CAM5 Climate Sensitivity

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Thanks to: C. Hannay, B. Medeiros, J. Kiehl, A. Conley, NCAR

CAM4= 3.1K CAM5.1 = 4.1K (-0.2,+0.8)

- Why is climate sensitivity different?
- What drives it? Feedback processes
- Explore climate feedbacks
- Describe method, runs
- Punch Line: Climate sensitivity can be tested in short runs, governed by ‘fast physics’. It may not be exactly what we think...

Radiative Kernel Method

Key feedbacks ($\lambda = \Sigma\lambda_x$):

T (& lapse rate Γ), H_2O, Albedo, Clouds

Decompose with a 'Kernel'

$\Delta F = \lambda\ \Delta Ts$ or $\lambda = \Delta F\ /\ \Delta Ts$ ($\lambda=1/\gamma$)

$\lambda_x = \Delta F/\Delta X\ \Delta X/\Delta Ts$

'kernel' K = $\Delta F/\Delta X$ (x,y,z,t)

Method works well, except clouds are a residual

Here: use kernels to adjust cloud forcing

Model Simulations

- Radiative kernels from CAM3
- Working on CAM4, CAM5 kernels (CAM4 & CAM5 not that different for kernels)
- SOM runs, last 20 years of 40 or 60 year runs.
- 'Modified Cess' experiments (prescribe dTs)

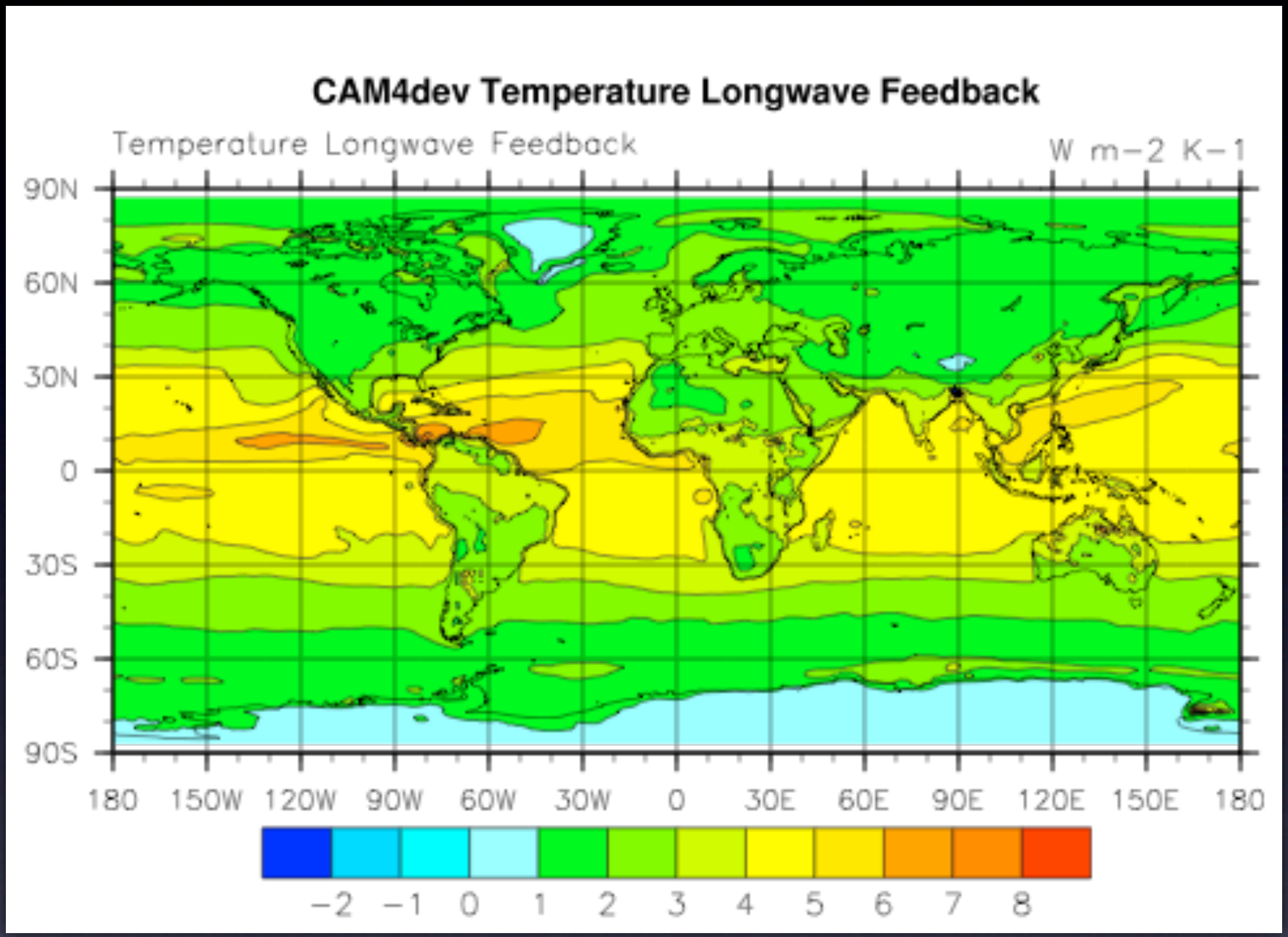
Near Final Development versions of:

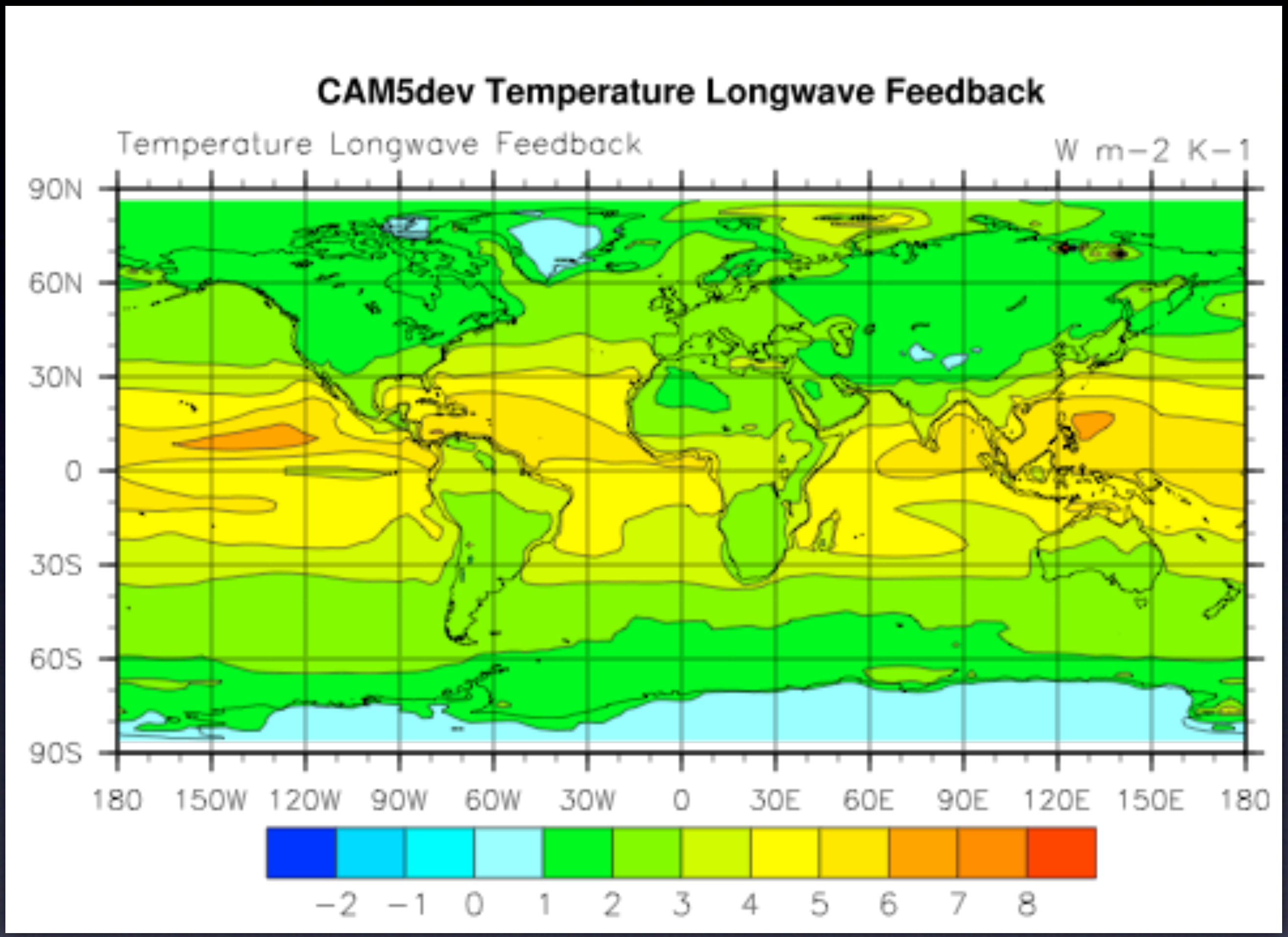
- CAM4 & CAM5 in CESM1

Status: nearing publication

CAM4

CAM5

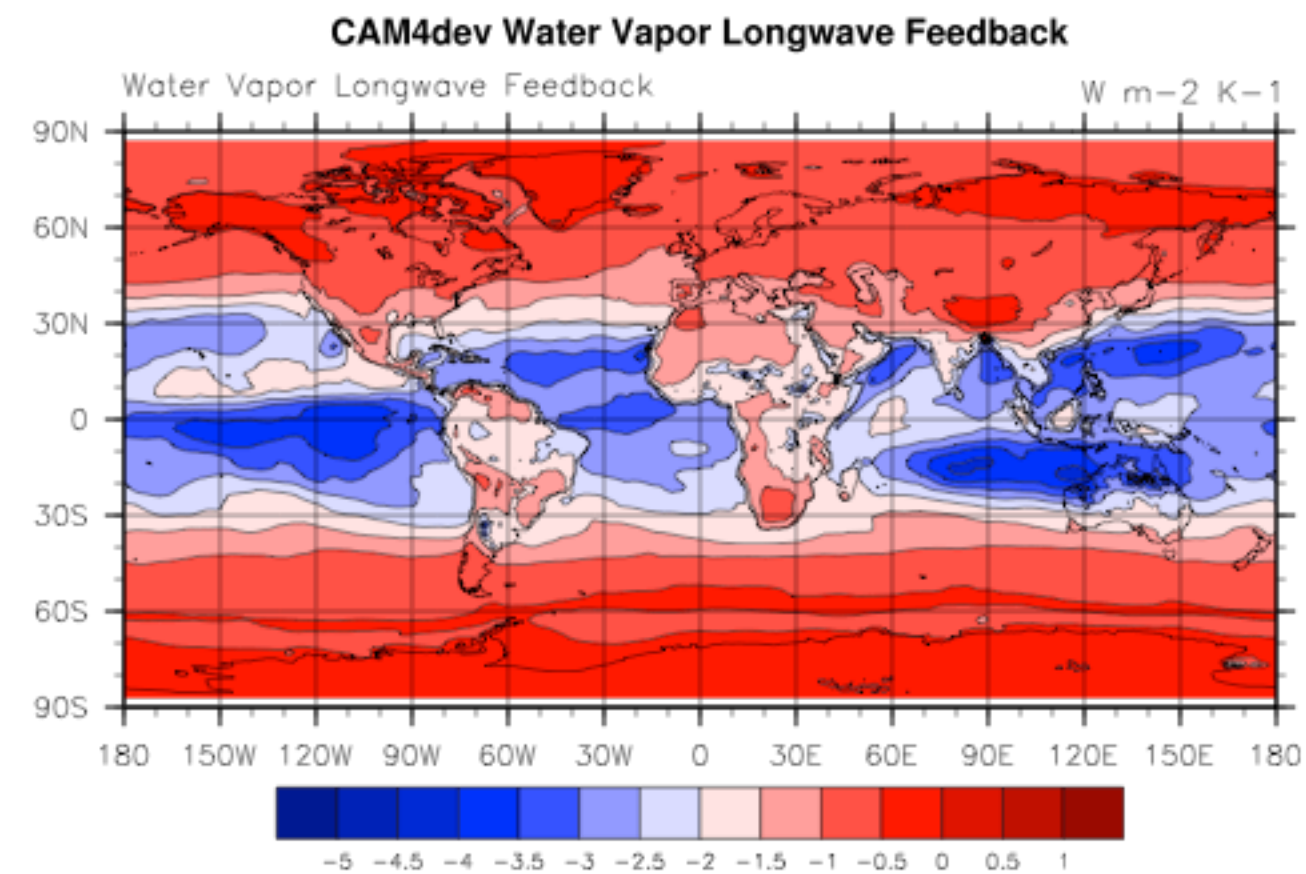


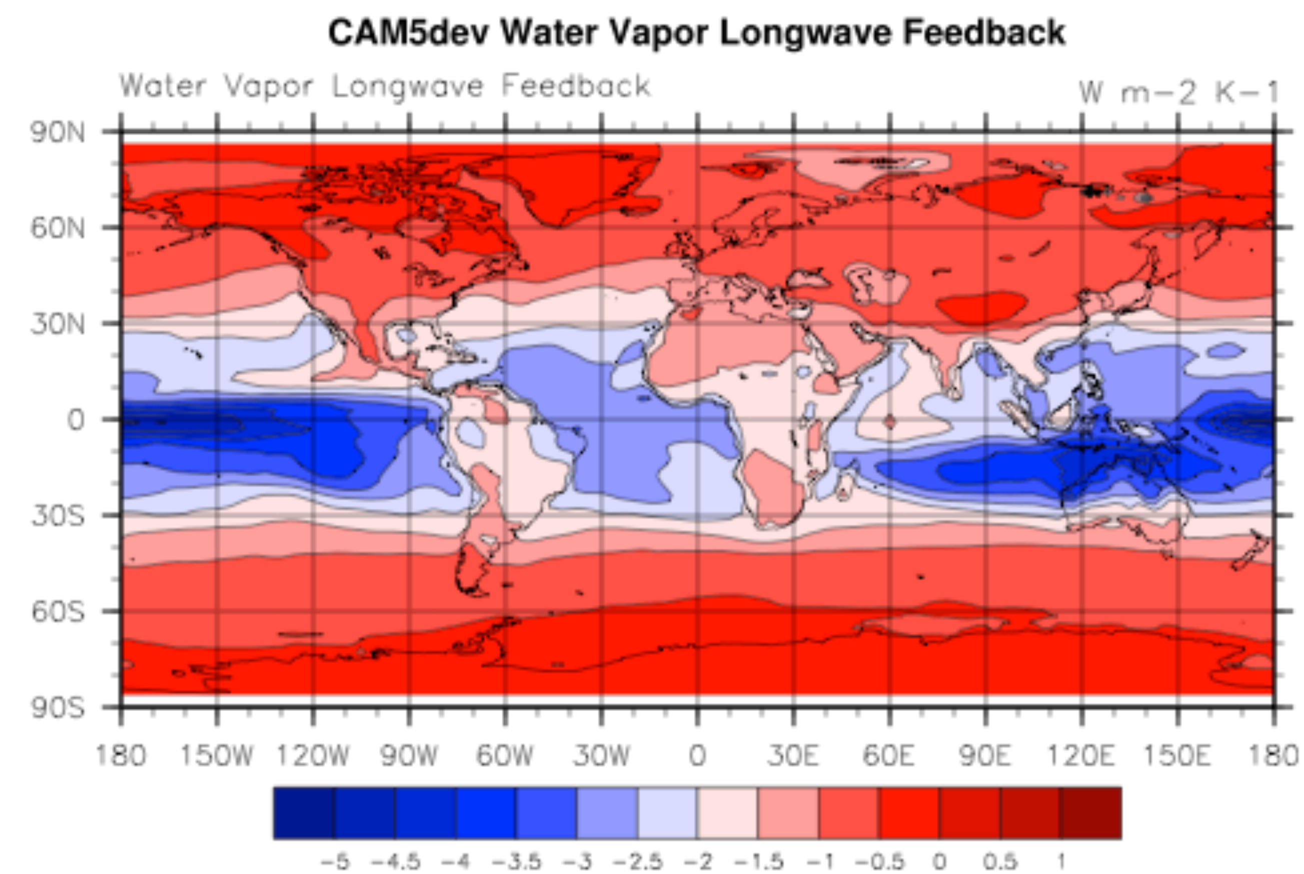


Temp (Planck) Feedback

CAM4

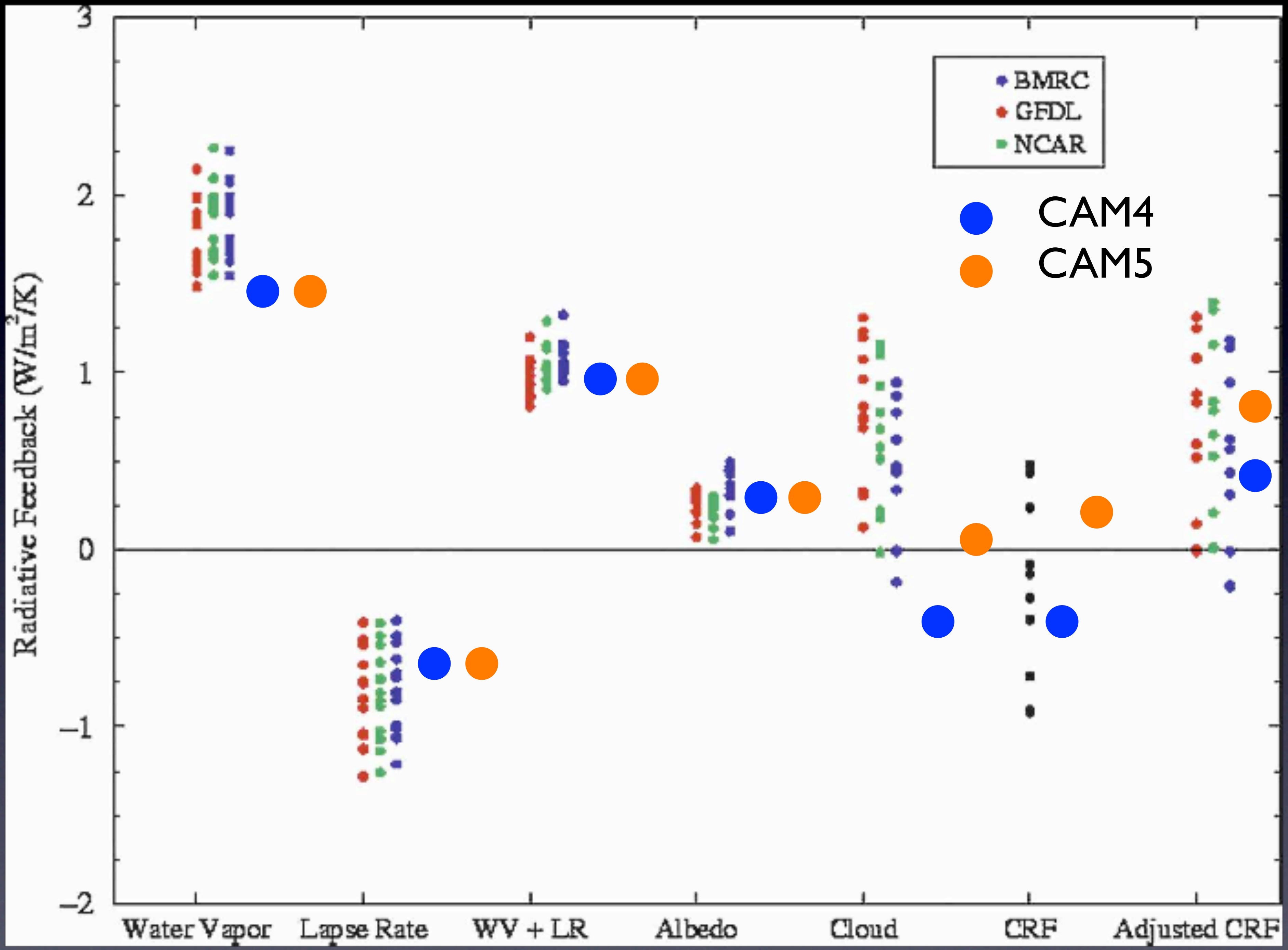
CAM5





LW H_2O Feedbacks

Feedback Comparison

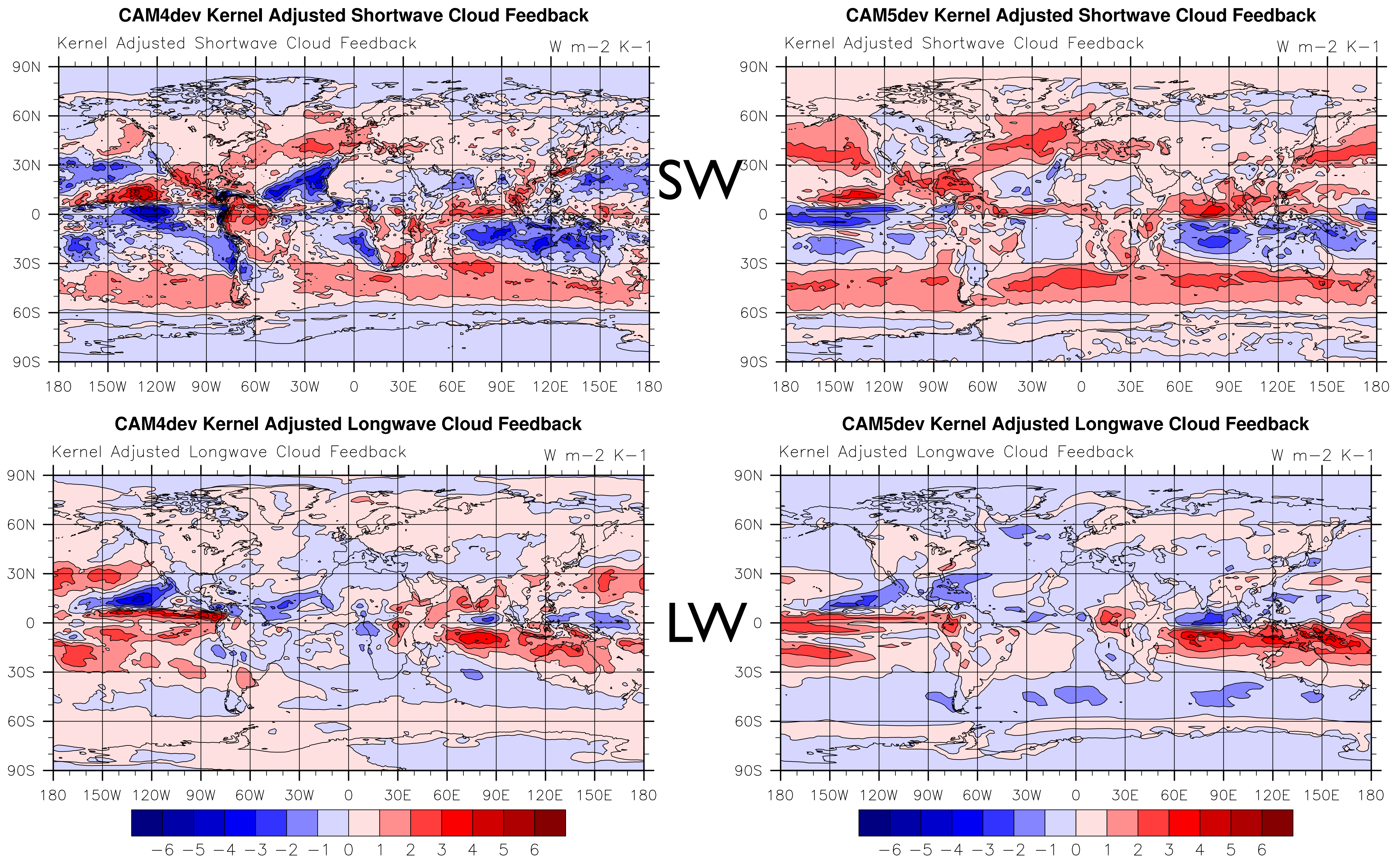


Soden, 2008 (also Colman, Bony)

Note: results not sensitive to kernel used

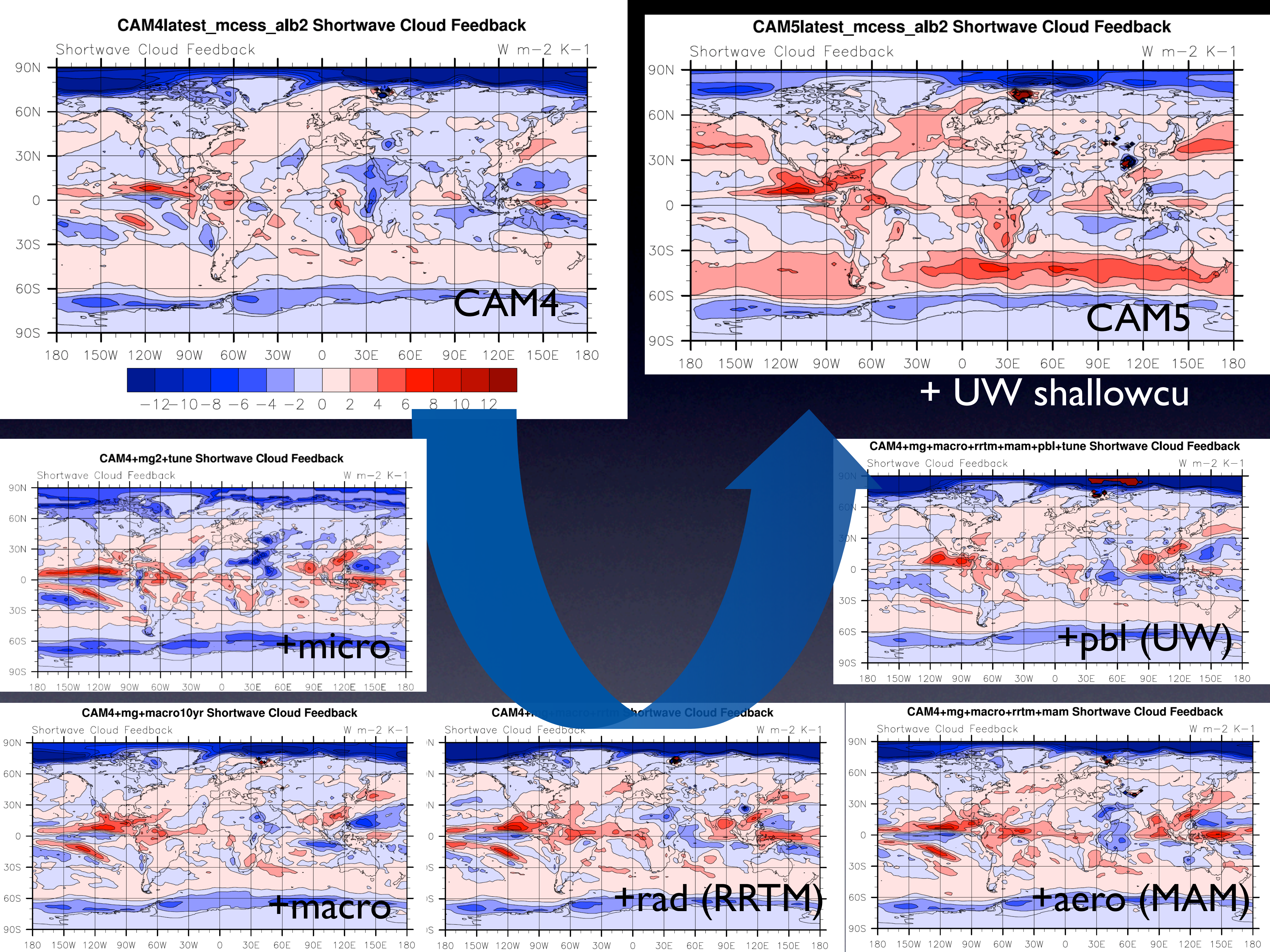
Cloud Feedbacks

CAM4 CAM5

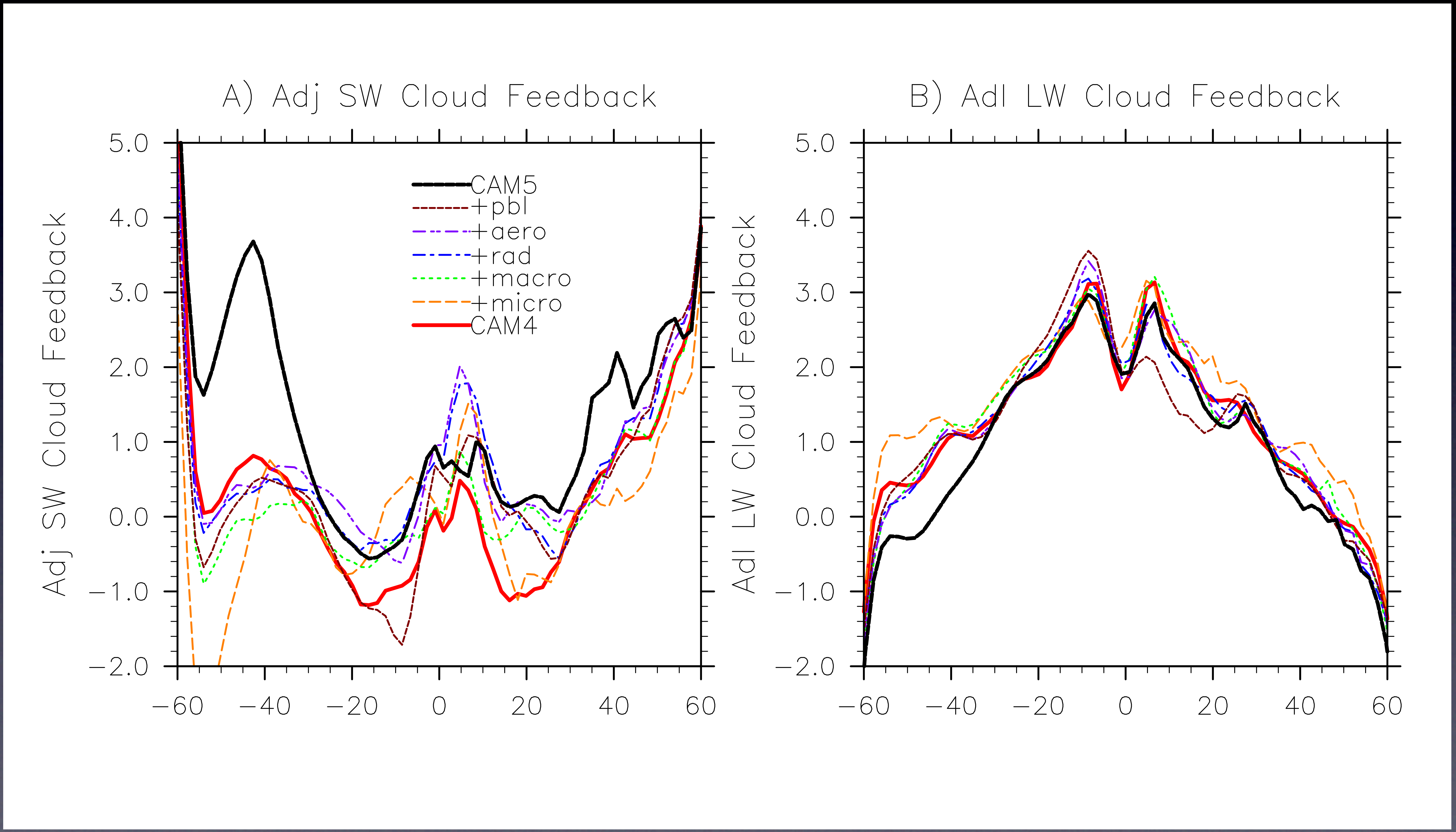


Which processes?

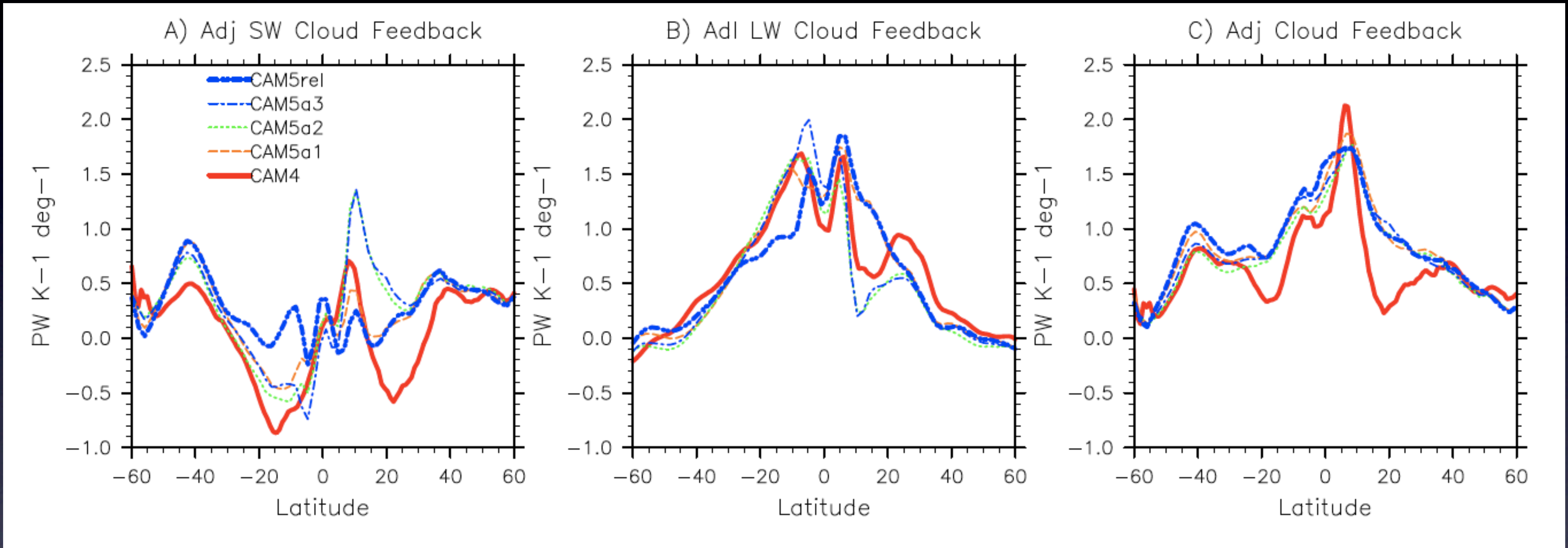
- SW Cloud forcing is biggest change
- What processes change it? Where?
- CAM4-5: Micro, Macro, Radiation, Aerosols, Boundary Layer, Shallow Convection
- Explore by analyzing cloud feedbacks in a series of stand-alone runs
- Have also used ‘adjusted cloud feedback’ with kernels


CAM4latest_mcess_alb2 Shortwave Cloud Feedback
Shortwave Cloud Feedback
W m−2 K−1
−12 −10 −8 −6 −4 −2 0 2 4 6 8 10 12
CAM4
CAM5latest_mcess_alb2 Shortwave Cloud Feedback
Shortwave Cloud Feedback
W m−2 K−1
CAM5
+ UW shallowcu
CAM4+mg2+tune Shortwave Cloud Feedback
+micro
CAM4+mg+macro+rrtm+mam+pbl+tune Shortwave Cloud Feedback
+pbl (UW)
CAM4+mg+macro10yr Shortwave Cloud Feedback
+macro
CAM4+mg+macro+rrtm Shortwave Cloud Feedback
+rad (RRTM)
CAM4+mg+macro+rrtm+mam Shortwave Cloud Feedback
+aero (MAM)

Zonal Mean: Cloud Feedbacks

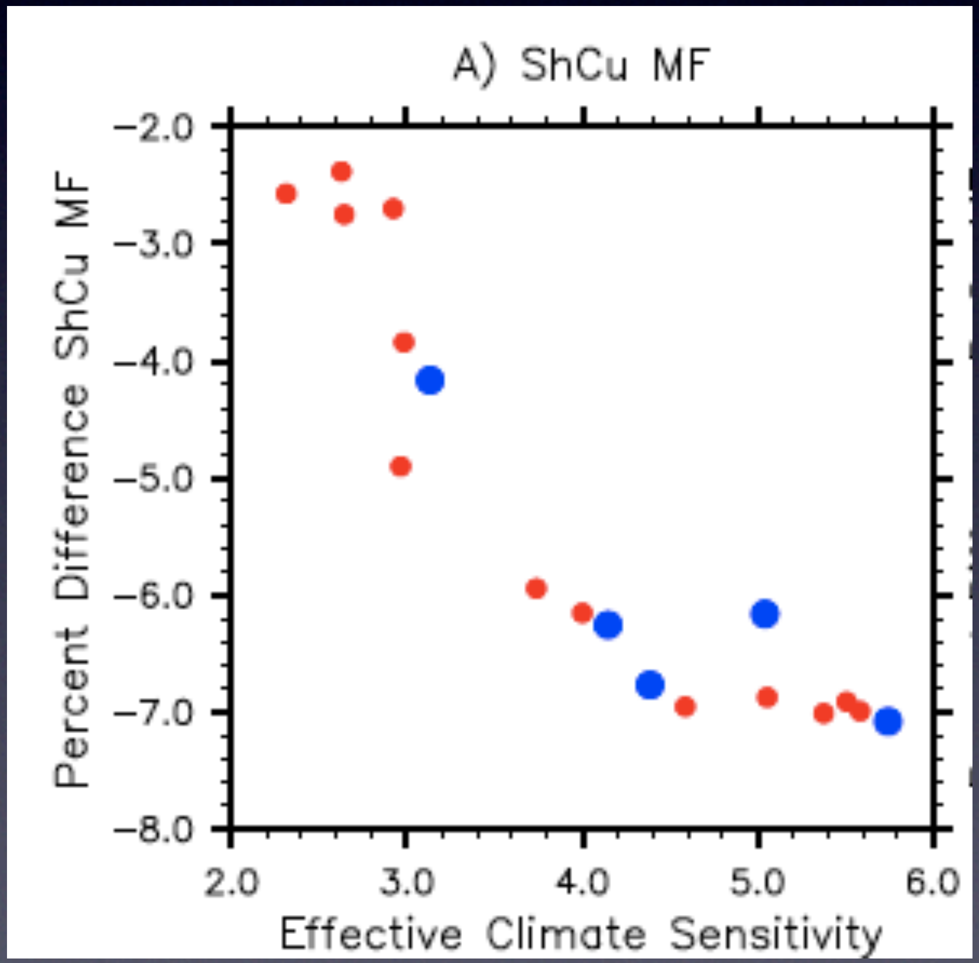


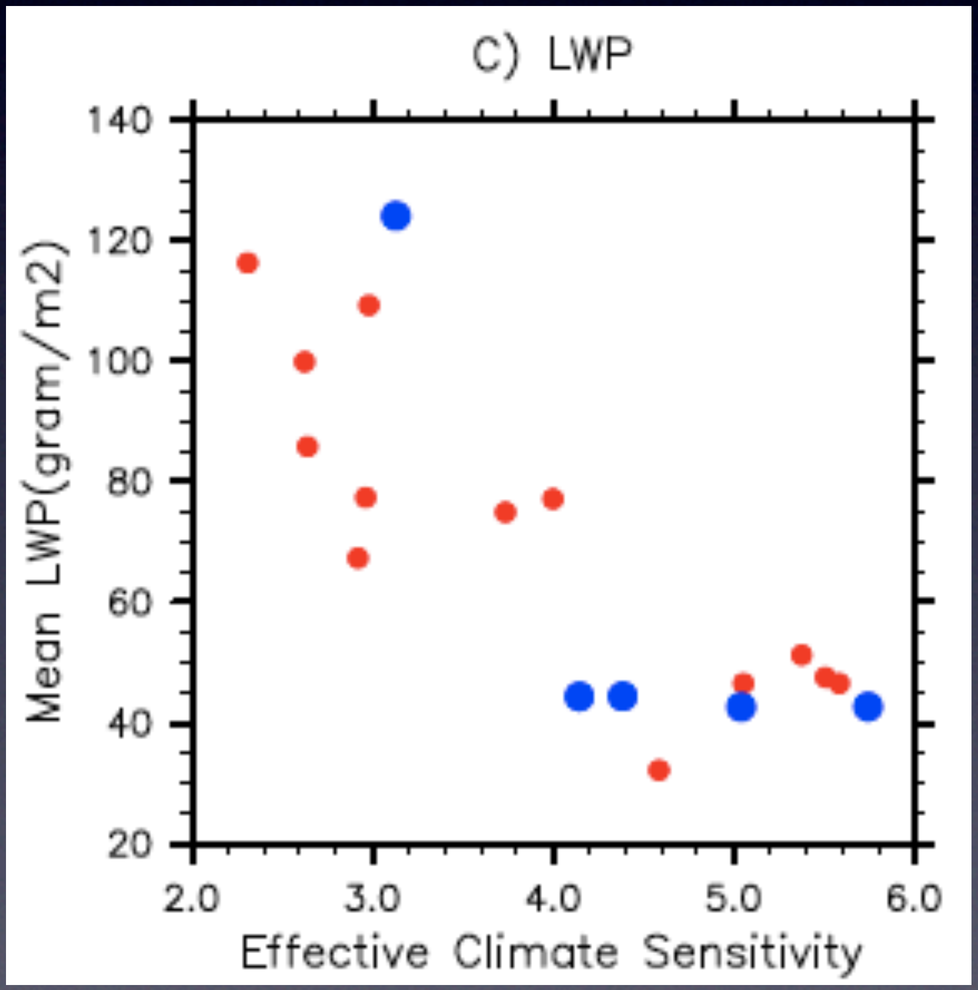
Variance...



Variable CAM5 climate sensitivity
3.9 - 5.1 K in pre-release versions
Have not looked at CAM5.1 yet

Related to Clouds & Convection?





Results

- CAM5 has higher climate sensitivity than CAM 4
- Difference driven by λ_{cld} (SW)
- Not just stratocumulus: mid-latitude λ_{cld} (SW) especially Southern Ocean
- What drives changes?
  - Tropics: Cloud Optics (radiation)
  - Mid-Lats: Shallow Cu & interactions
- Also looked at:
  - Aerosols (little impact)
  - Tuning parameters (small impact due to clouds)

Summary

- H2O & LR feedbacks stable
- SW Cloud Feedback is dominant effect
- Fast physics (clouds) are the cause
- Note: not treating Ice, Ocean fully (cloud feedback due to ice treated)
- Importance of Strato-cumulus may be overstated
- Method allows for in-depth analysis of processes
- Base state of climate seems to matter
- Path forward for zeroing in on processes