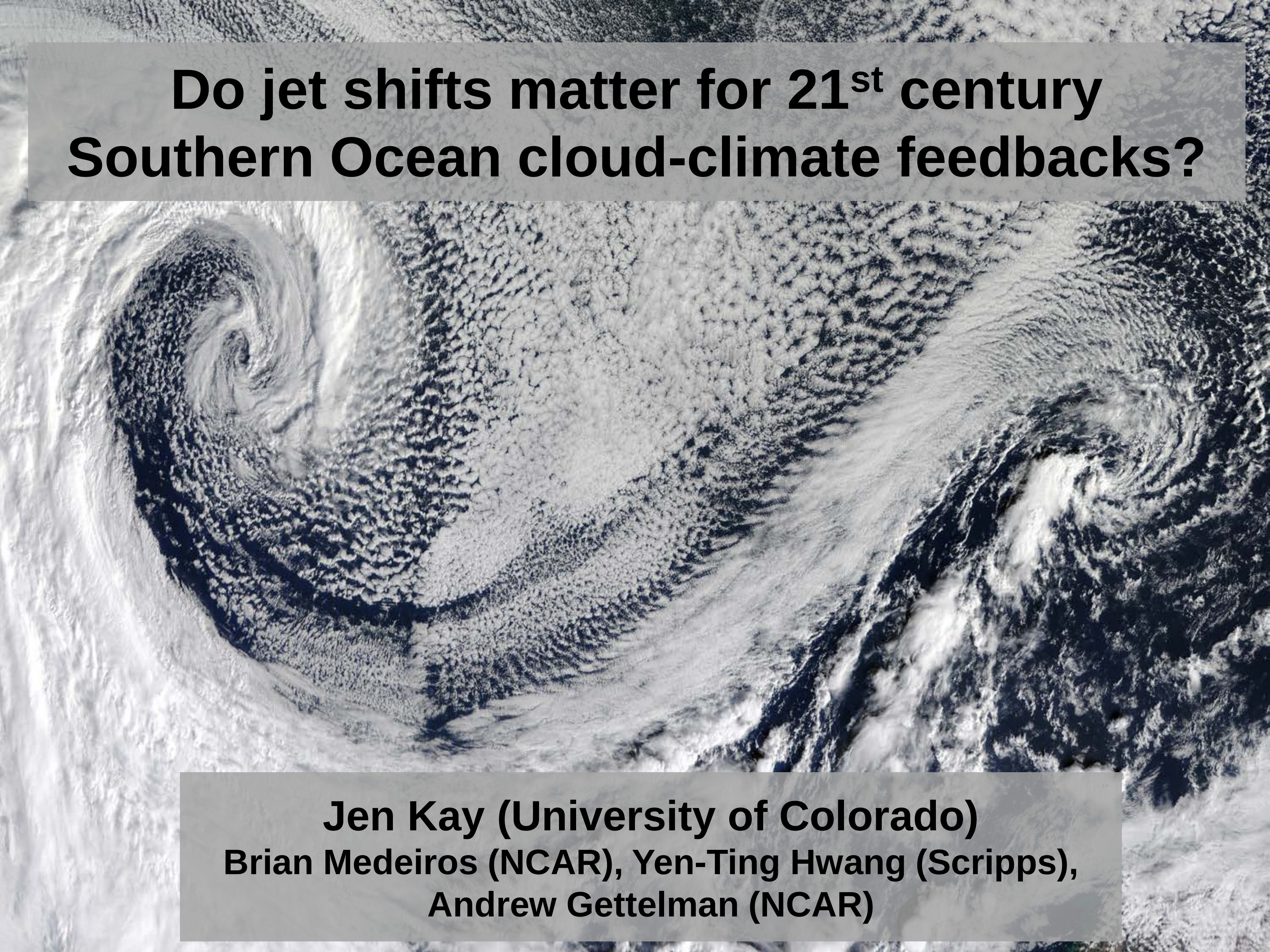
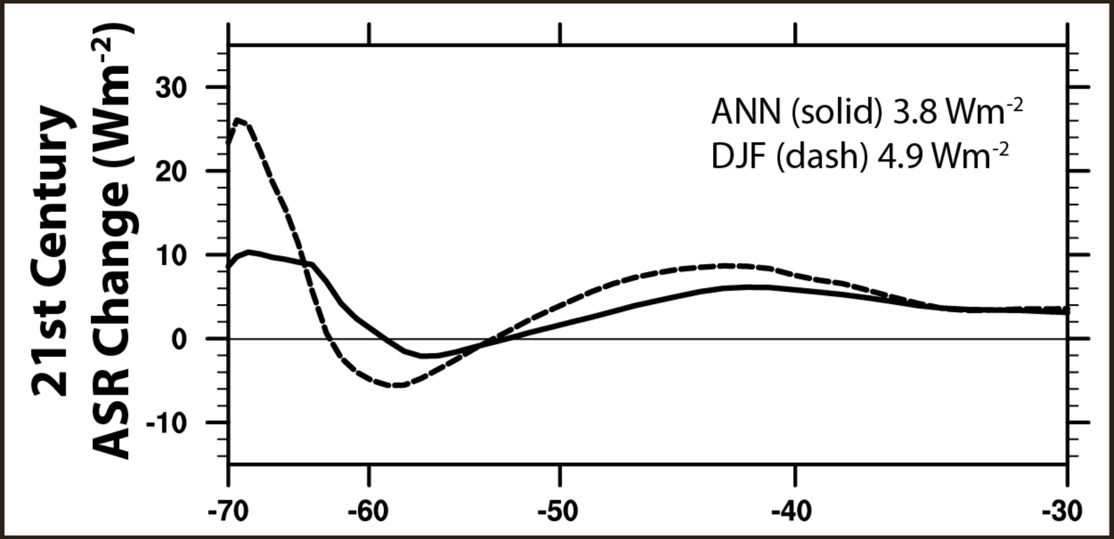


Do jet shifts matter for 21st century Southern Ocean cloud-climate feedbacks?

Jen Kay (University of Colorado)
Brian Medeiros (NCAR), Yen-Ting Hwang (Scripps), Andrew Gettelman (NCAR)

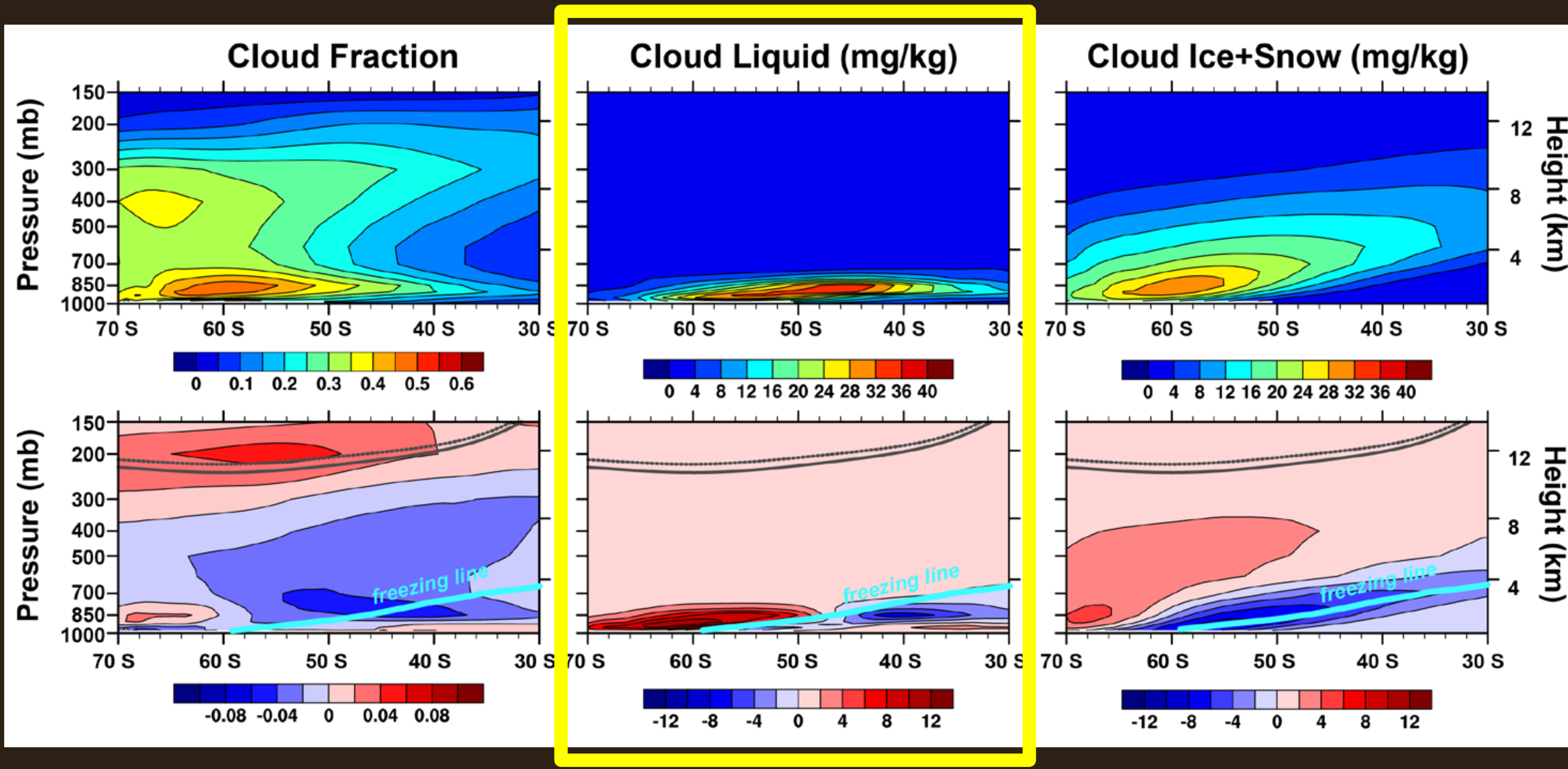
Let's start with 21st century Absorbed SW Radiation Changes in CESM-CAM5



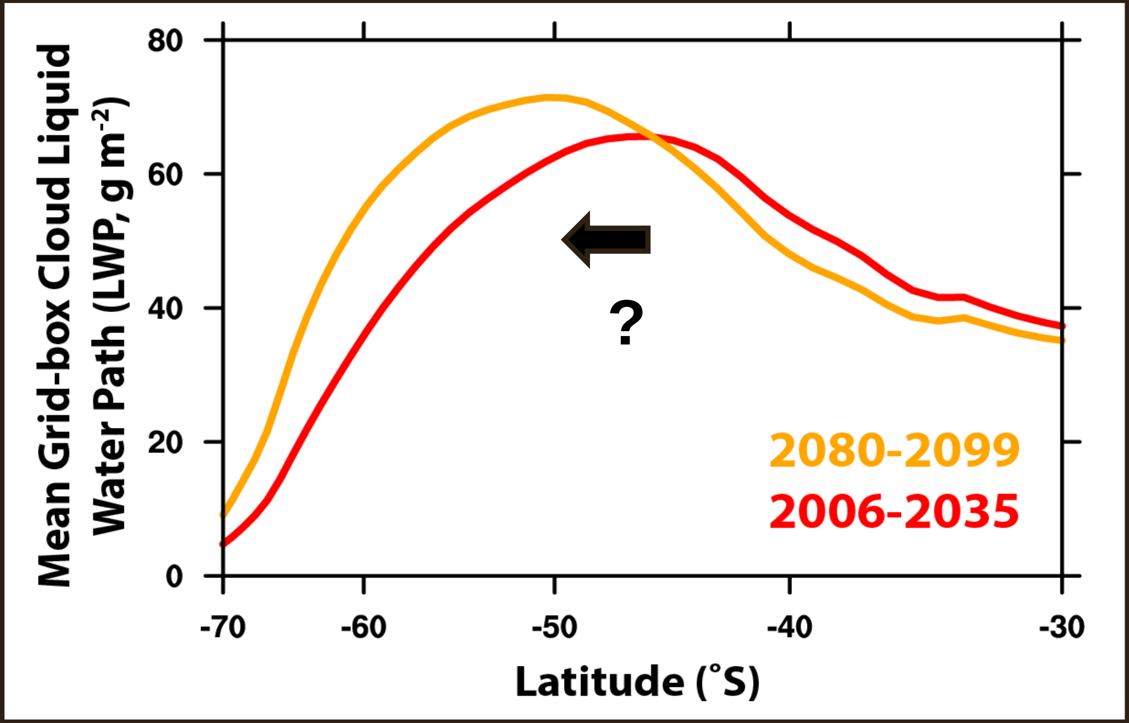
Kay et al. 2014 Figure 1

21st century Southern Ocean clouds

top=early 21st C, bottom=21st C change

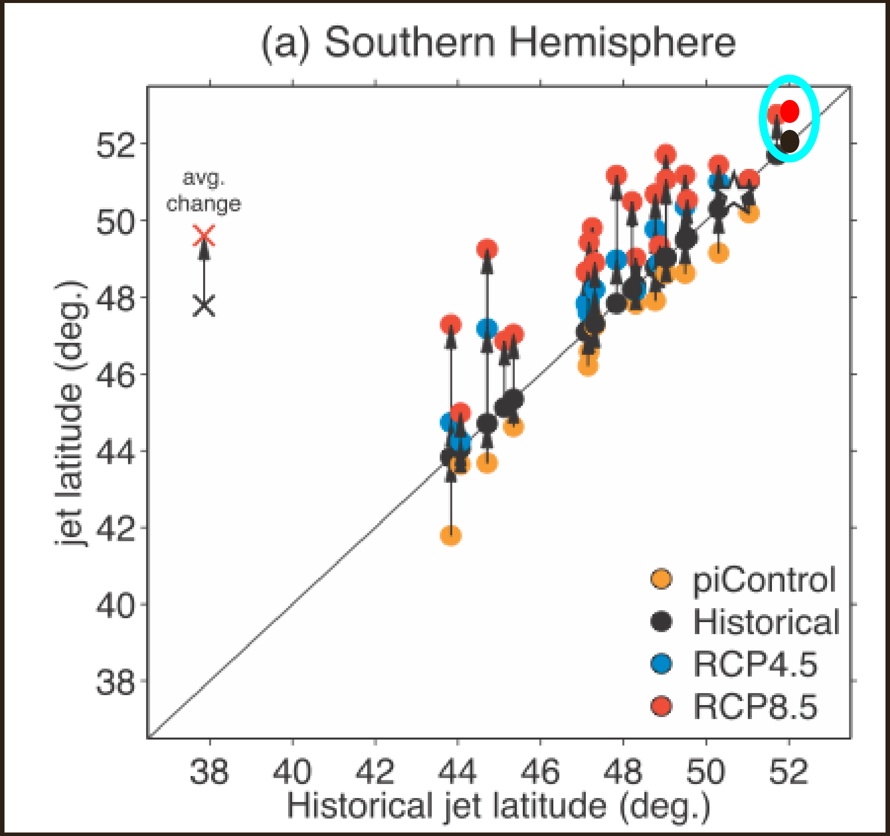


Are the radiatively important clouds "shifting poleward"?



Why would the radiatively important clouds "shift poleward"?

Maybe the clouds "shift poleward" because the jet shifts poleward?

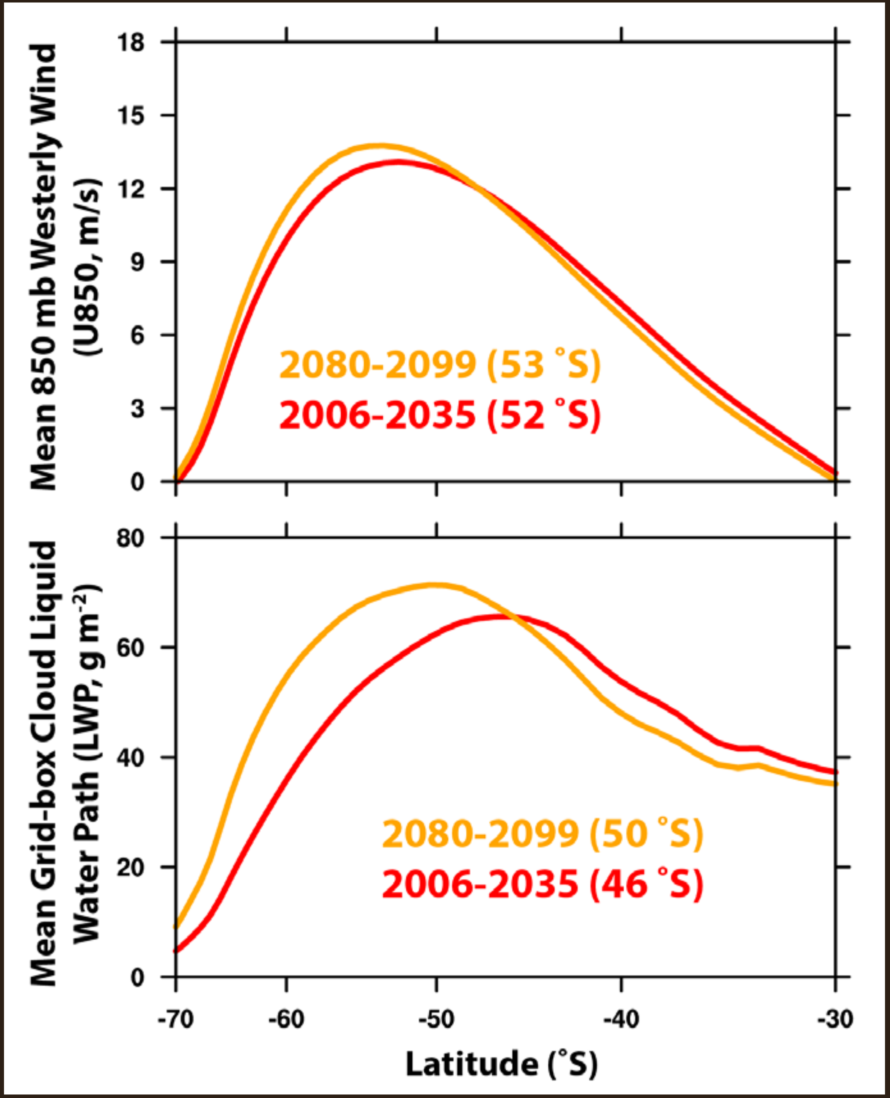


CMIP5 jets and jet shifts
Barnes and Polvani 2013, Figure 2

CESM-CAM5:
1° jet shift
RCP8.5,
52° S to 53° S

Small jet shift consistent with more poleward (realistic) mean jet location.

Jet shifts ≠ cloud "shifts"

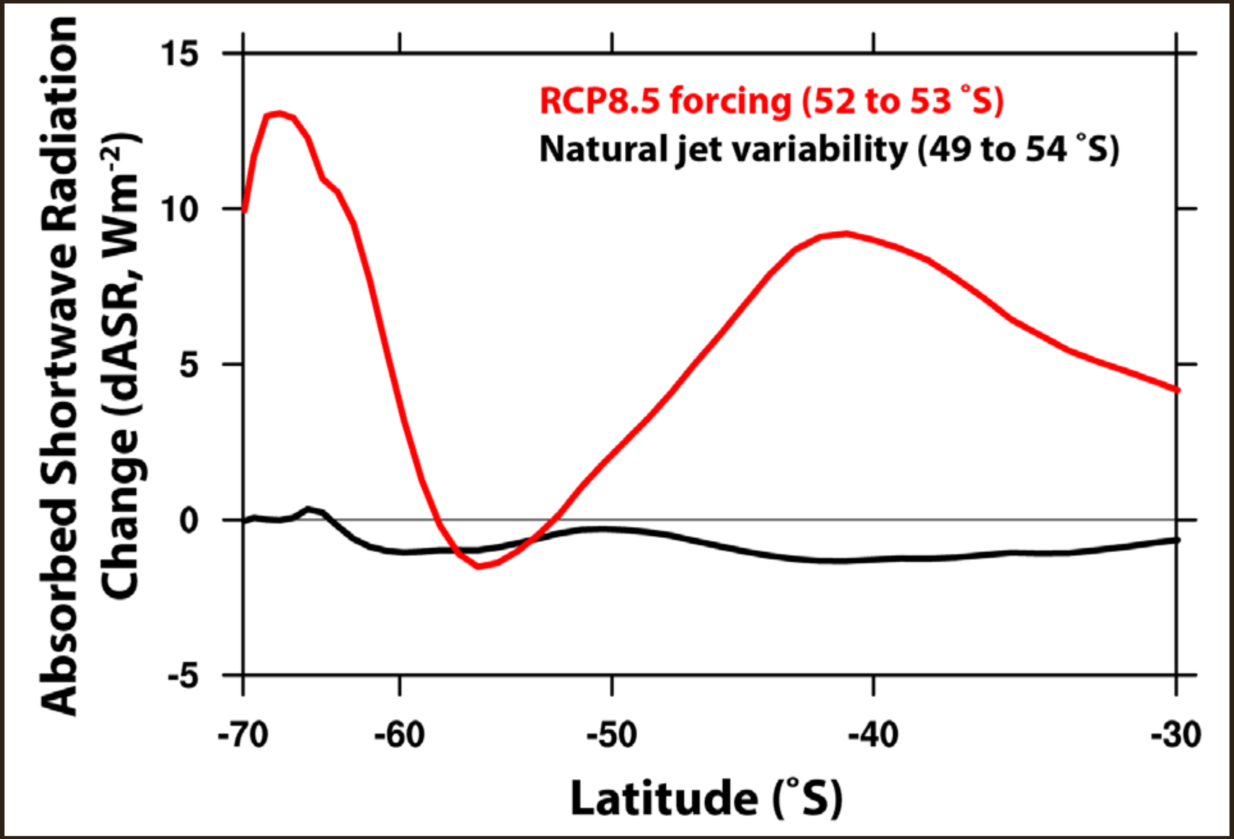


If not jet shifts then what?

Warming and low level stability influence on shallow convection

Adapted from Kay et al. 2014 Figure 3

But what if the jet moves a lot … then radiation changes, right?



Kay et al. 2014

RCP8.5 forcing >> natural jet variability

(also true in CCSM4 and other CMIP5 models (Ceppi et al. 2014))

Support from a multi-model analysis
Ceppi et al. (2014)

"much of the RCP8.5 ASR response is unrelated to the poleward jet shift; this agrees with the results of Kay et al. [2014] with the CESM-CAM5 and CCSM4 models"

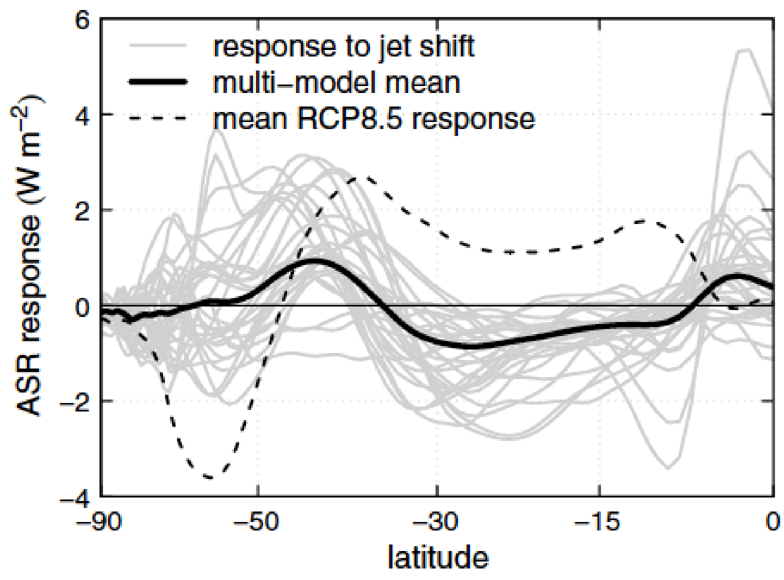


Figure 5. ASR response to interannual jet shifts (in W m^{-2}) in preindustrial control simulations of CMIP5 models. The model responses are calculated by least squares regression of the annual-mean ASR onto the annual-mean jet latitude using 100 year time series. The regression coefficients are multiplied by the multimodel mean RCP8.5 jet shift. The thick black line denotes the multimodel mean response, while the dashed line represents the mean RCP8.5 cloud-related ASR response (2050–2099 minus 1950–1999; cf. Figure 1b). The *x* axis is scaled by the sine of latitude.

Grise and Polvani (JClim, in press)

“type I models” = total cloud fraction is reduced at SH mid-latitudes as the jet moves poleward, contributing to enhanced shortwave radiative warming. (e.g., CCSM4)

“type II models” = this dynamically-induced cloud-radiative warming effect is largely absent. (e.g., CESM-CAM5)

“the cloud-dynamics behavior of type II models is more realistic, but both models have strengths/weaknesses.”

Do jet shifts matter for 21st century Southern Ocean cloud-climate feedbacks?

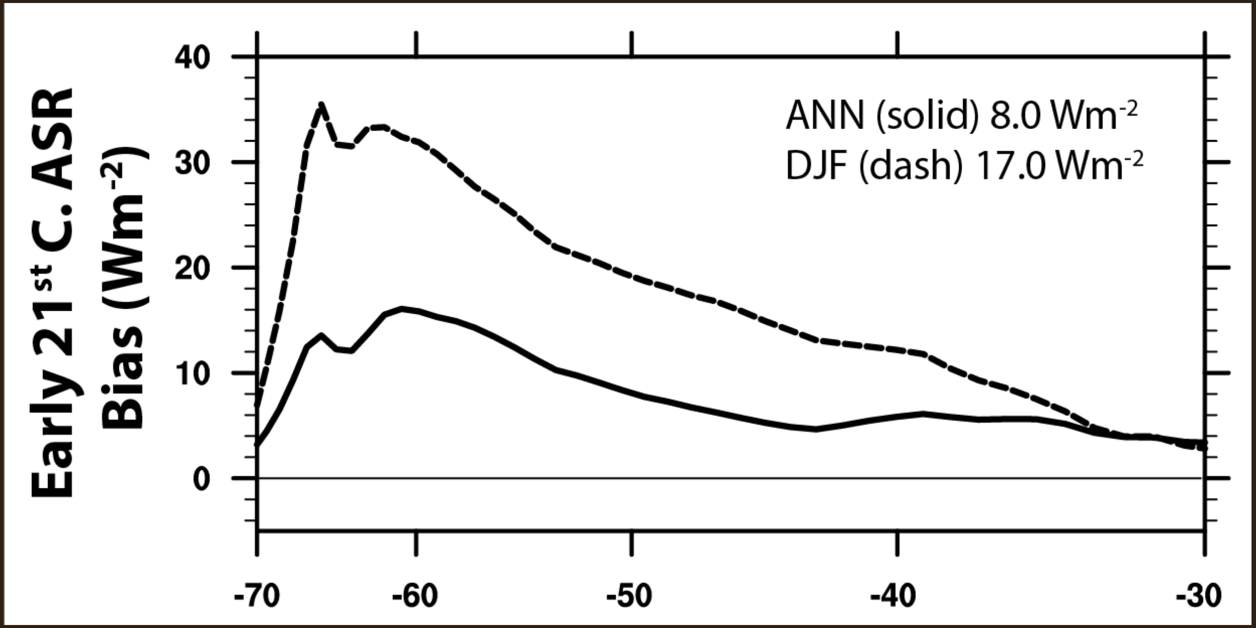
No (Kay et al. 2014 - GRL).

The radiatively important low-level liquid clouds respond primarily to warming and stability changes, not jet variability and jet shifts.

See also Grise and Polvani (2014), Ceppi et al. (2014)

Are mean state biases affecting feedbacks?

Speaking of weaknesses…

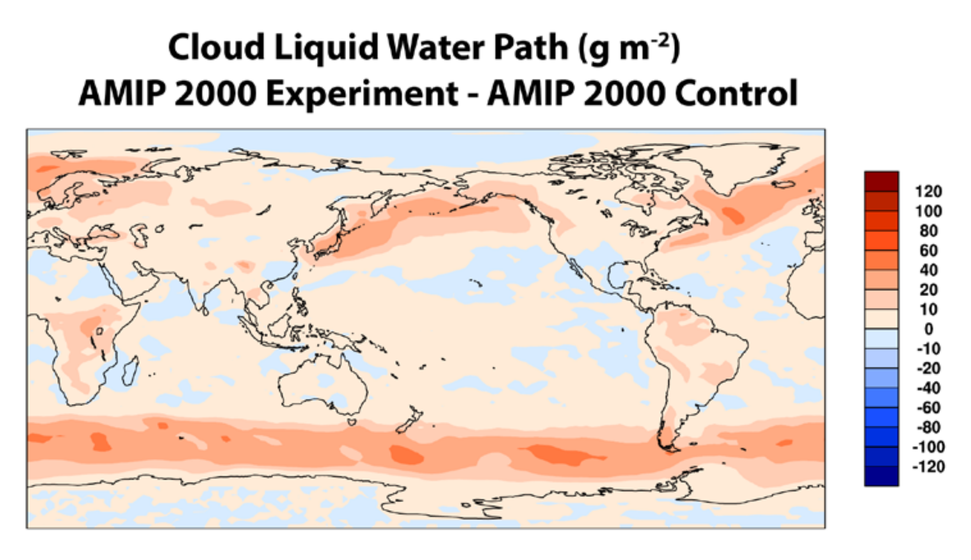


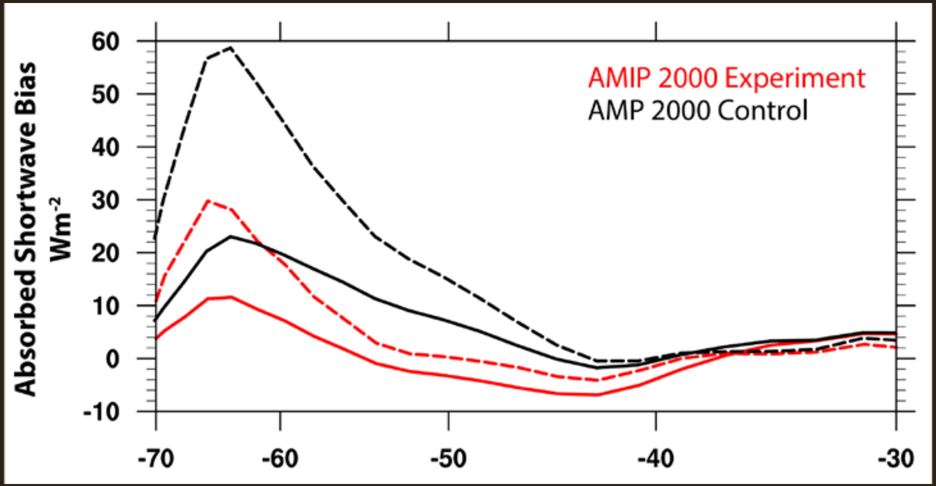
Kay et al. GRL Figure 1

What can be done to reduce this bias?

Hypothesis: Southern Ocean clouds are not “bright” enough in CAM5 because they contain insufficient amounts of supercooled liquid water.

Test hypothesis with fixed sea surface temperatures/sea ice experiment

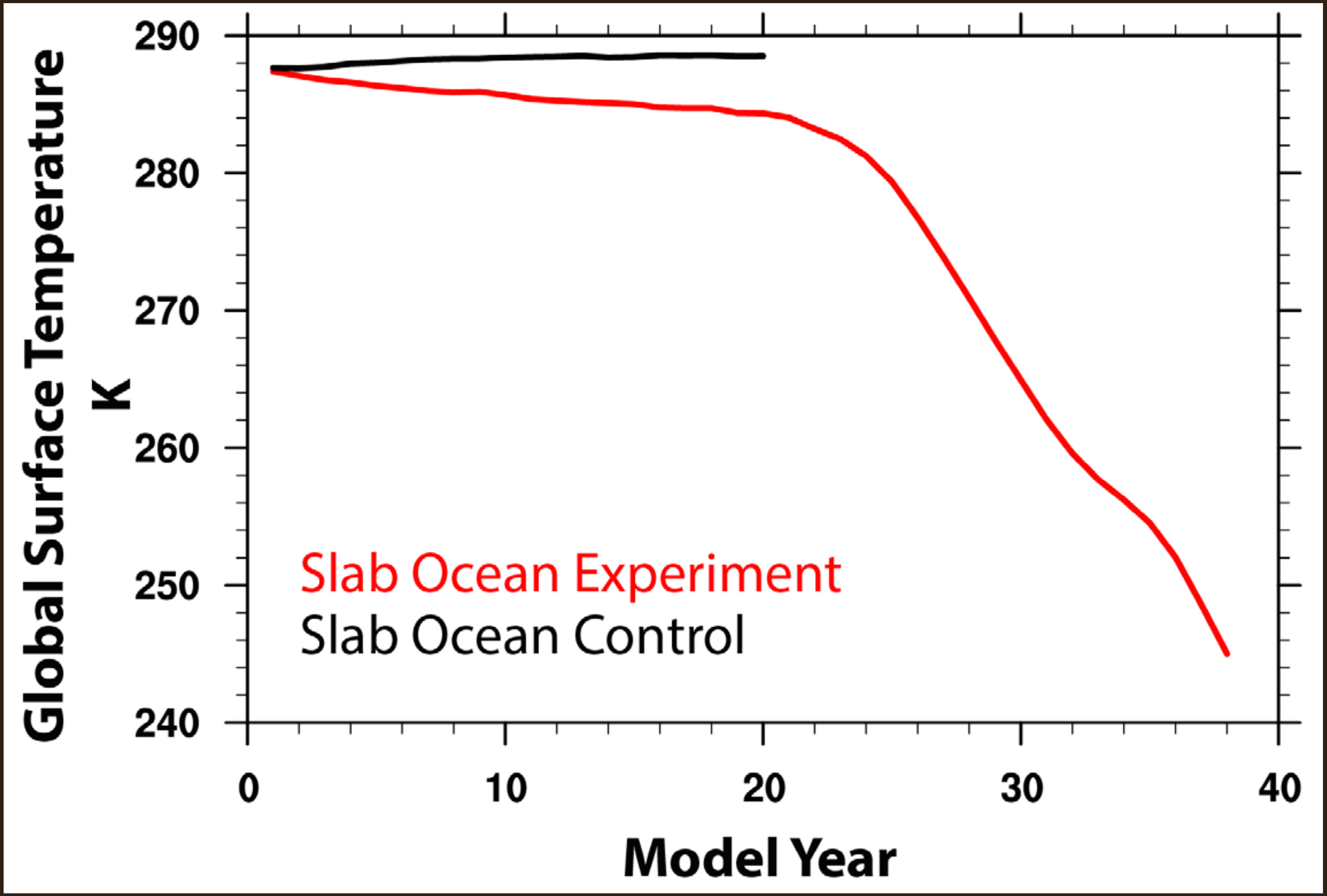




Success!!

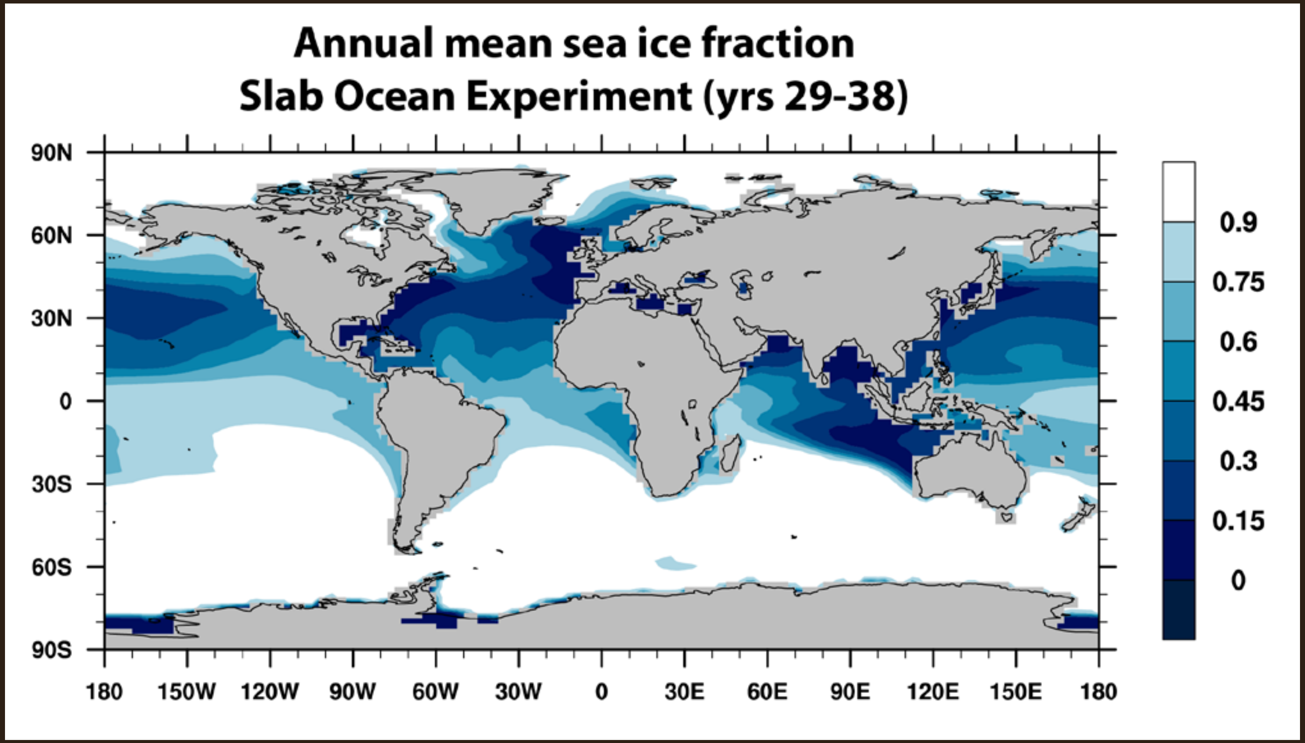
Experiment with increased supercooled liquid in shallow convective clouds reduces Southern Ocean absorbed shortwave bias.

PROBLEM: Similar experiment in a coupled framework leads to global cooling!



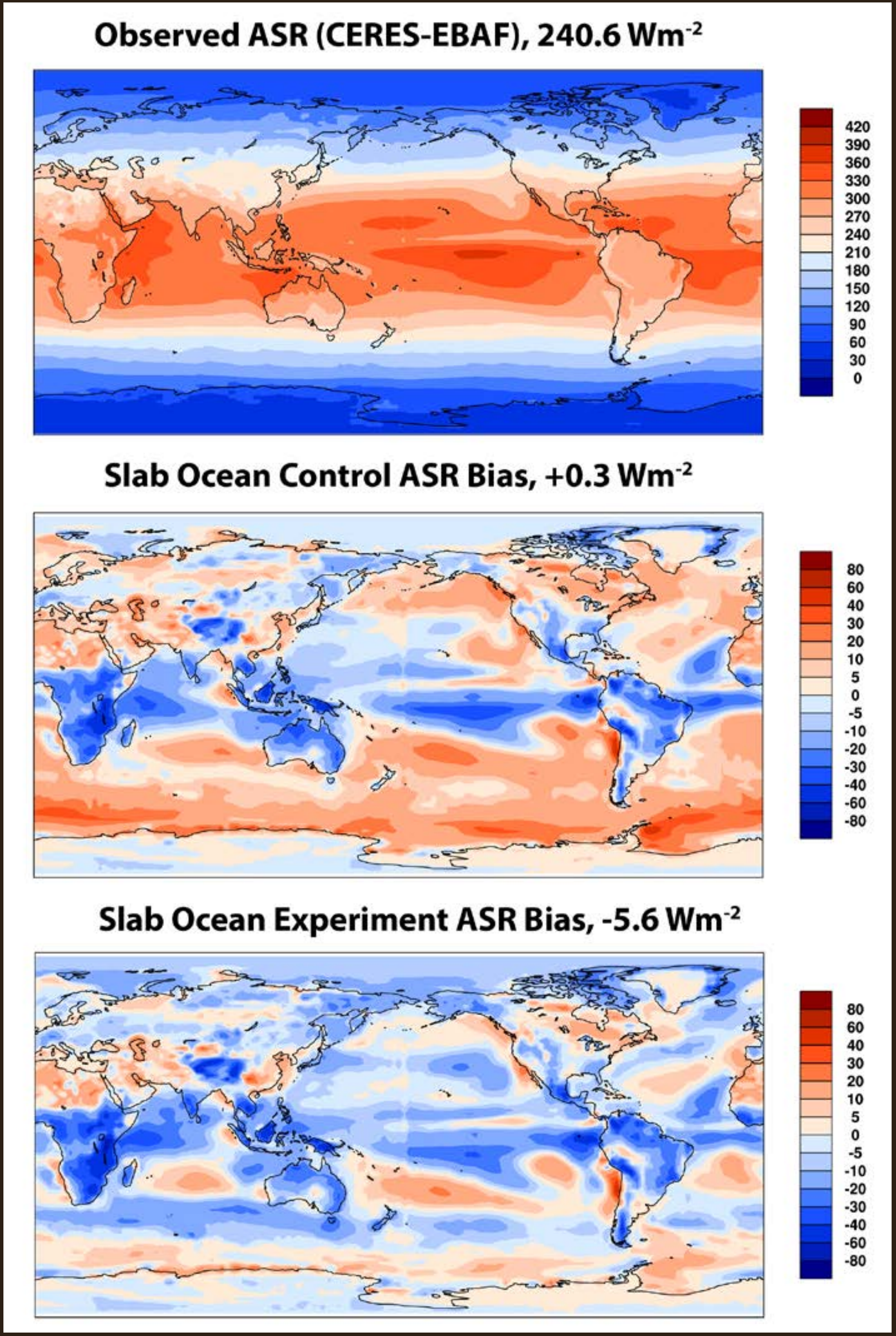
Runaway global cooling!

Runaway cooling, sea ice in the tropics, happy polar bears!

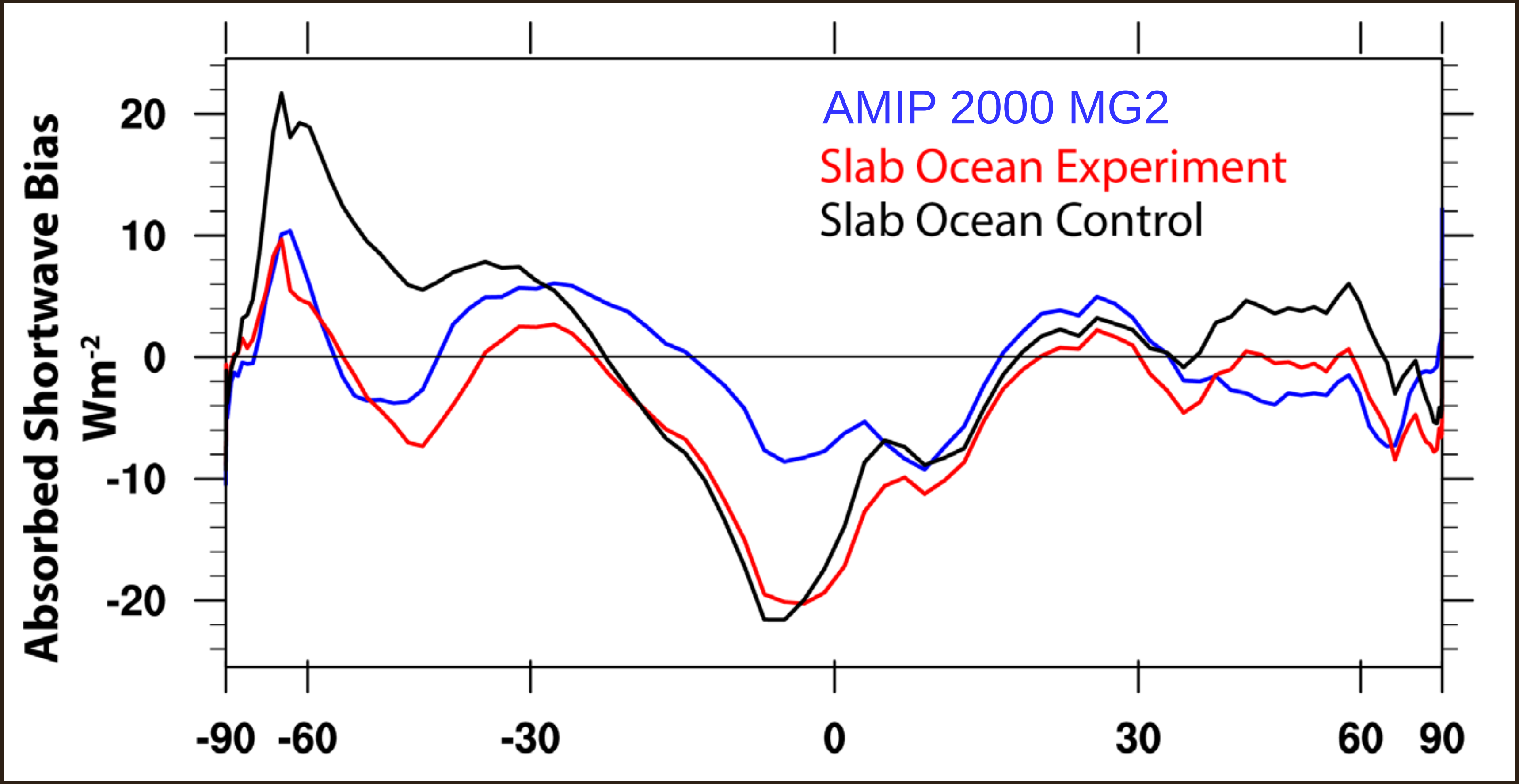


Not so happy Jen:

Can't "fix" large regional radiation biases without considering global radiation balance



Encouraging results in CAM model development world



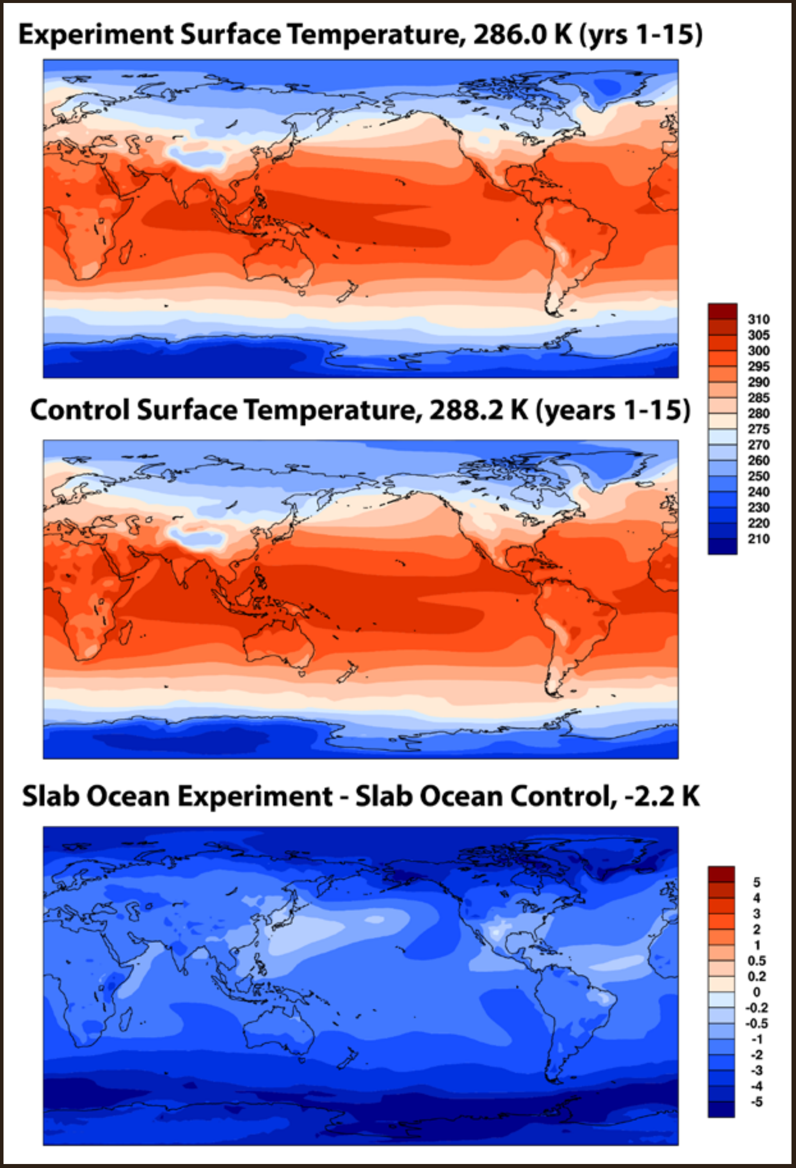
Courtesy: Andrew Gettelman

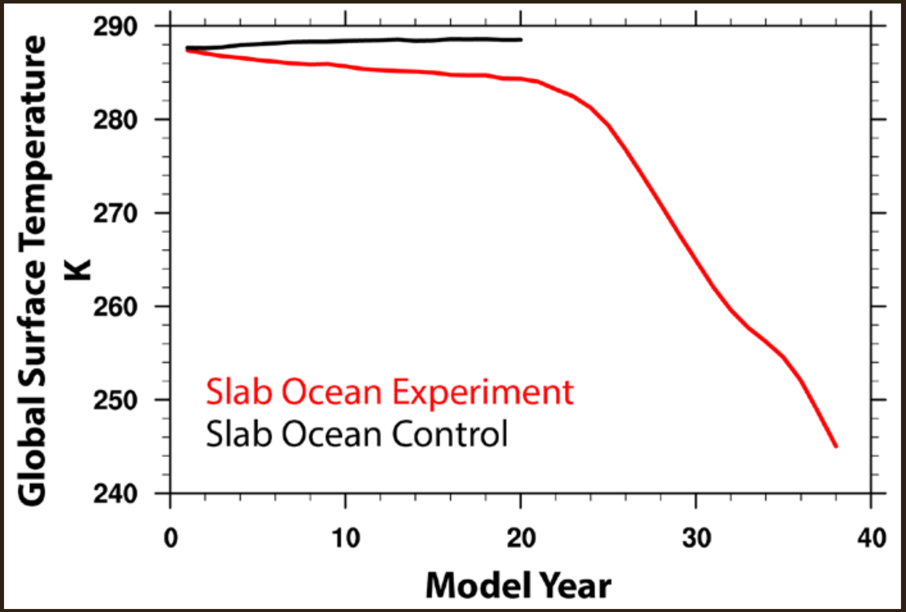
Summary – Kay et al.
Processes controlling Southern Ocean cloud-climate feedbacks

1. The radiatively important clouds over the Southern Ocean are low-level liquid clouds.
2. Low-level liquid clouds respond primarily to warming and stability changes, not jet variability and jet shifts.
3. Increasing supercooled liquid in shallow convective clouds can reduce the excessive Southern Ocean shortwave model bias.
4. BUT…. coupled modeling requires a global perspective on radiation bias reduction.

EXTRA

PROBLEM: Similar experiment in a coupled framework leads to global cooling!





Runaway global cooling!

Why Southern Ocean Shortwave Feedbacks?

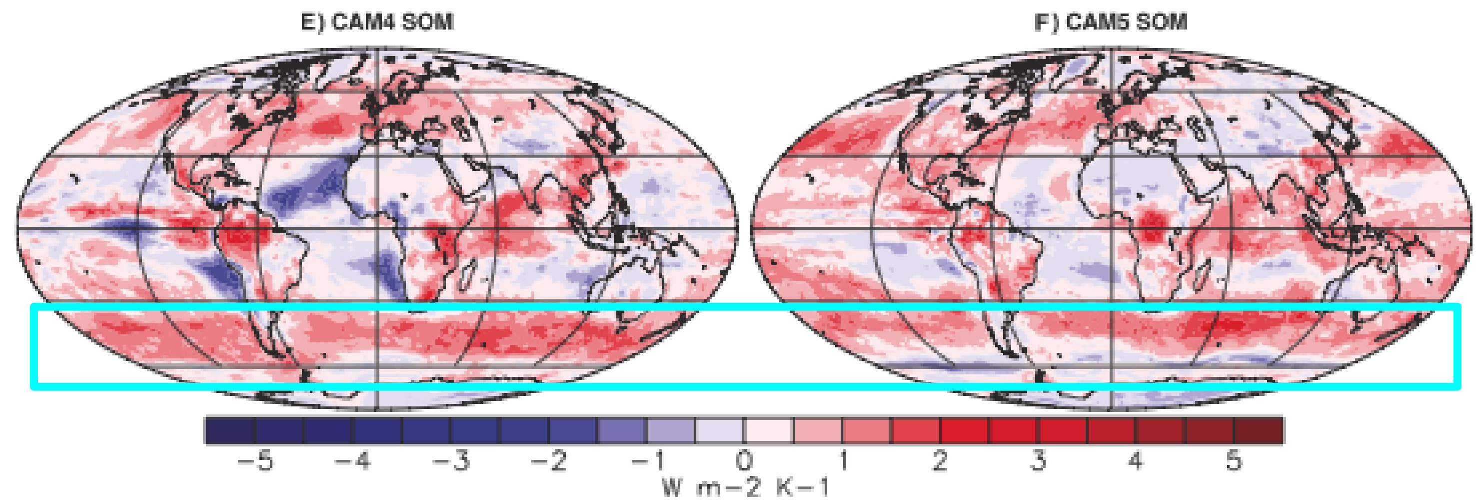
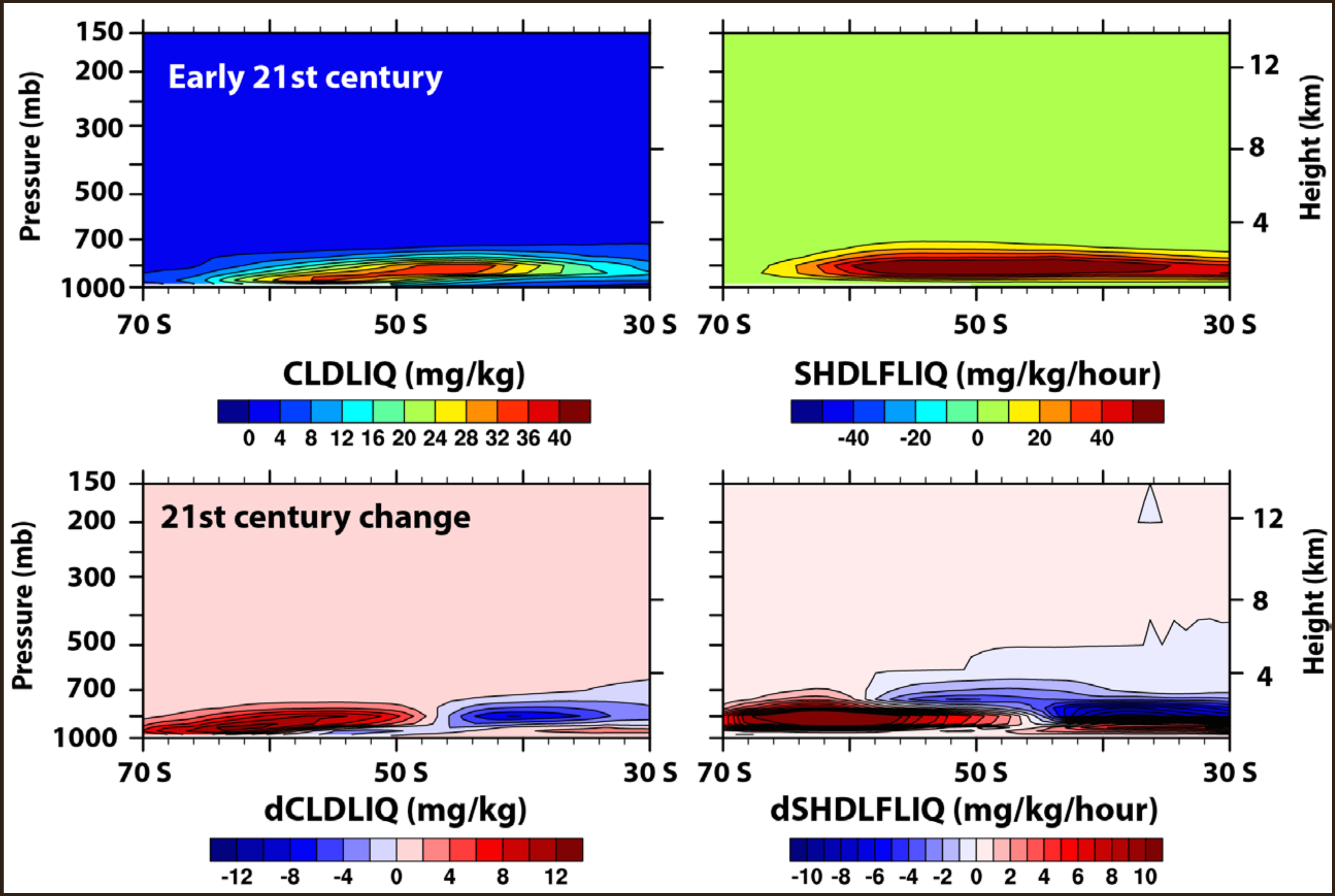


FIG. 6. Adjusted cloud feedback (W m^{-2} K^{-1}) for ASCF in (a) CAM4-SOM and (b) CAM5-SOM, for ALCF in (c) CAM4-SOM and (d) CAM5-SOM, and For net ACF in (e) CAM4-SOM and (f) CAM5-SOM.

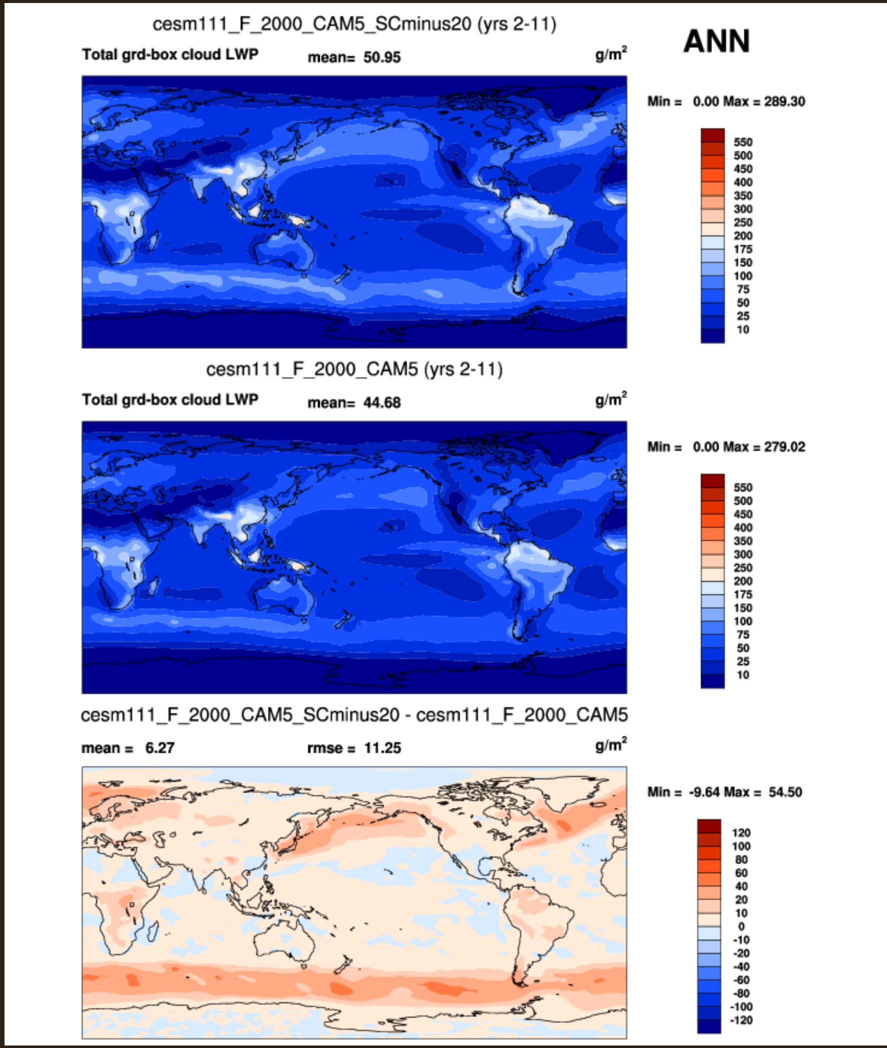
Cloud feedbacks in idealized 2xCO_2 experiments
***Gettelman, Kay, and Shell* (2012)**

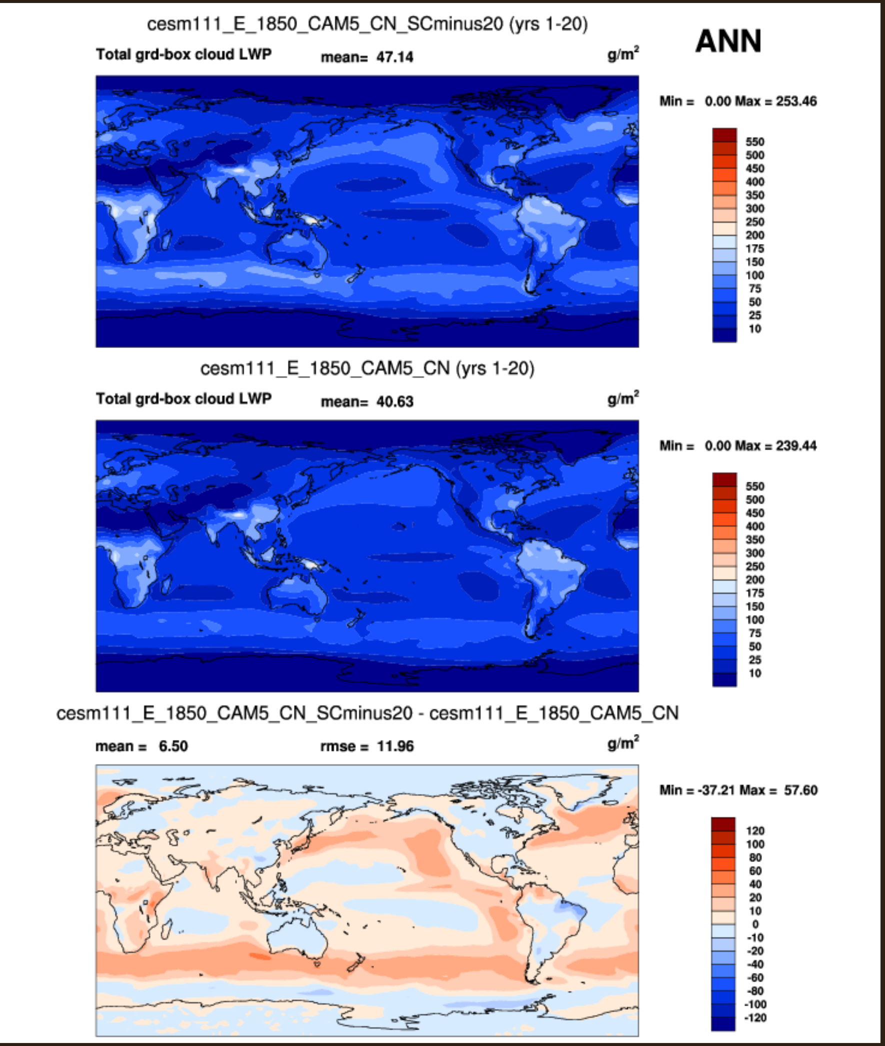
1) Literature focuses on mean state including model biases, not feedbacks
2) Robust feedback pattern [e.g., CMIP5, *Zelinka et al.* 2013, *Vial et al.* 2013]
3) Southern Ocean radiation has global impacts [e.g., *Hwang et al.* 2013]

Shallow convection detrainment…

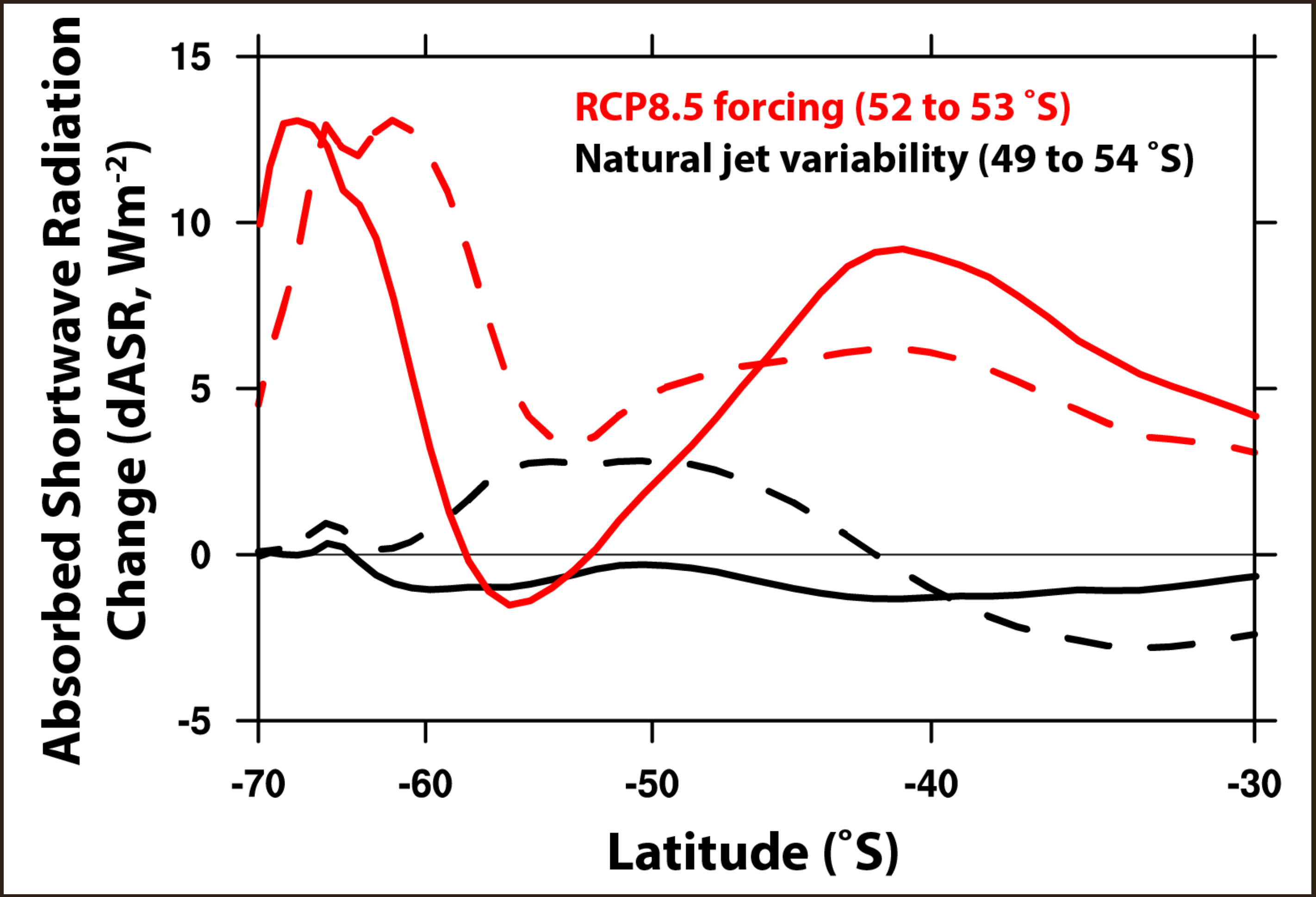


AMIP vs. Coupled to mixed layer ocean cloud liquid water path changes





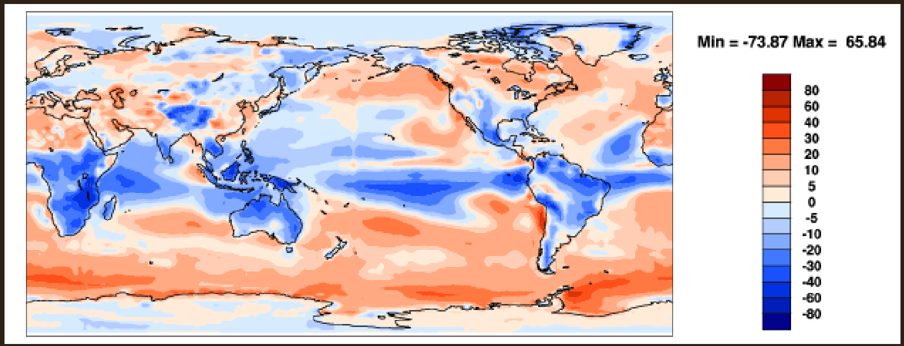
Similar results with CCSM4 (dashed)

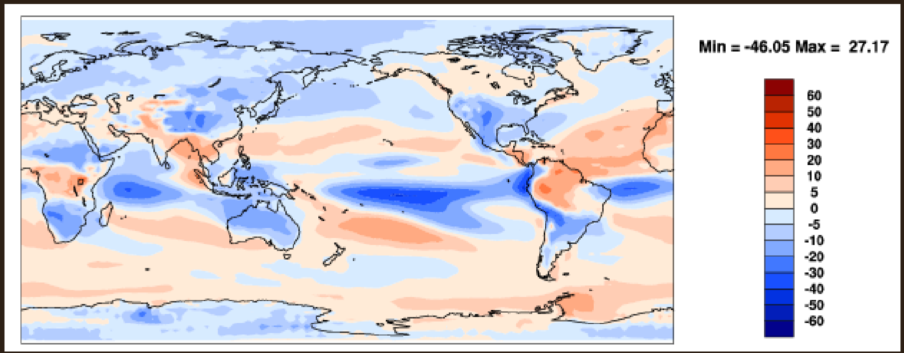


Kay et al. 2014

For ASR: RCP8.5 forcing >> natural jet variability

Compensating biases lead to a balanced model state in many climate models





FSNTOA bias vs. CERES (top)
FLUT bias vs. CERES (bottom)
cesm111_E_1850_CAM5_CN

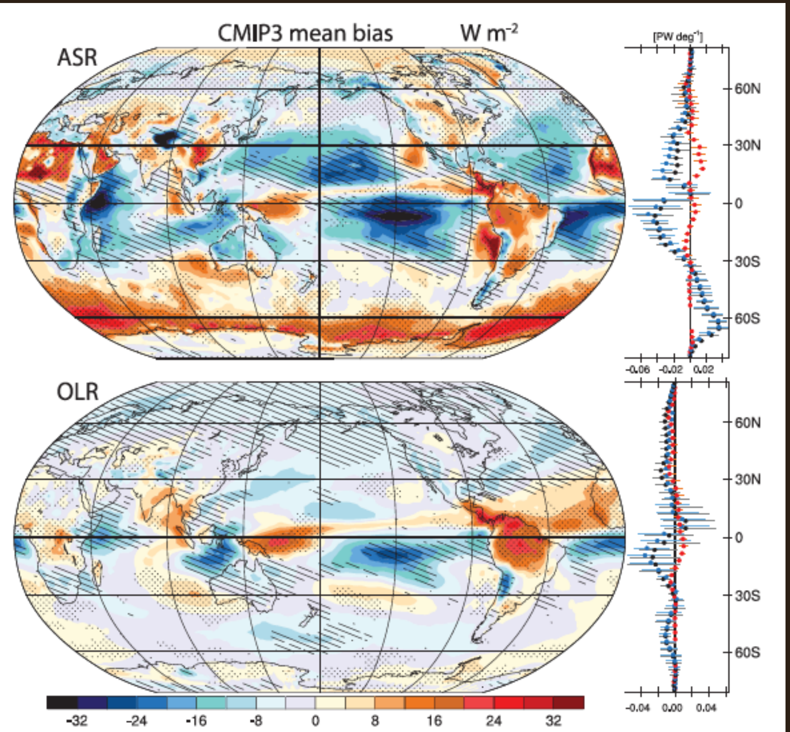
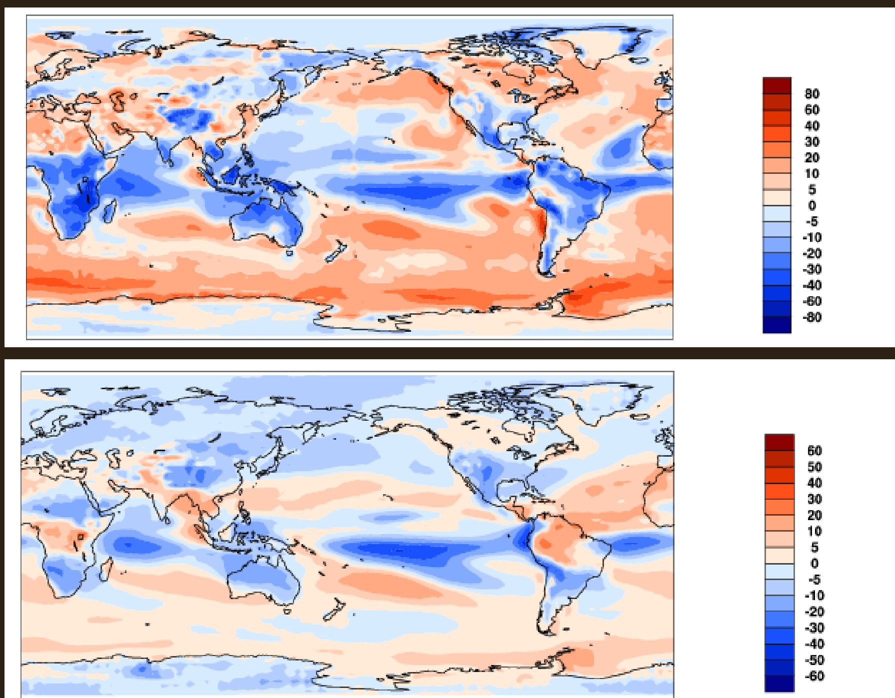
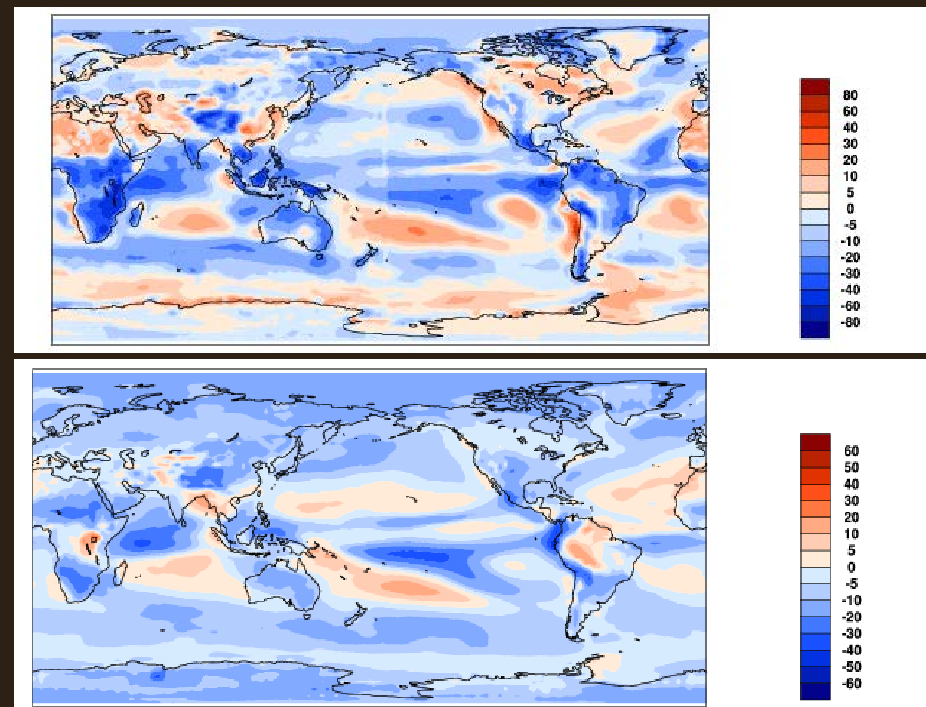


FIG. 6. Biases in (top) ASR and (bottom) OLR relative to observations regionally for 1990–99 in W m^{-2}, where stippled (hatched) regions correspond to regions in which at least three quarters of the models share a common positive (negative) bias. (right) The model zonal mean is given (dots) with the 25th to 75th percentile range (lines) over land (red), ocean (blue), and all (black) surfaces.

Compensating biases mean that you cannot fix biases in isolation



FSNTOA bias (top)
FLUT bias (bottom)
cesm111_E_1850_CAM5_CN



FSNTOA bias (top)
FLUT bias (bottom)
cesm111_E_1850_CAM5_CN_SCminus20