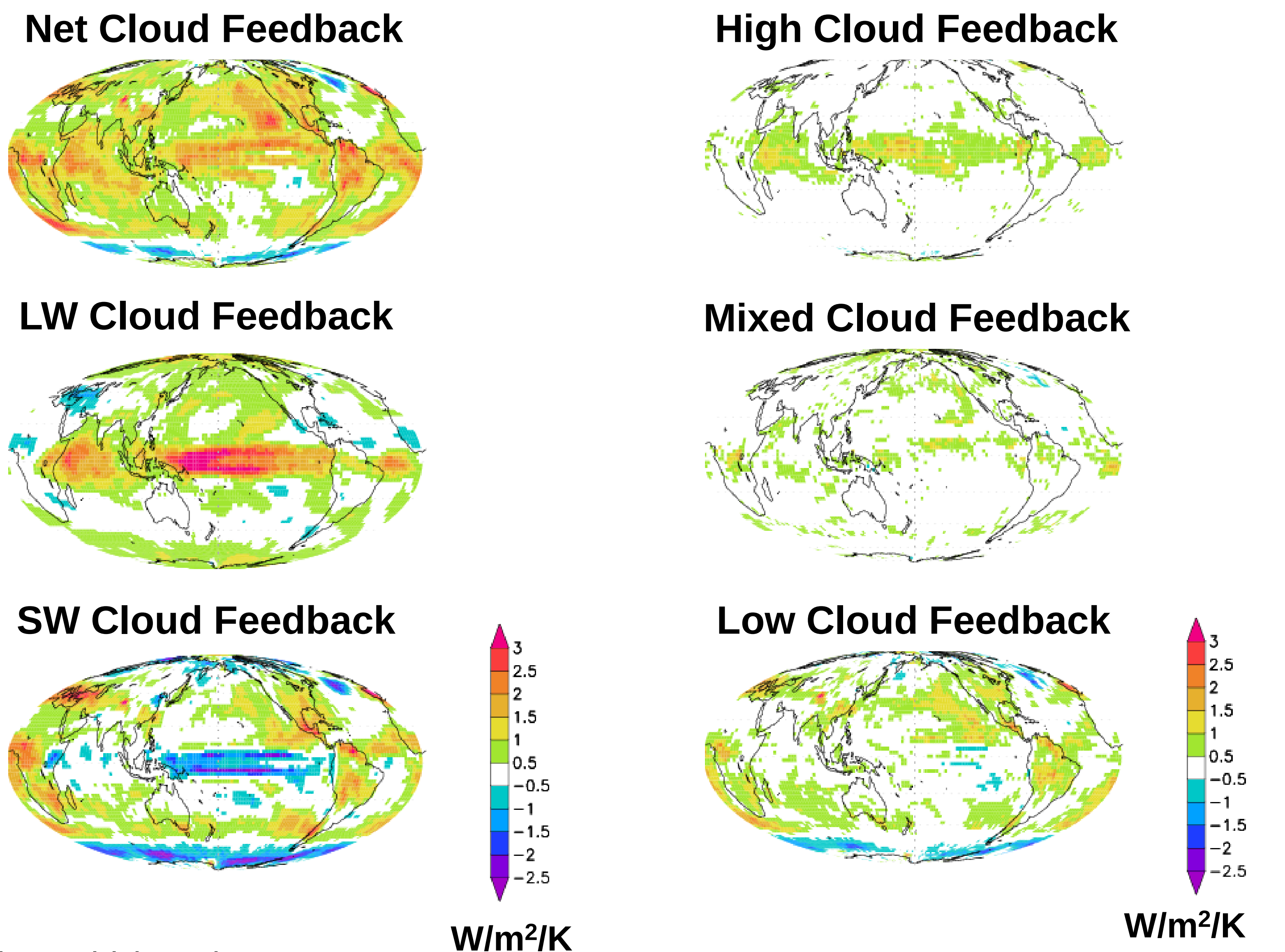
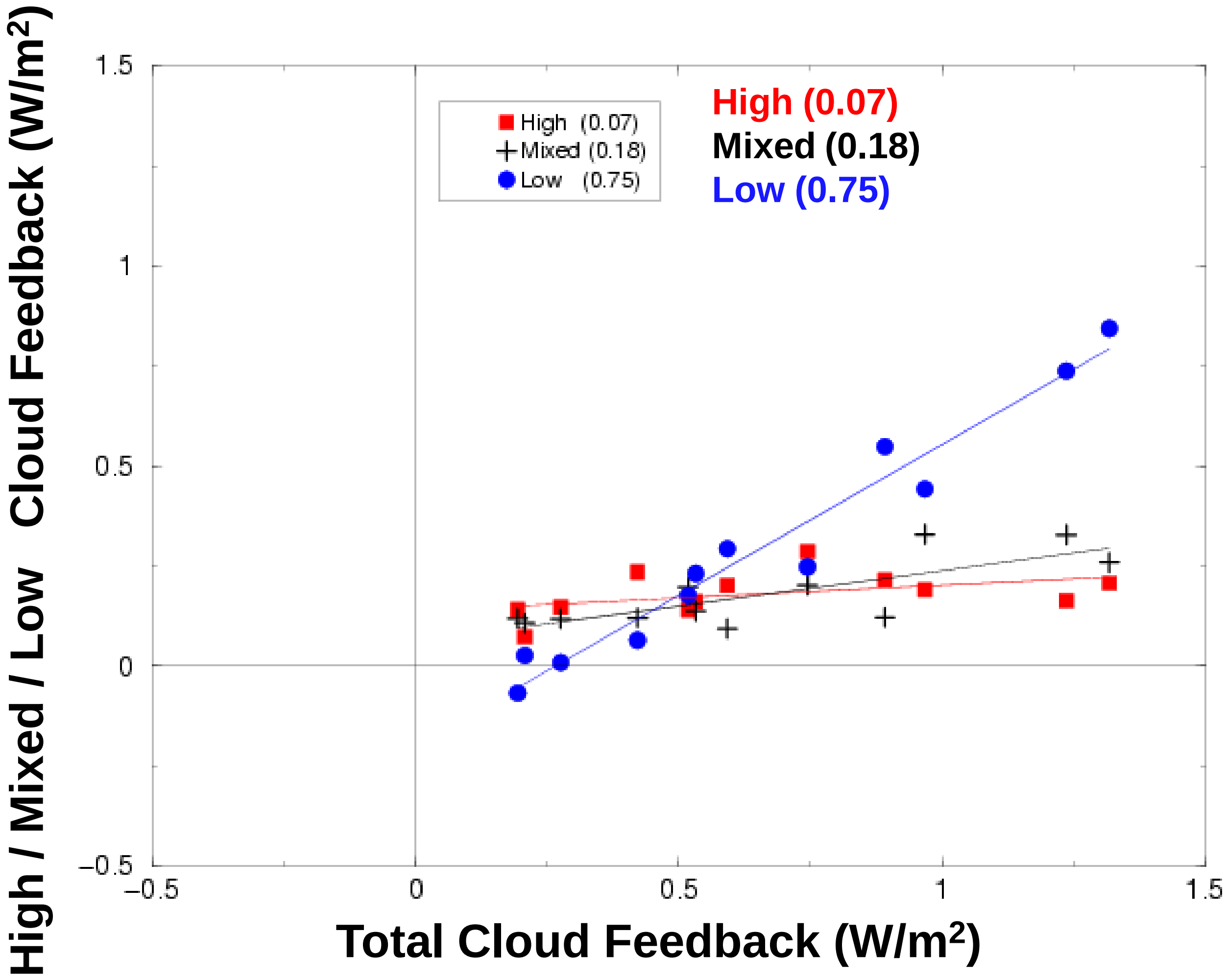
CMIP3 Ensemble Mean Cloud Feedback



Soden and Vecchi (2011)

Intermodel Spread in Cloud Feedback



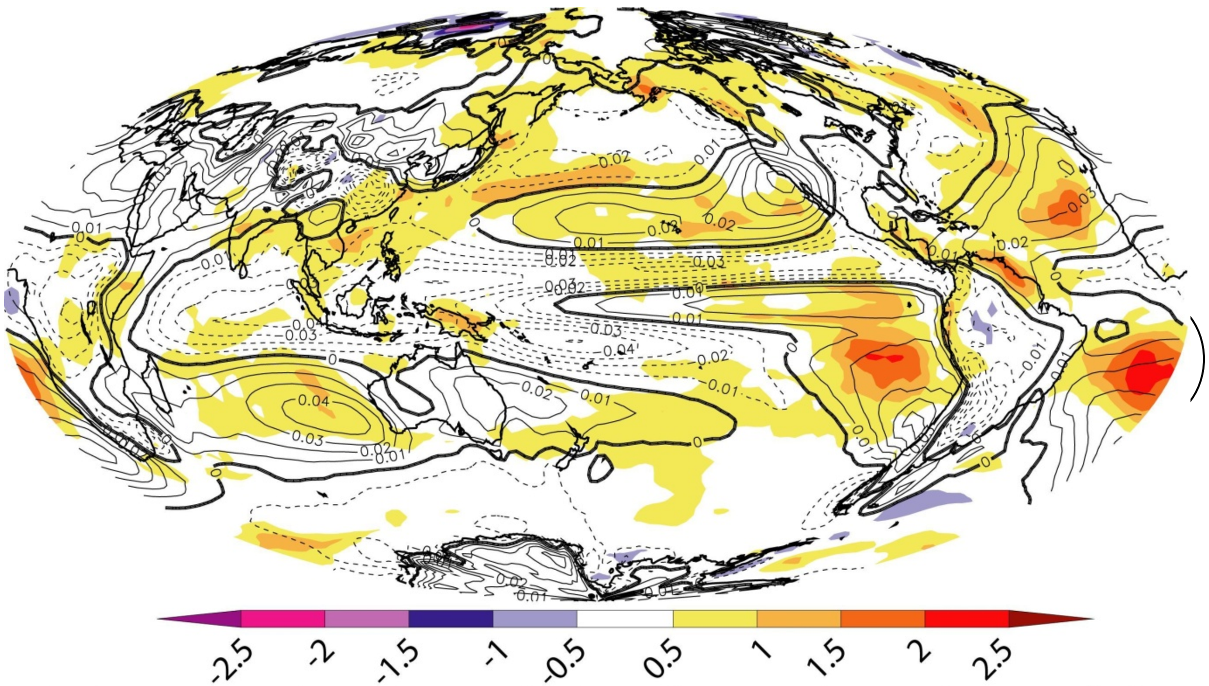
• High cloud feedback is positive and robust.

See also Zelinka and Hartmann (2010, 2011)

• Low cloud feedback is dominant cause of intermodel spread.

Soden and Vecchi (2011)

Local contribution to intermodel spread in cloud feedback



Shade: Regression of Local Cloud Feedback to Global-mean Cloud Feedback ($W \cdot m^{-2} \cdot K^{-1}$)
Contour: Background 500hPa Pressure Velocity ($Pa \cdot s^{-1}$)

- **Most of intermodel spread arises from low stratocumulus/cumululs regions**

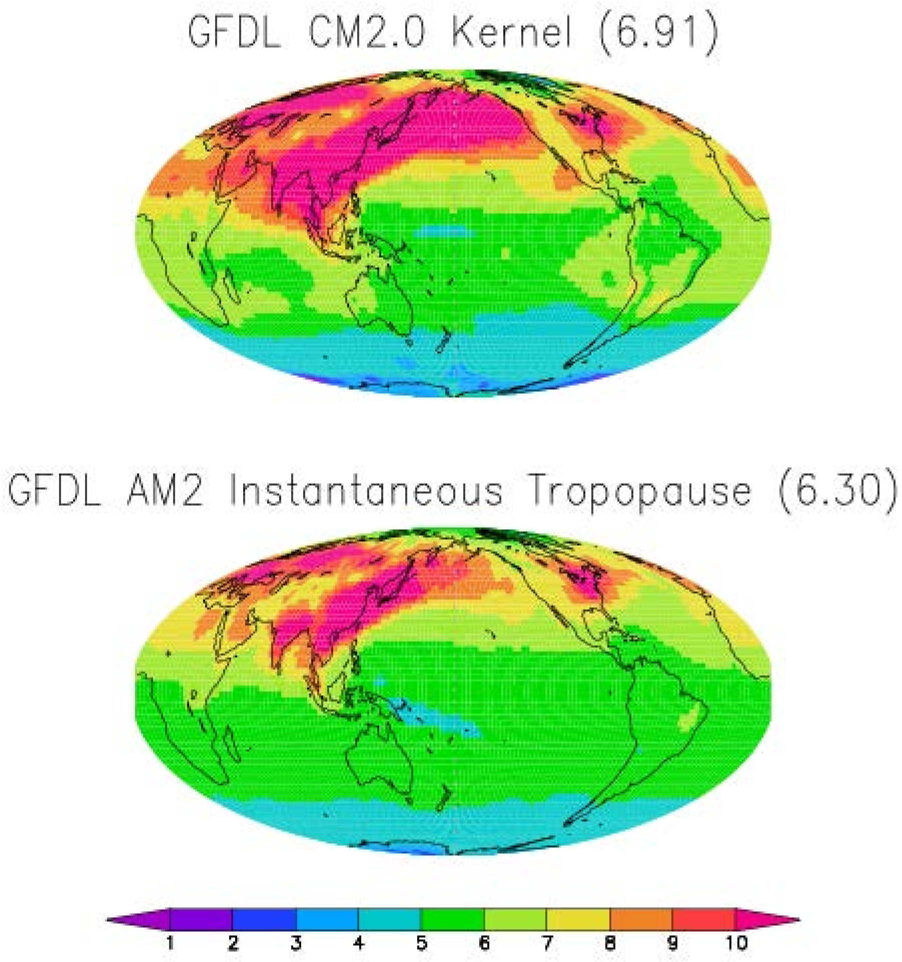
Soden and Vecchi (2011)

Future Work

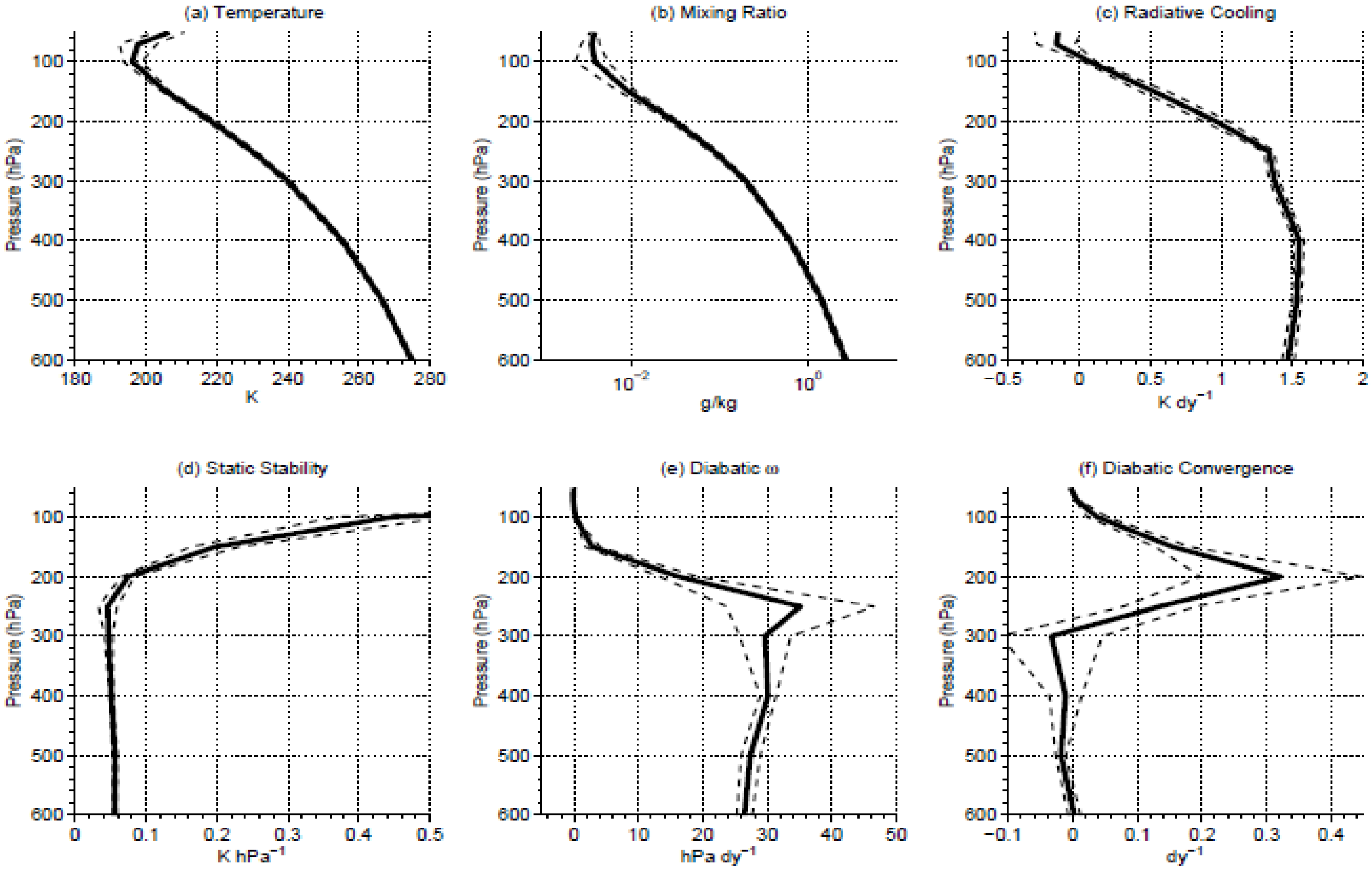
- Account for cloud masking of radiative forcing
- Apply to CMIP5 Models
- Evaluate surface radiative forcings
- Isolate “indirect” (fast) forcings

Extra Slides

Radiative Forcing: Kernel vs. Direct Calculation



Why is High Cloud Feedback Positive?



Zelinka and Hartmann (2010)

$$\sigma = \frac{\kappa T}{p} - \frac{\partial T}{\partial p},$$

$$\omega = \frac{Q_R}{\sigma}.$$

$$conv \equiv -\nabla_H \cdot \mathbf{U} = \frac{\partial \omega}{\partial p}.$$

As climate warms, there is an upward shift in the level of divergence (and Q_R) due to increased water vapor

Observational Evidence for PHAT

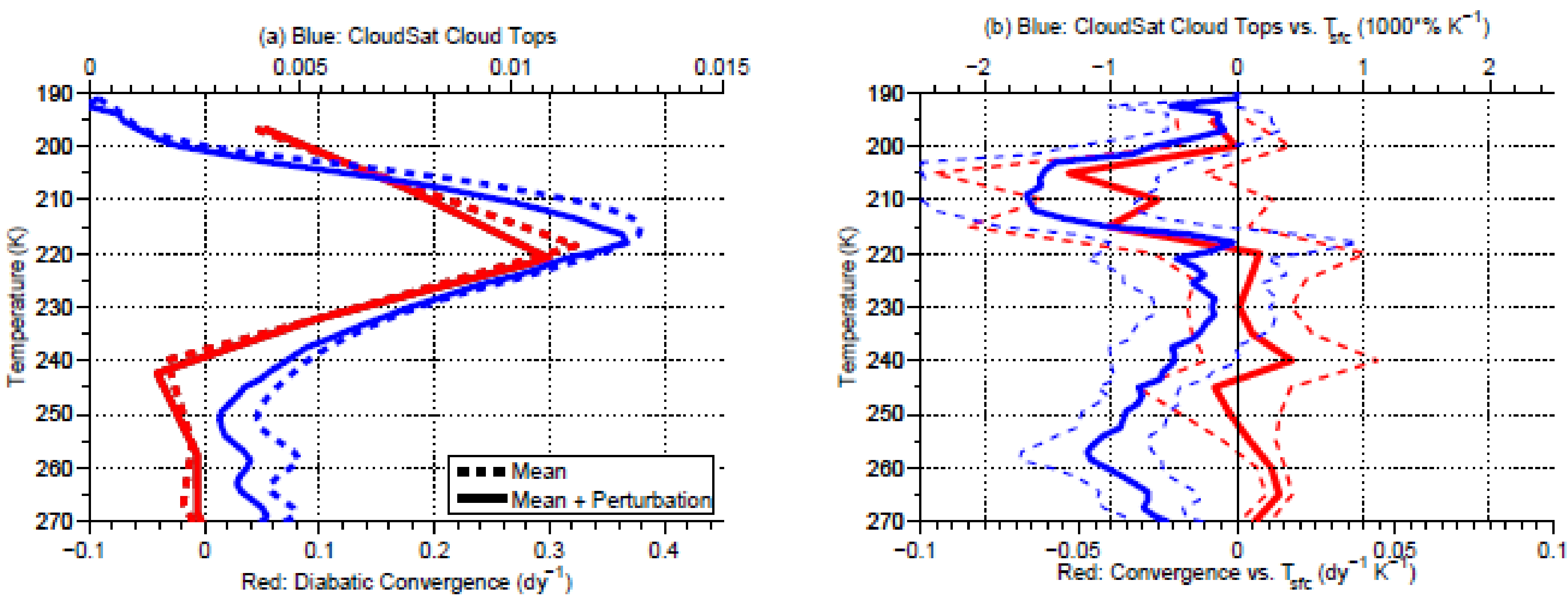


Figure 9. (a) Tropical mean (blue) CloudSat cloud top frequency of occurrence and (red) diabatic convergence. The dashed lines represent the mean profile and the solid lines represent the sum of the mean and perturbation profile shown in panel b. (b) Sensitivity of tropical mean (blue) CloudSat cloud top frequency of occurrence and (red) diabatic convergence to tropical mean surface temperature. The dashed lines represent the 2σ range on the regression coefficients computed using a bootstrapping method as described in the text.

Observed interannual changes in tropical high clouds follow FAT/PHAT.

Zelinka and Hartmann (2011)