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

- $T$ (and lapse rate $\Gamma$), $H_2O$, Albedo, Clouds

Decompose with a ‘Kernel’

$$\Delta F = \lambda \Delta Ts \text{ or } \lambda = \Delta F / \Delta Ts \quad (\lambda = 1 / \gamma)$$

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

‘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
Temp (Planck) Feedback
CAM4

CAM5

LW H₂O Feedbacks
Feedback Comparison

Note: results not sensitive to kernel used
Cloud Feedbacks

CAM4dev Kernel Adjusted Shortwave Cloud Feedback

CAM5dev Kernel Adjusted Shortwave Cloud Feedback

CAM4dev Kernel Adjusted Longwave Cloud Feedback

CAM5dev Kernel Adjusted Longwave Cloud Feedback

Legend:
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
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
Zonal Mean: Cloud Feedbacks

A) Adj SW Cloud Feedback

B) Adj LW Cloud Feedback
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 $\lambda_{cld}$ (SW)
• Not just stratocumulus: mid-latitude $\lambda_{cld}$ (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