



NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Global Feedbacks: an inverse methodology

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Thanks to:

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Jerry Meehl, NCAR

Alex Jonko, OSU

Jen Kay, NCAR

Mark Zelinka, LLNL



Kernel Analysis

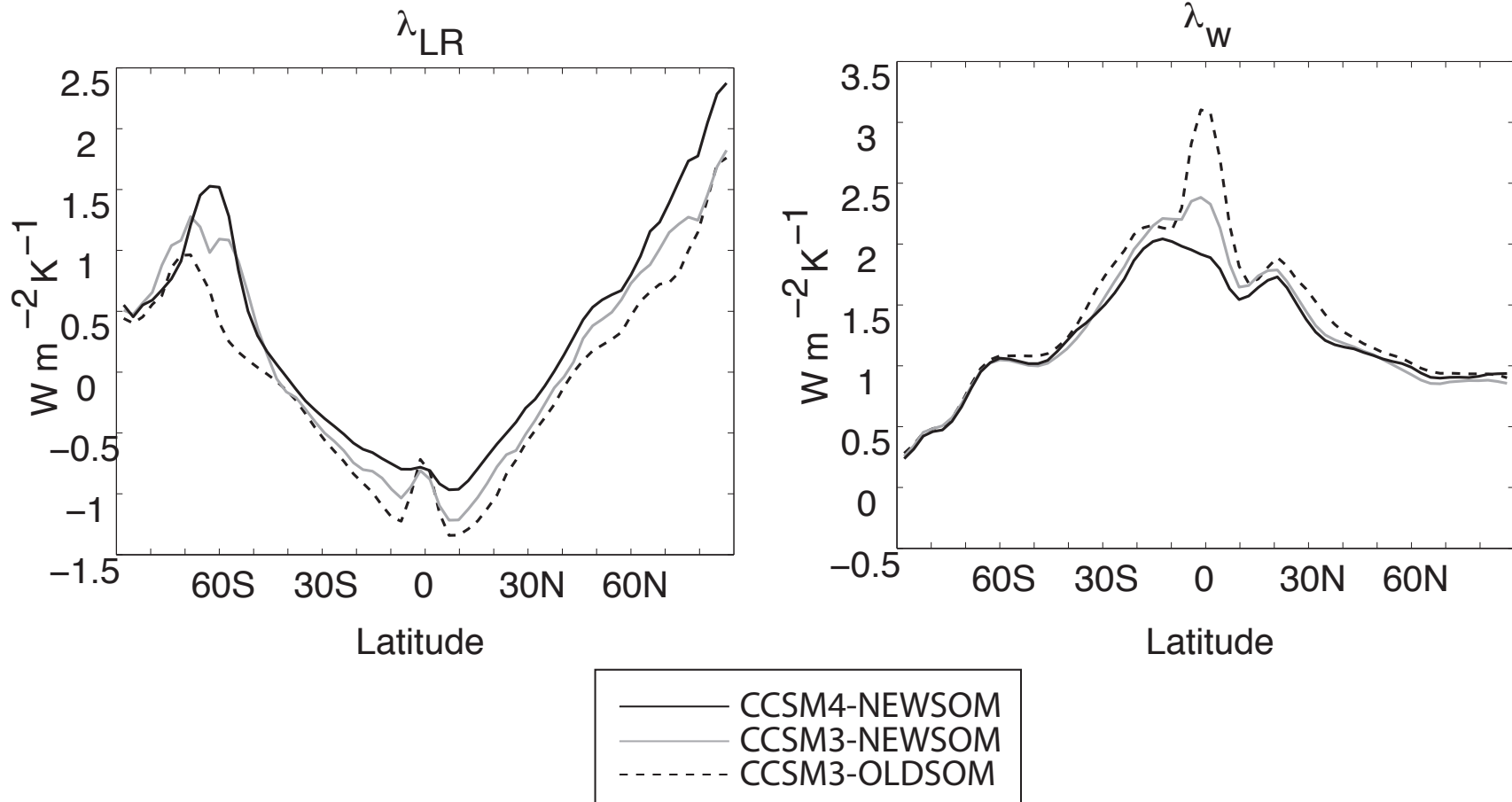
$$R=f(x) \quad (i)$$

$$(R-R_0) \approx k(x-x_0)$$

$$\Delta R \approx k \Delta x \quad (ii)$$

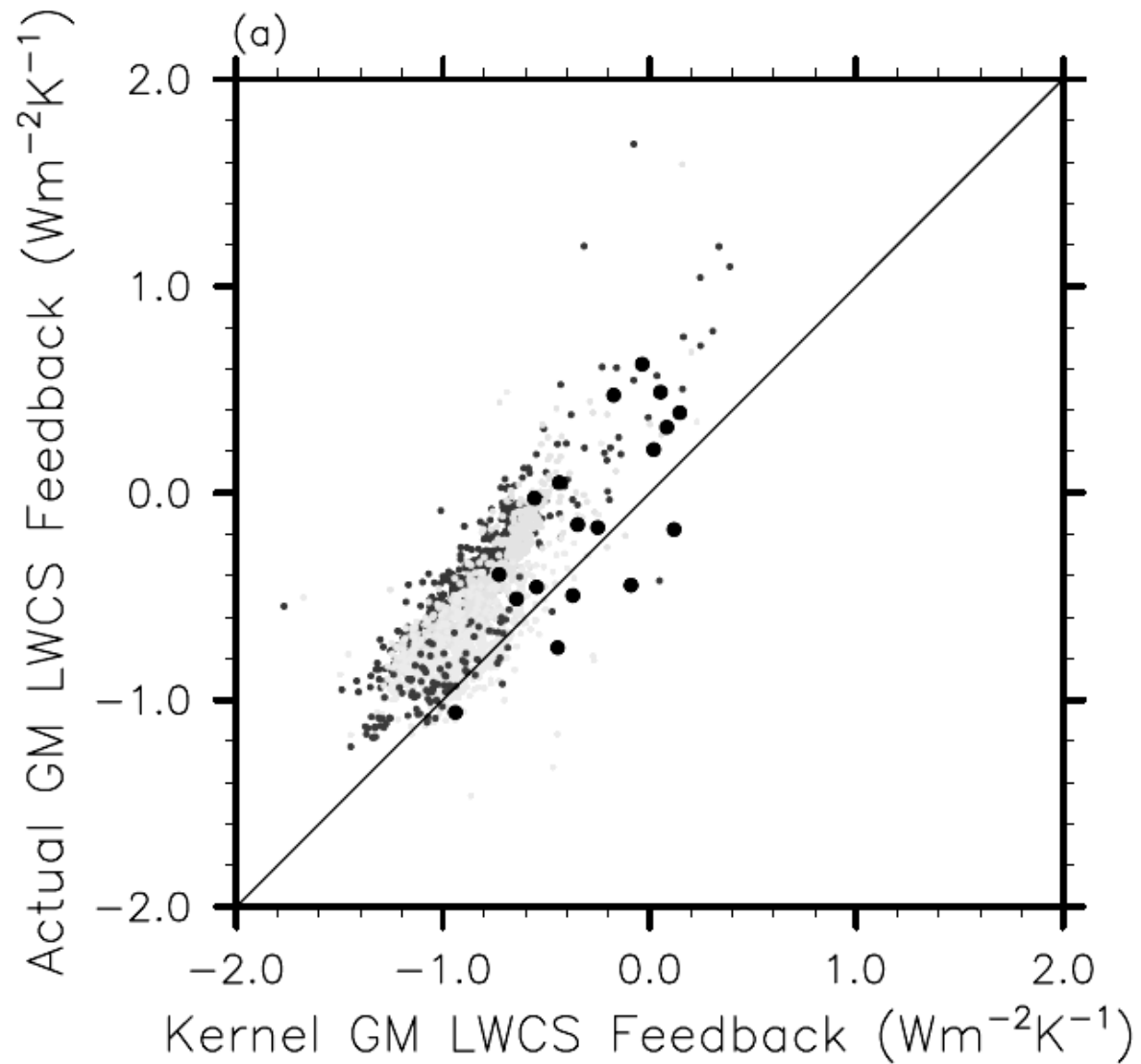
* $x=\{T,q,T_s,\text{albedo},\text{CO}_2\}$

Kernel Analysis



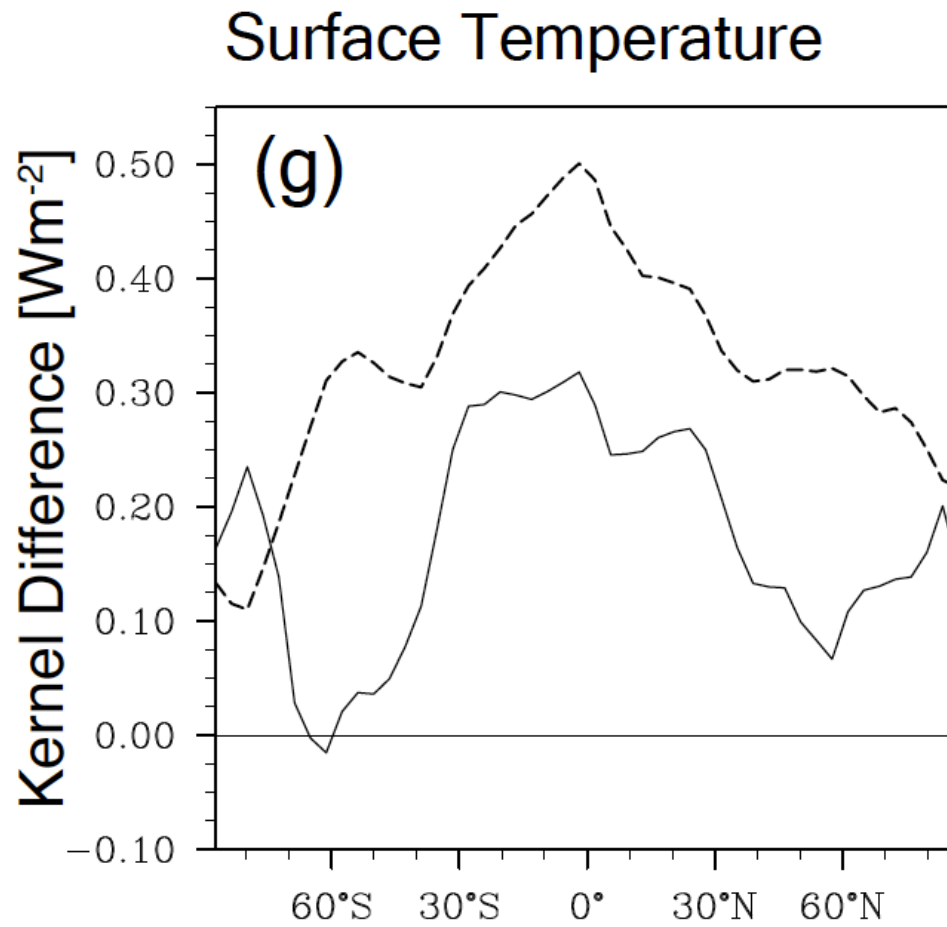
Bitz *et al.* (J. Clim Special issue, submitted)

Kernels in perturbed climates...



Sanderson *et al* (2010)

... or large climate changes



Jonko *et al.* (submitted)

Updating the kernel...

$$\Delta R \approx k \Delta x$$

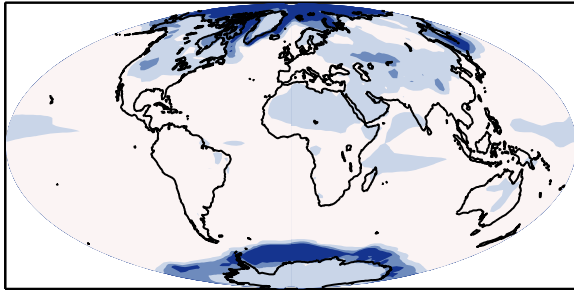
$$\Delta R \approx (k_0 + \Delta k) \Delta x$$

$$\Delta k \approx (\Delta R - \Delta k \Delta x) \cdot (\Delta x)^{-1} \quad \text{(iii)}$$

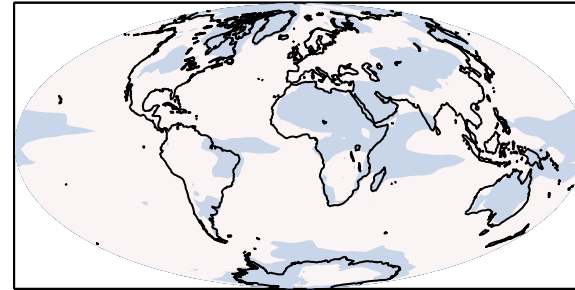
*x={T,q,Ts,CO₂}

CAM5 clear-sky validation (2XCO2 Δ TOA Flux)

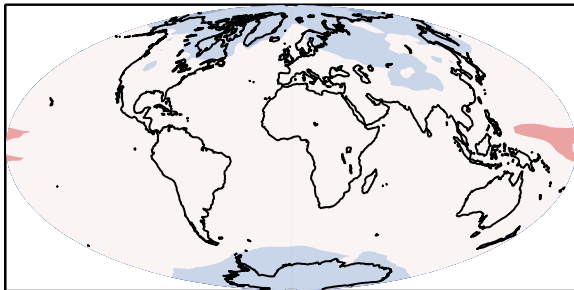
Org SW Kernel error



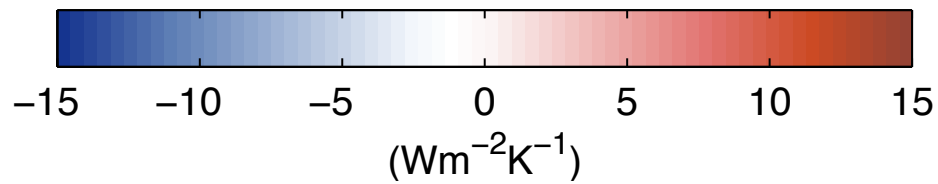
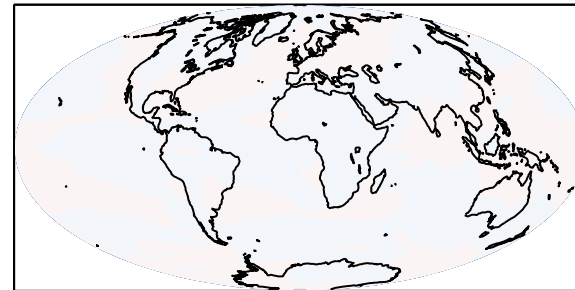
Adj SW Kernel error



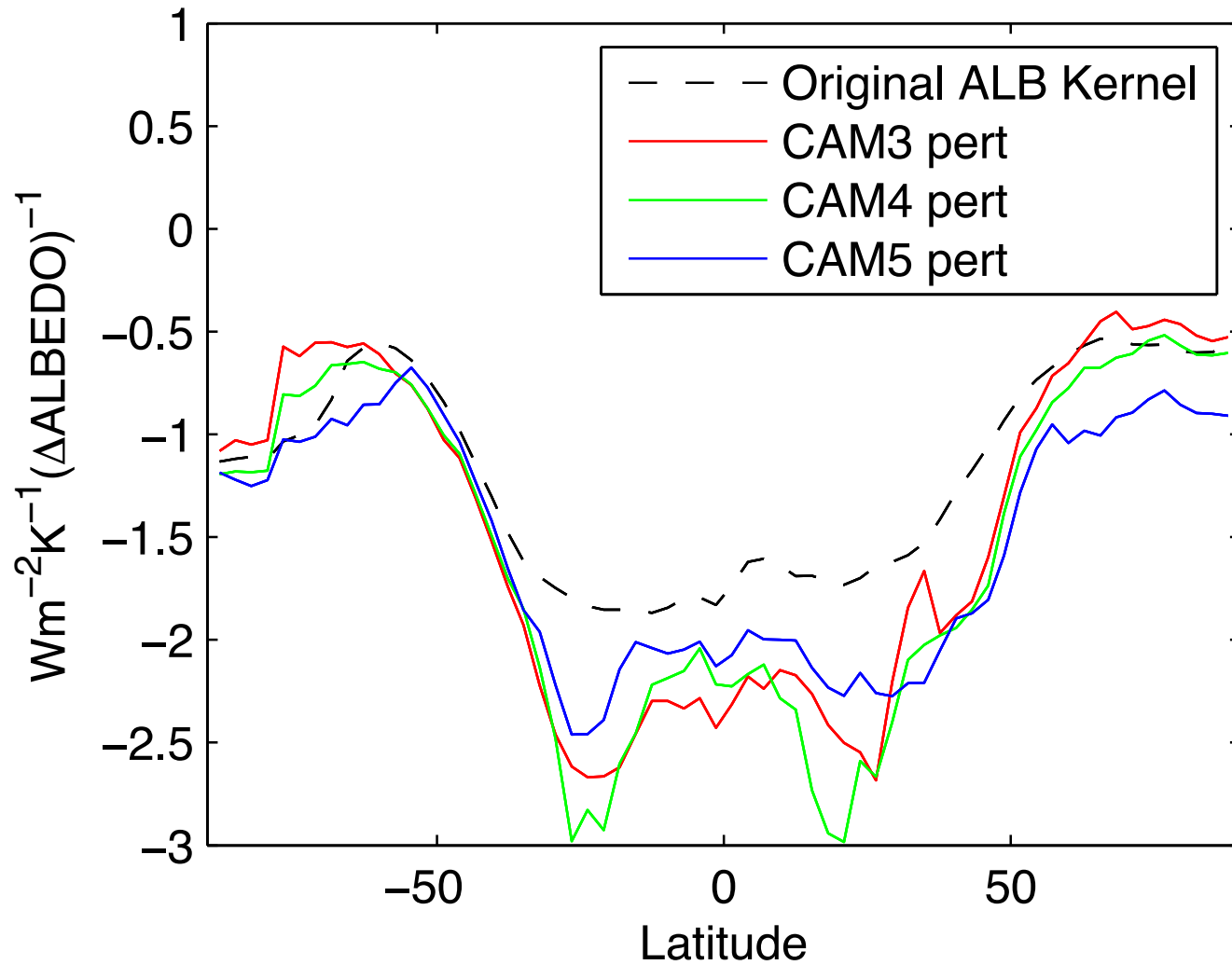
Org LW Kernel error



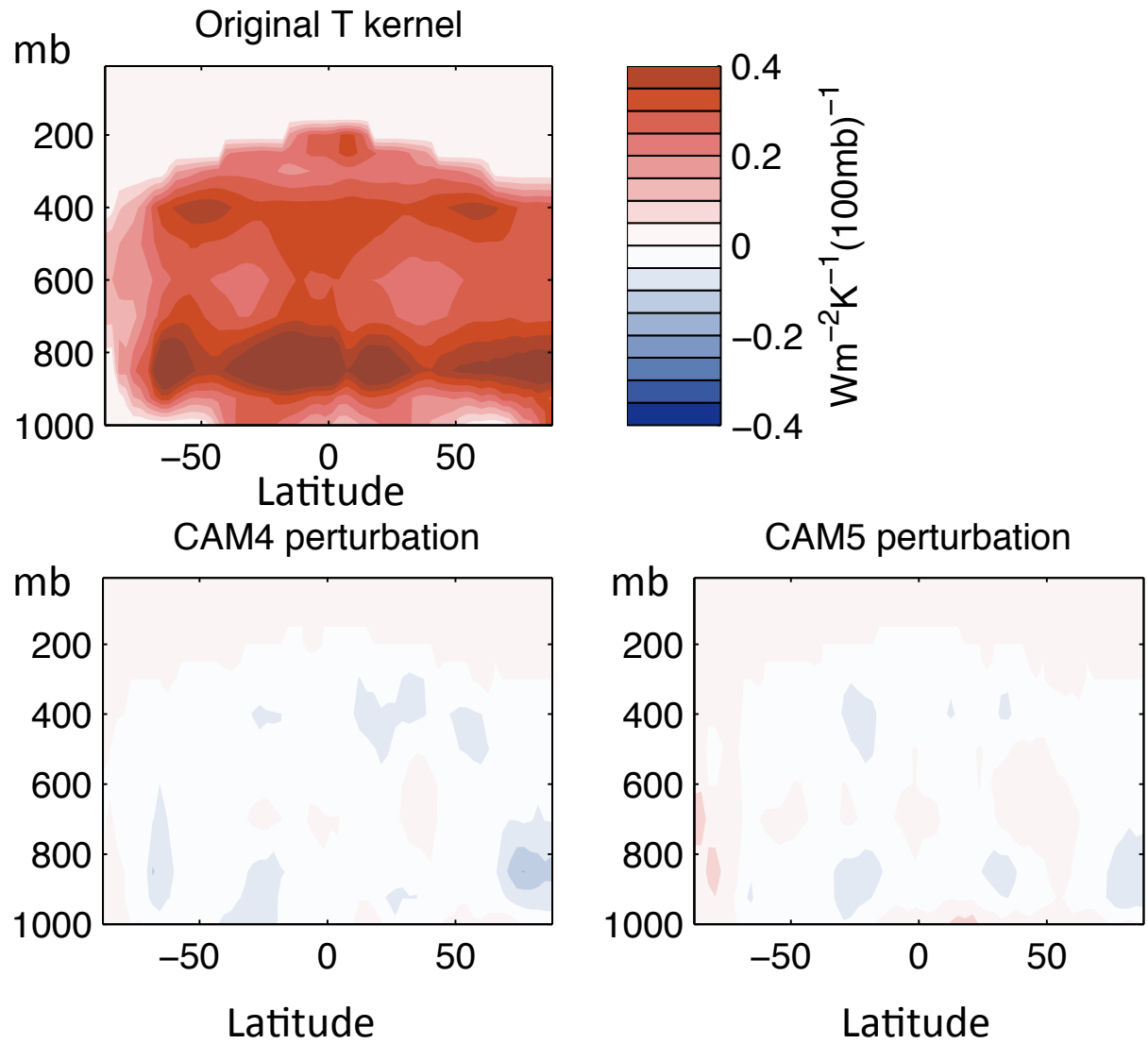
Adj LW Kernel error



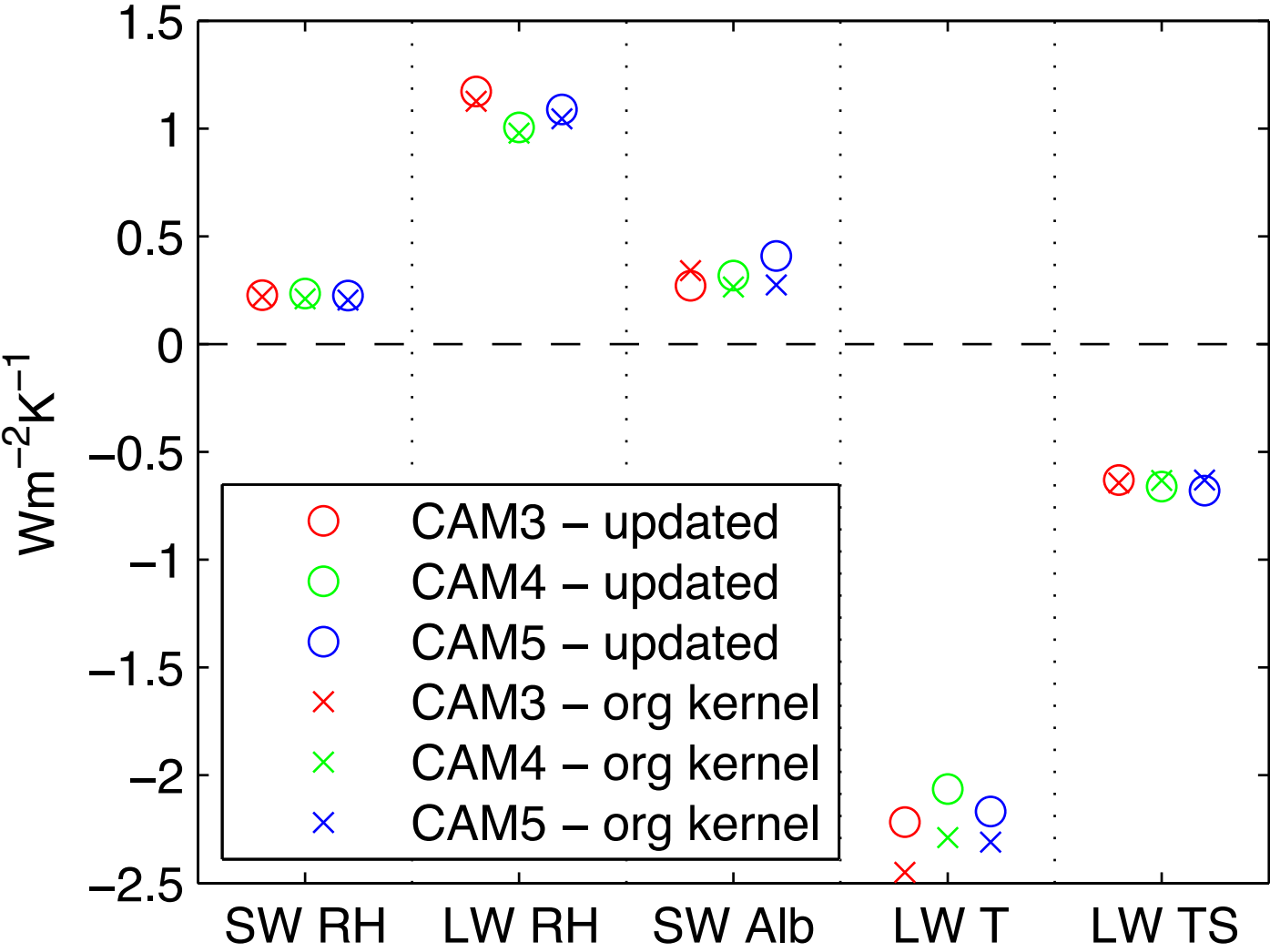
Albedo Kernel



Atmospheric Temperature Kernel



Does it make a difference?



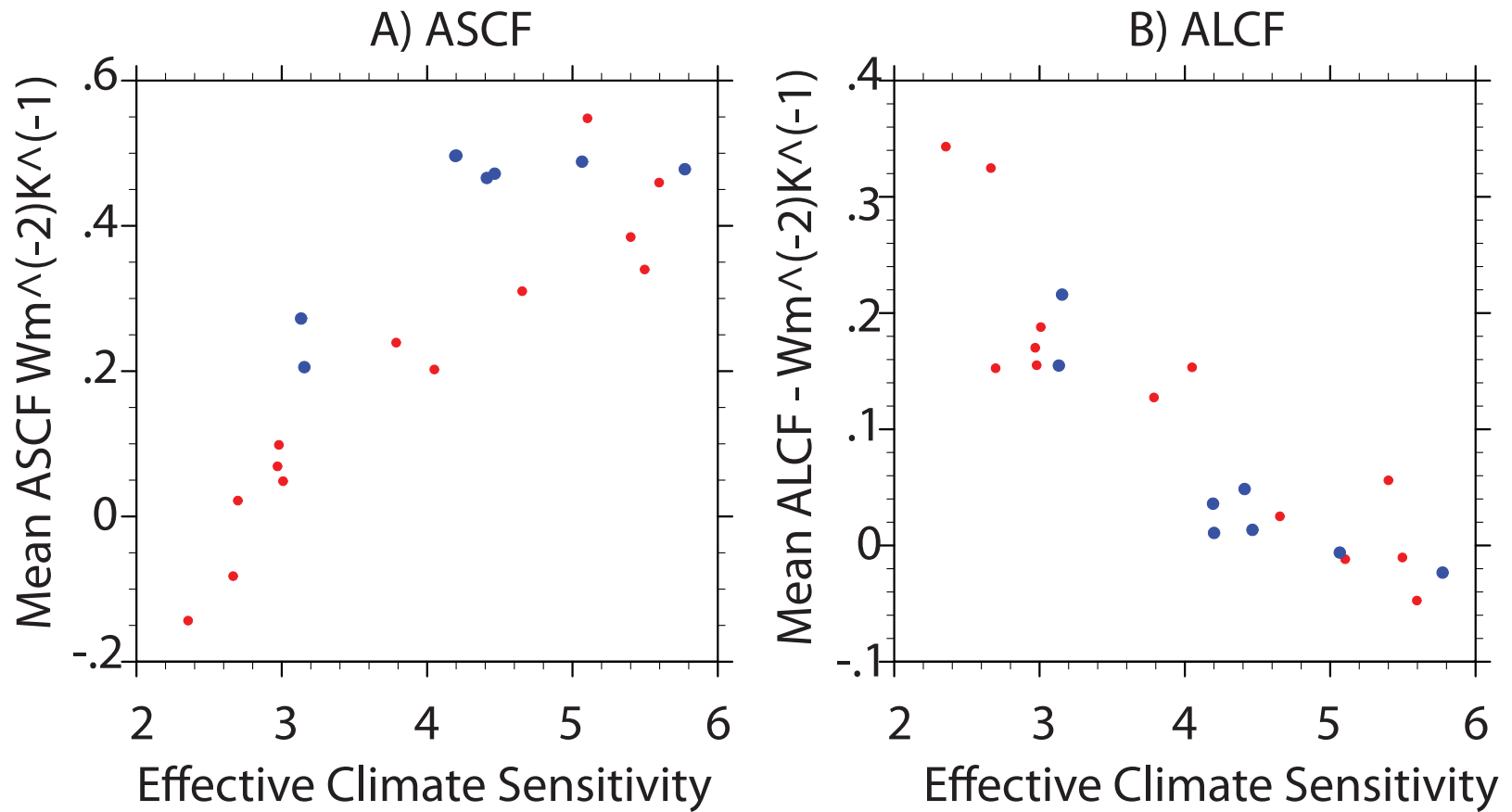
But what about **clouds**?

Adjusted Cloud Radiative Forcing

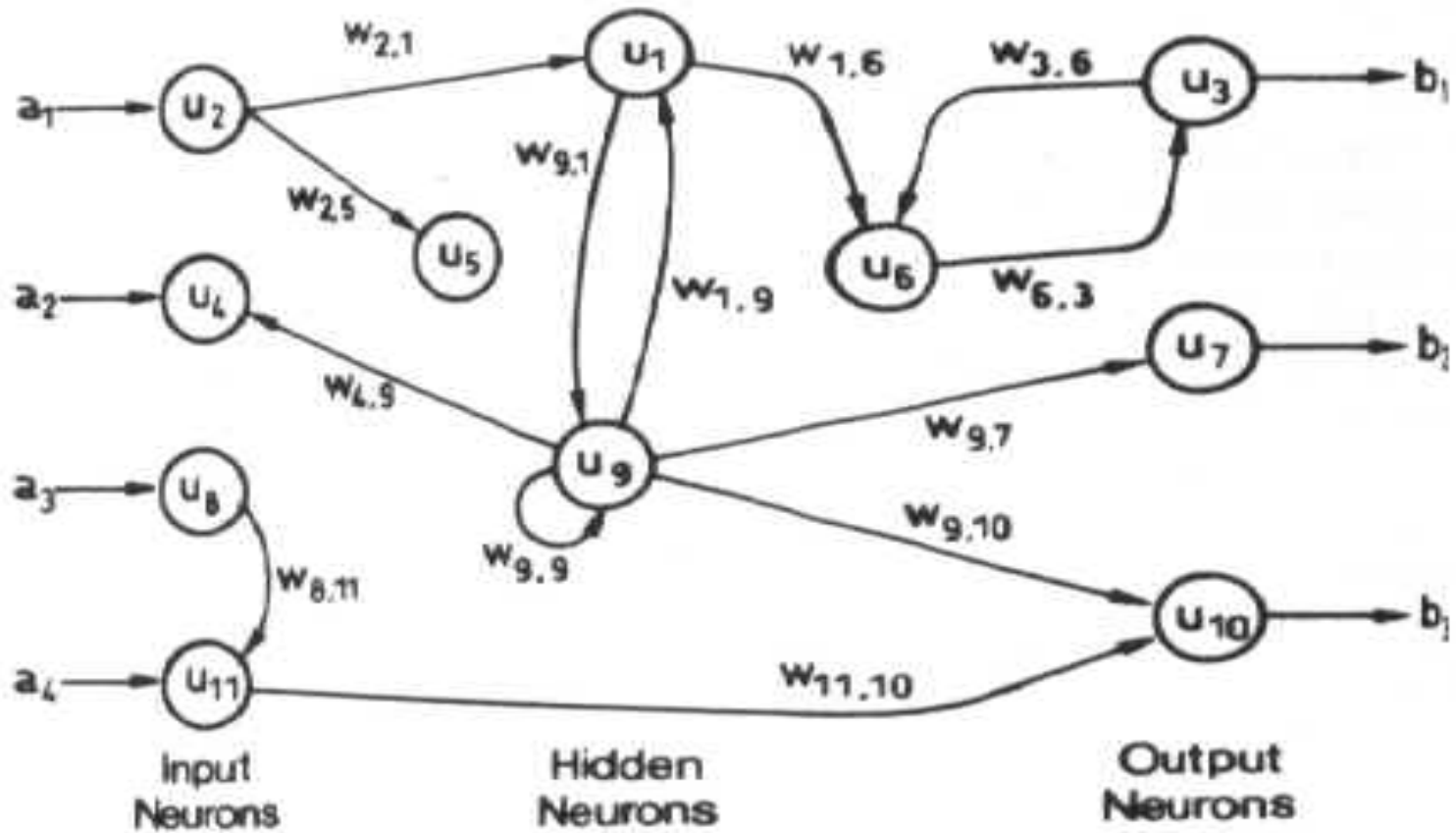
$$\Delta\text{CRF} = \Delta F_{\text{as}} - \Delta F_{\text{cs}}$$

$$a\Delta\text{CRF} = \Delta\text{CRF} + (k_{\text{as}} - k_{\text{cs}})\Delta x$$

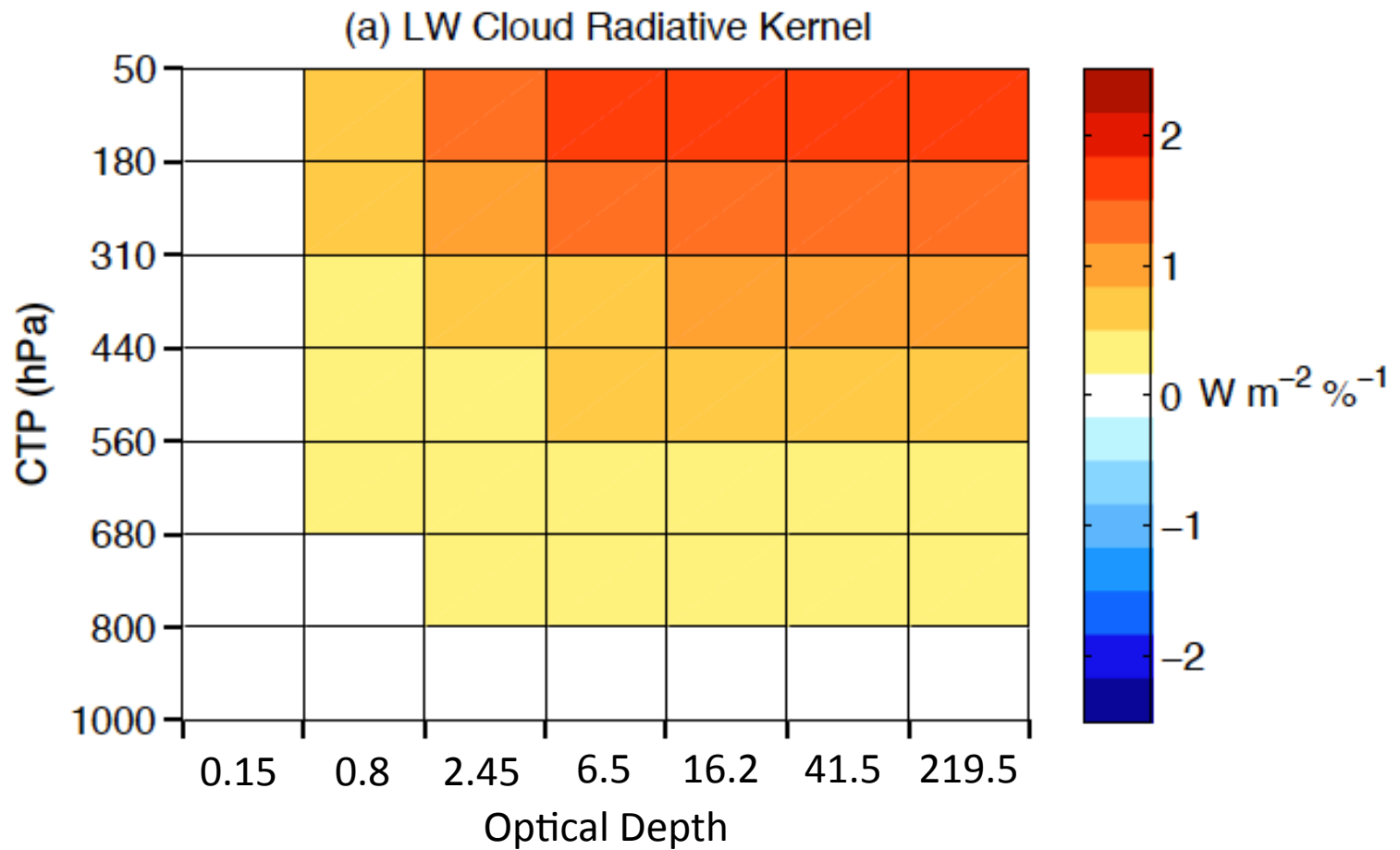
CAM5 Sensitivity



The sledgehammer approach...

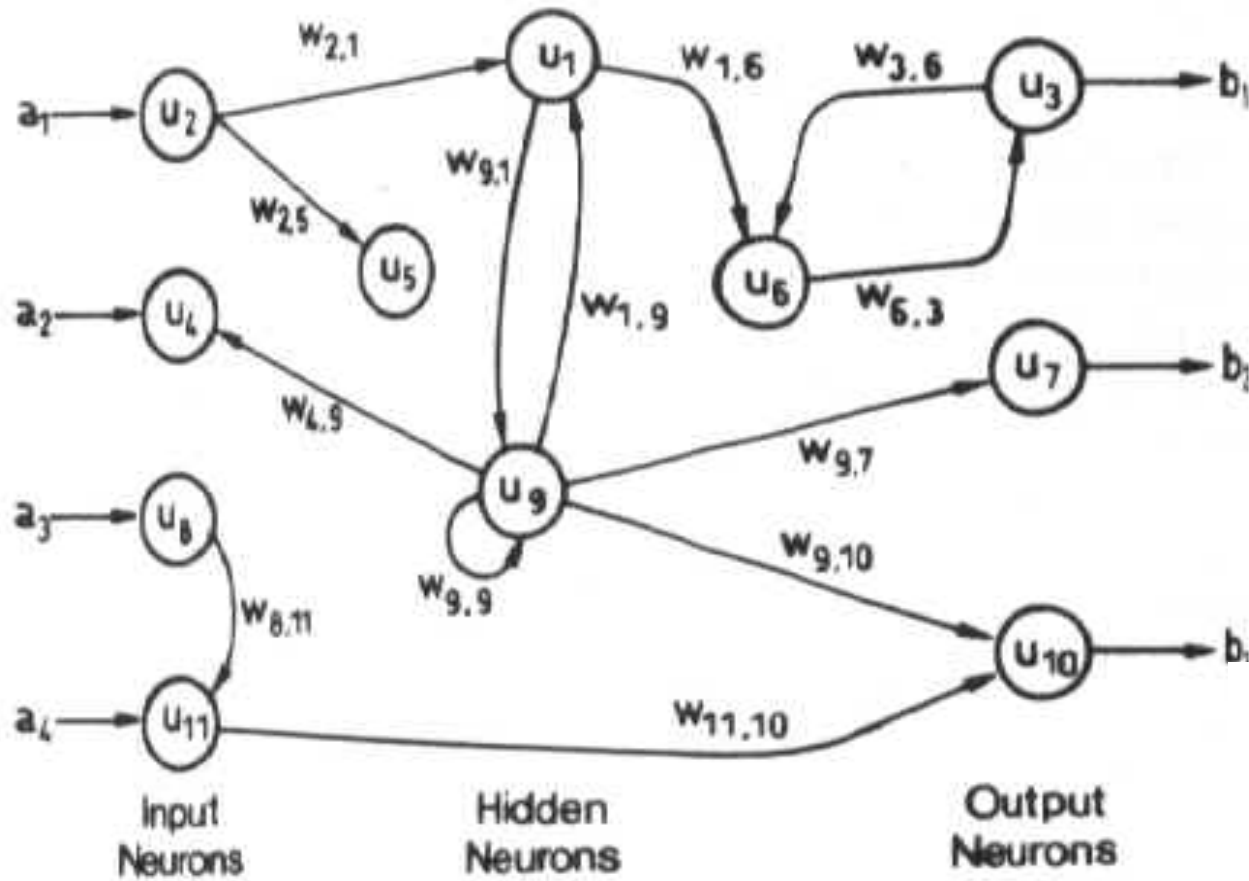


... may not be necessary



Zelinka *et al.* (submitted)

Which means 2 things...

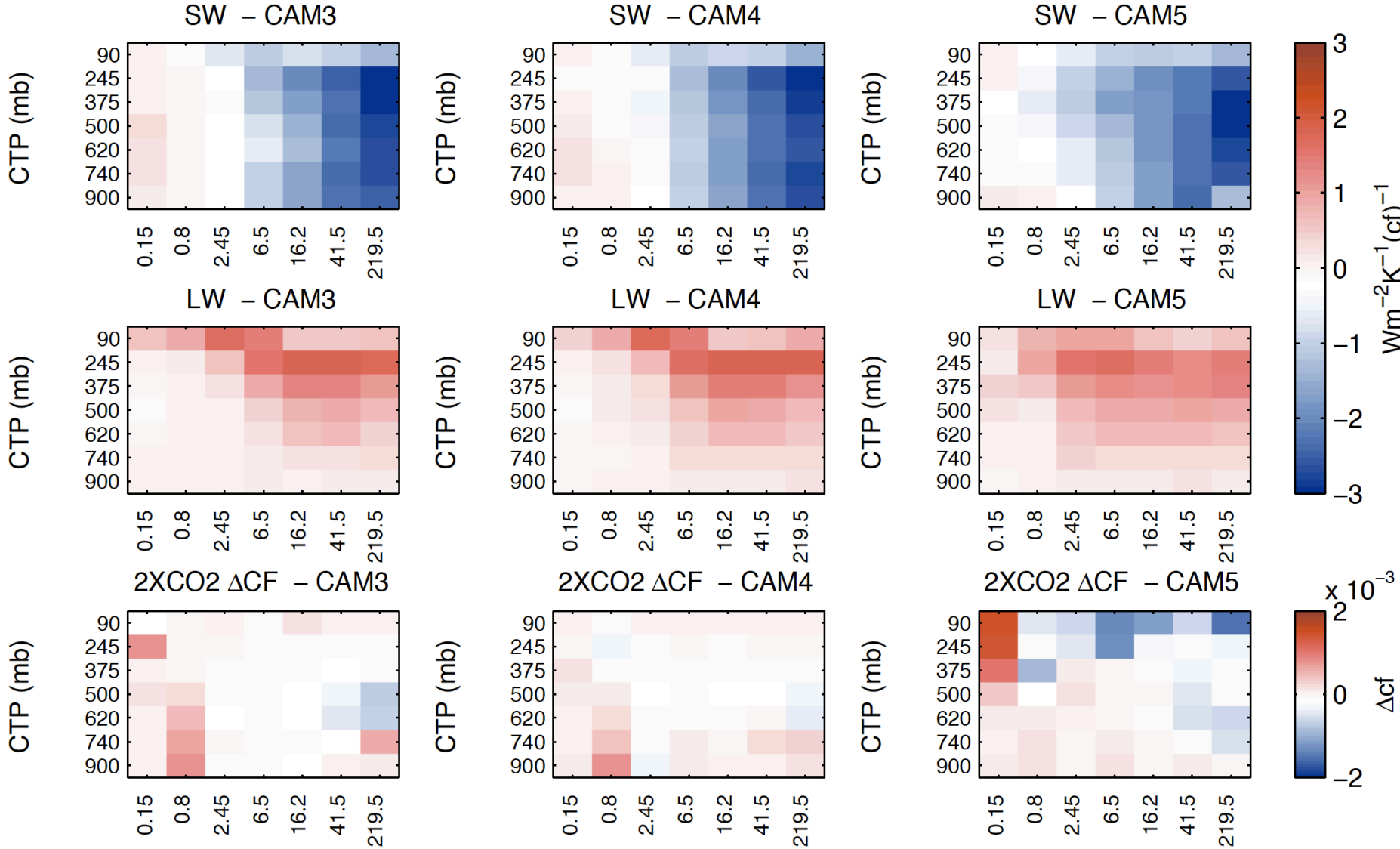


But on the bright side...

$$\Delta k \approx (\Delta R - \Delta k \Delta x) \cdot (\Delta x)^{-1}$$

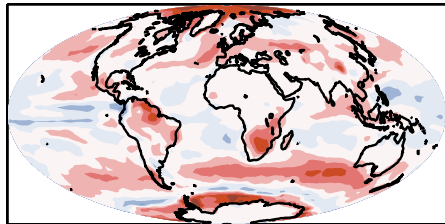
*x={T,q,Ts,CO₂,FISCCP}

Cloud Feedback Calculation

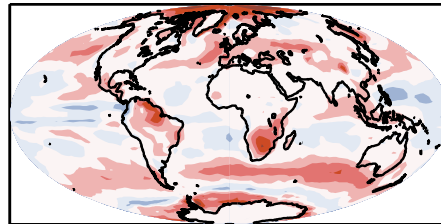


CAM5 All-Sky validation

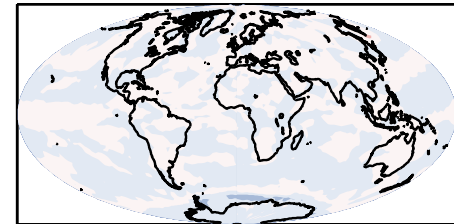
2xCO2 \Delta FLUT



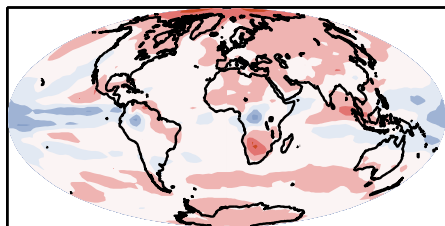
2xCO2 LW Kernel Output



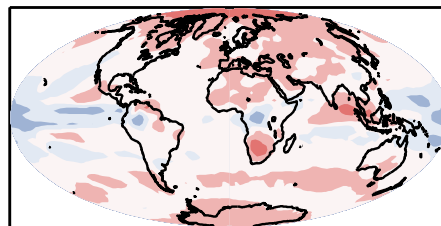
LW Residual



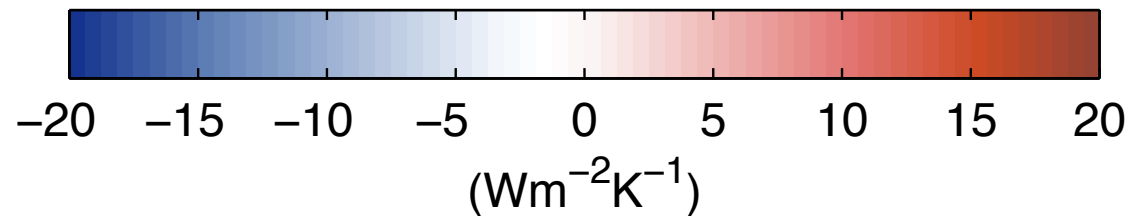
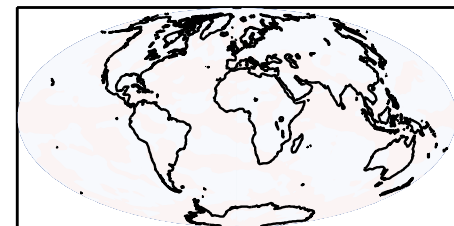
2xCO2 \Delta FSNTOA



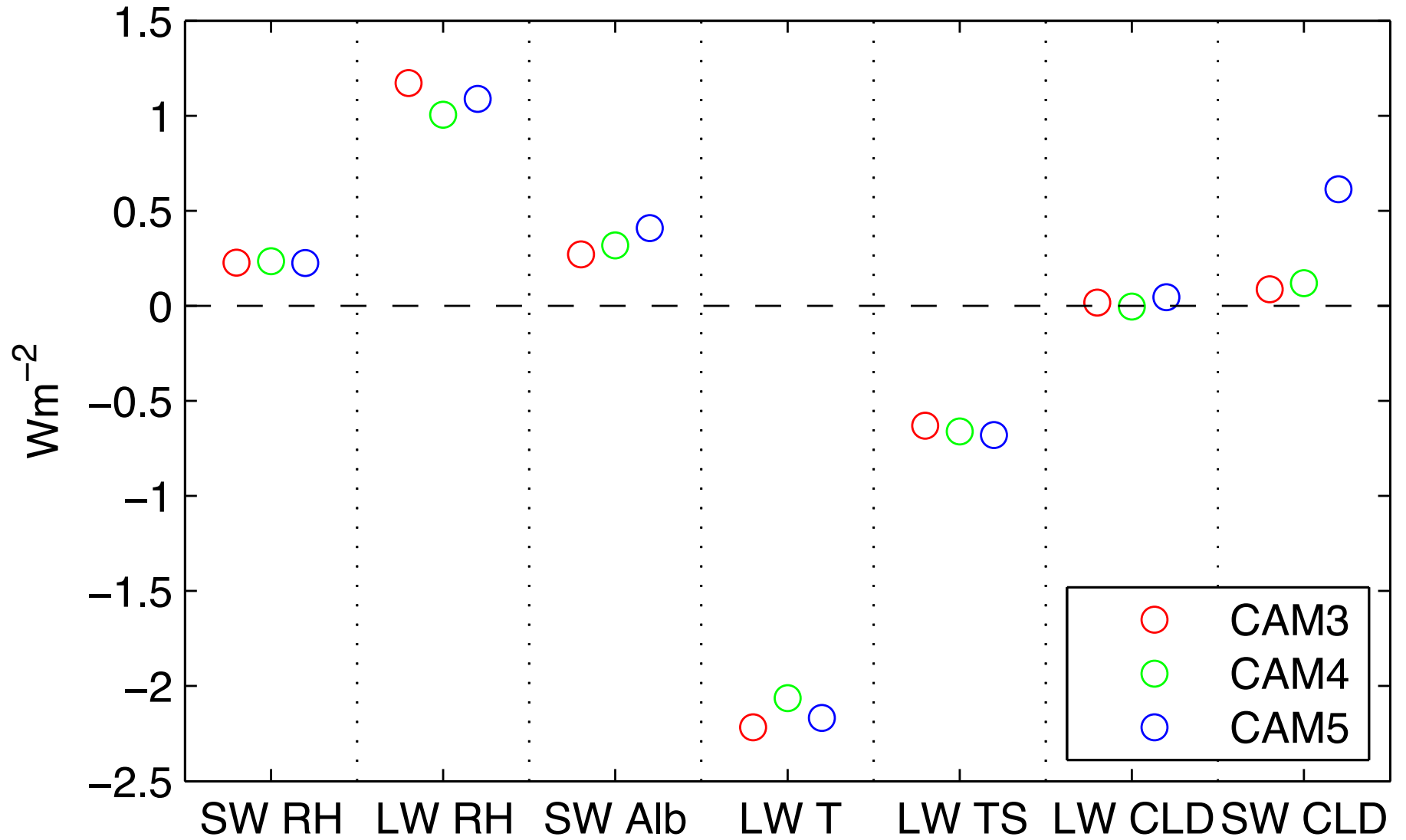
2xCO2 SW Kernel Output



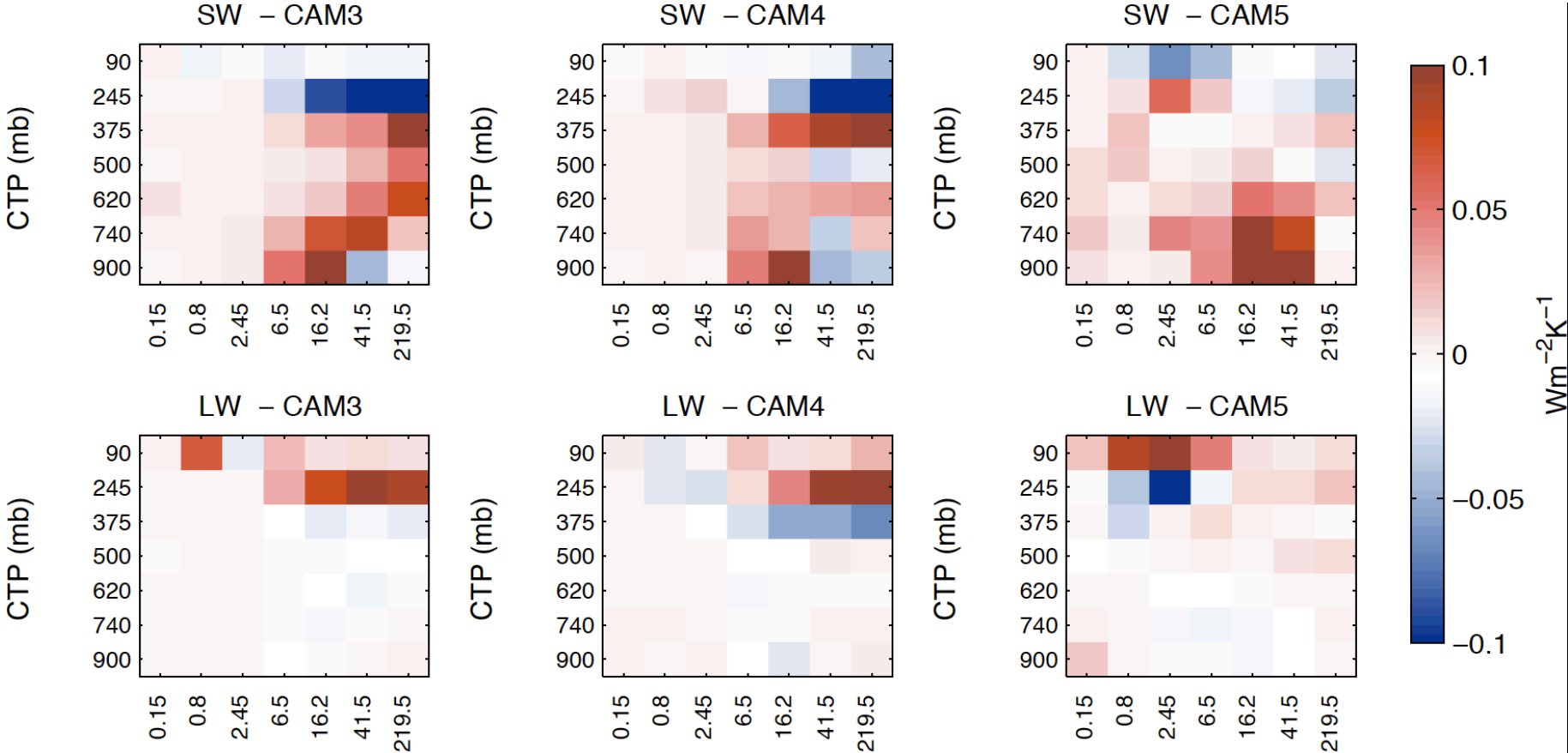
SW Residual



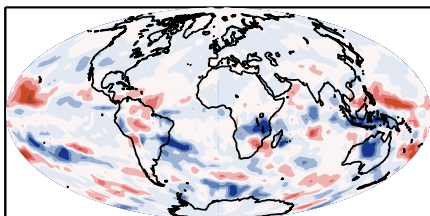
Clouds – not a residual anymore...



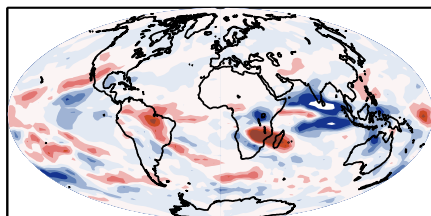
Global Mean Cloud Feedbacks by ISCCP type



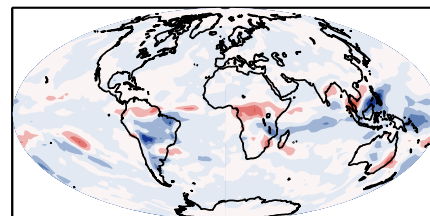
CAM3 – low,thin



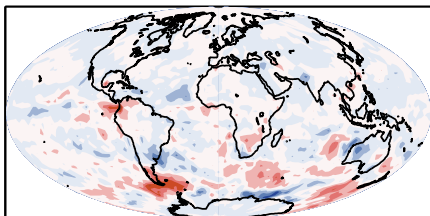
CAM4 – low,thin



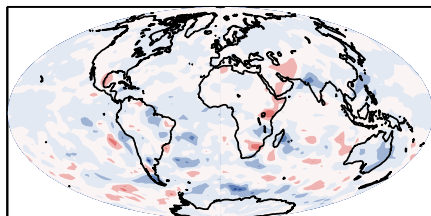
CAM5 – low,thin



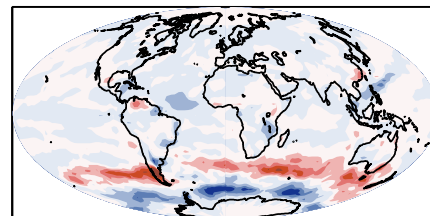
CAM3 – low,thick



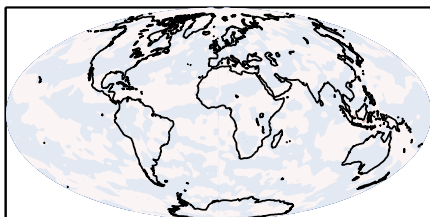
CAM4 – low,thick



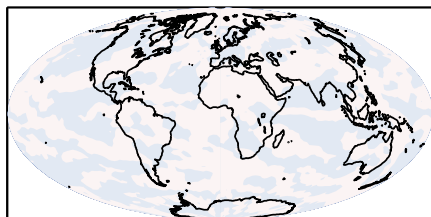
CAM5 – low,thick



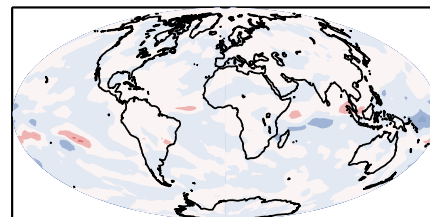
CAM3 – high,thin



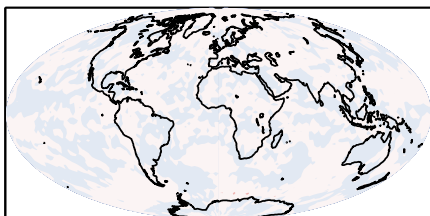
CAM4 – high,thin



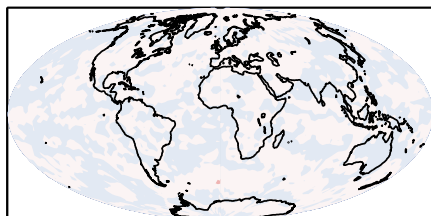
CAM5 – high,thin



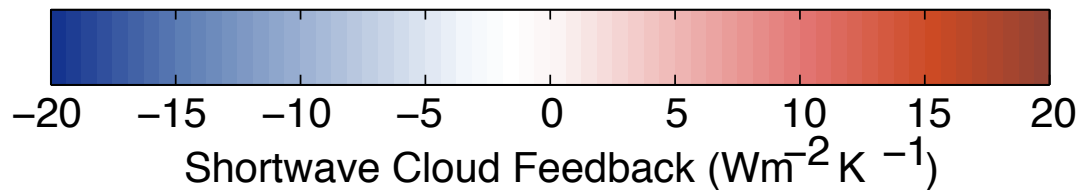
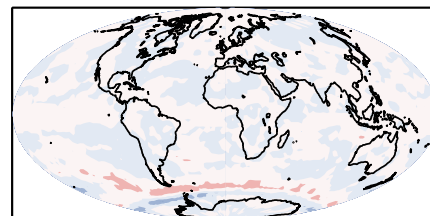
CAM3 – high,thick



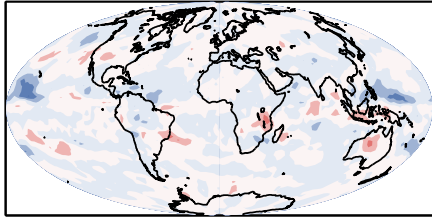
CAM4 – high,thick



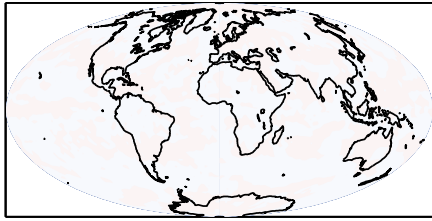
CAM5 – high,thick



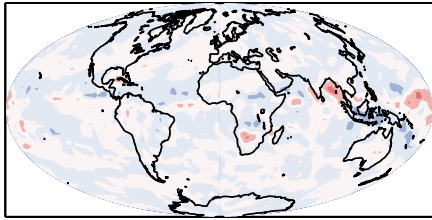
CAM3 – low,thin



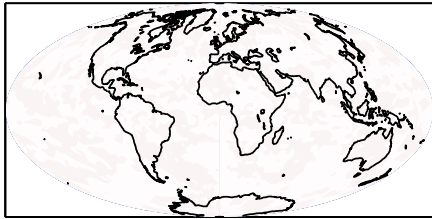
CAM3 – low,thick



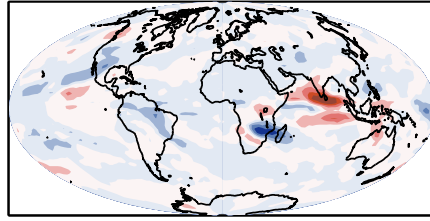
CAM3 – high,thin



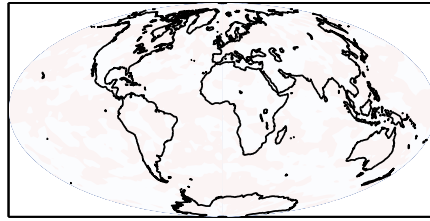
CAM3 – high,thick



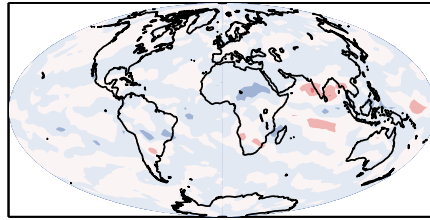
CAM4 – low,thin



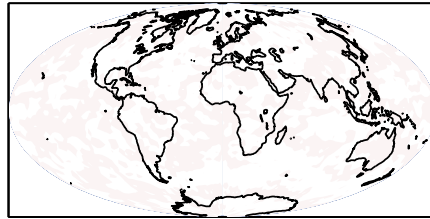
CAM4 – low,thick



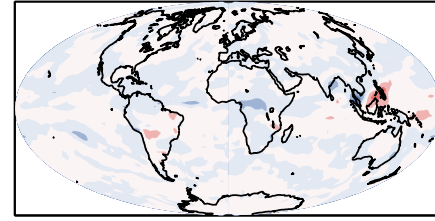
CAM4 – high,thin



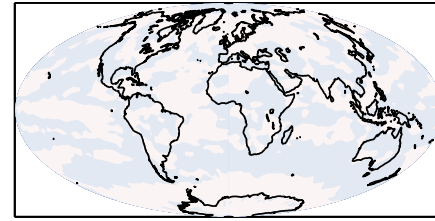
CAM4 – high,thick



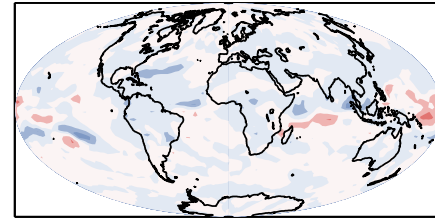
CAM5 – low,thin



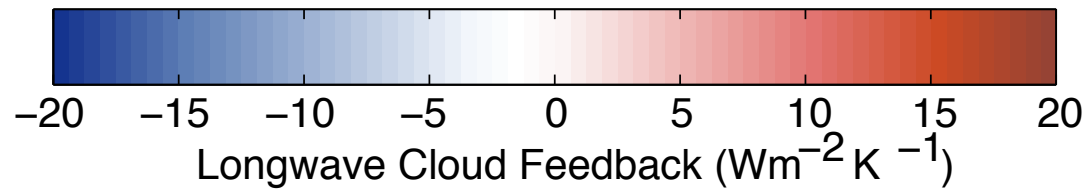
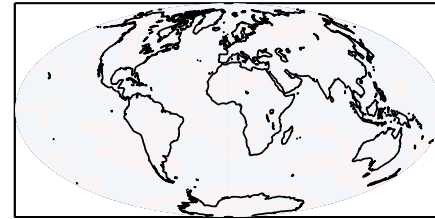
CAM5 – low,thick



CAM5 – high,thin



CAM5 – high,thick



Conclusions

- Inverse approach can derive kernels, and feedbacks directly from climate change simulation
- Cloud feedbacks can be derived similarly from ISCCP/COSP output
- Preliminary results show CAM5 increased sensitivity is complex:
 - decreased -ve SW cld fdb in the SE Pacific
 - enhanced +ve Southern ocean low SW cld fdb
 - enhanced +ve LW cirrus fdb throughout Tropics
 - enhanced effect of surface albedo feedback