# The influence of “fixing” the Southern Ocean shortwave radiation model bias on global energy budgets and circulation patterns

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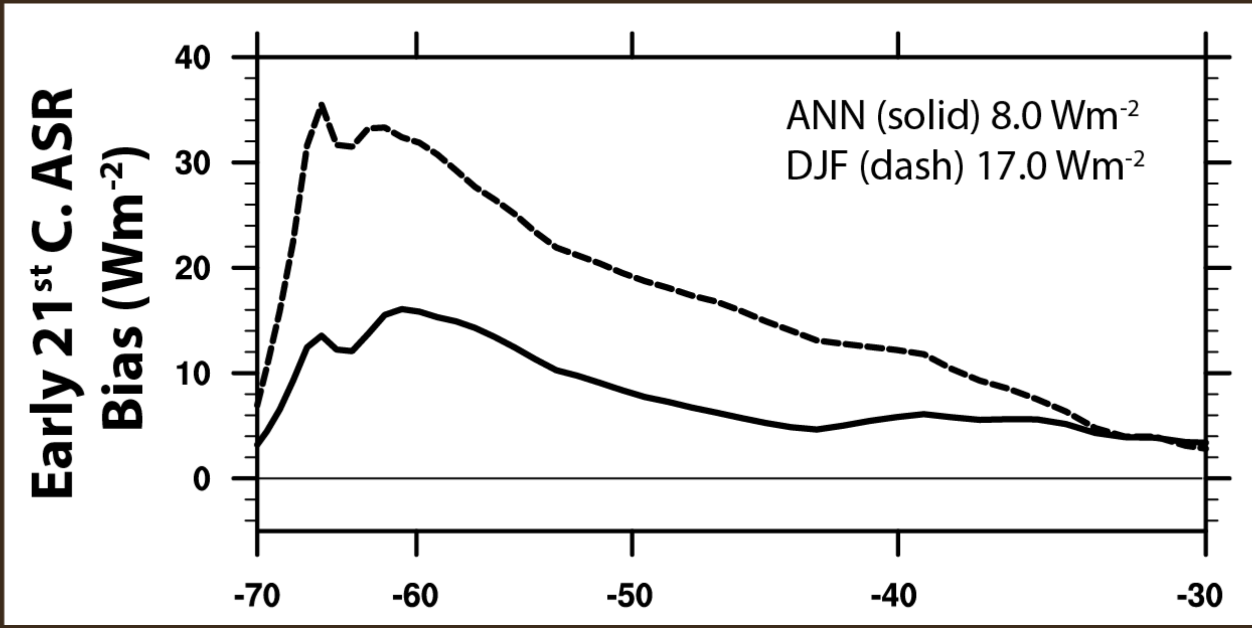
University of Colorado Boulder

# Excessive Absorbed Shortwave Radiation over Southern Ocean (e.g., CESM-CAM5 below)



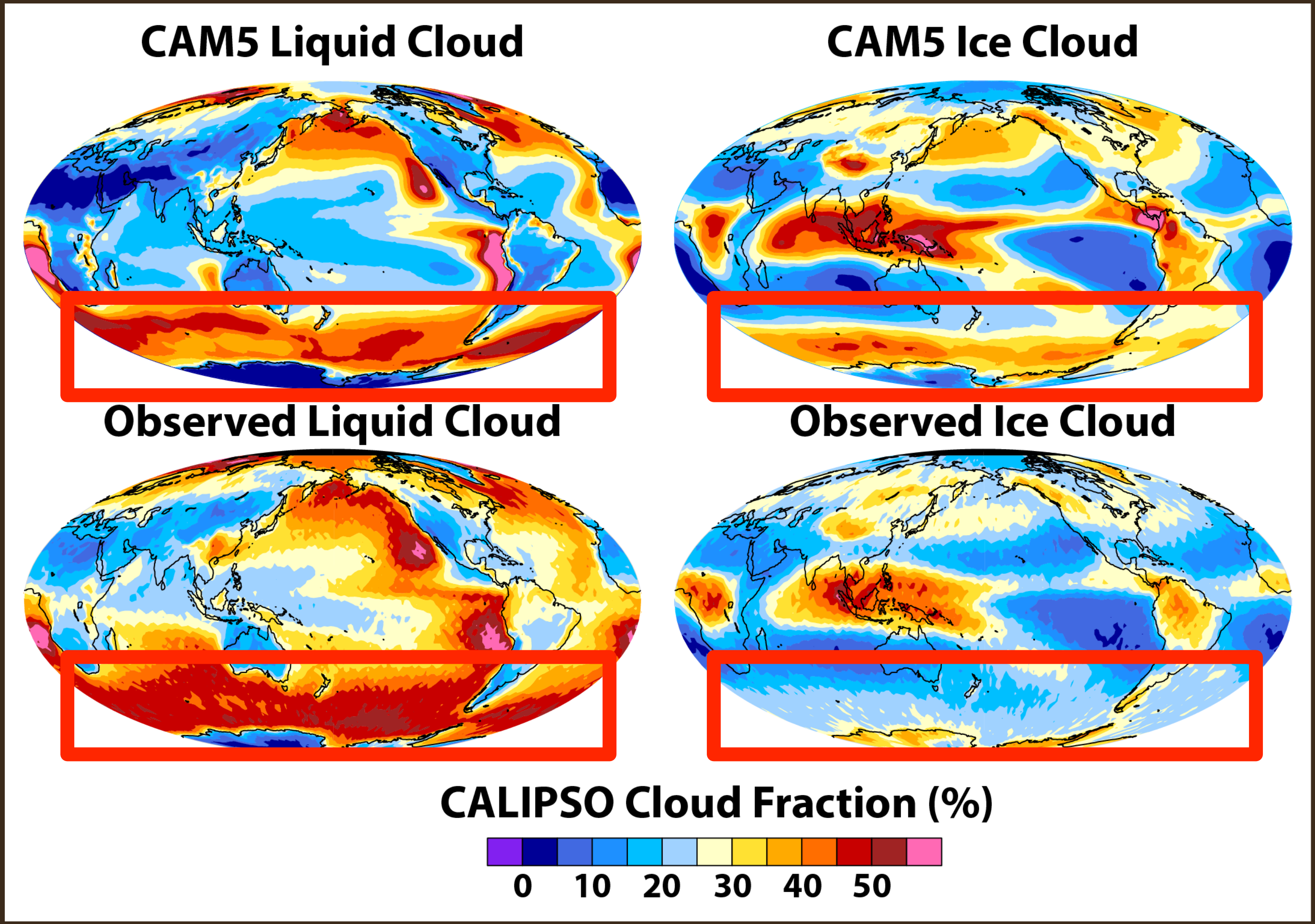

*Kay et al. 2014 Figure 1*

Today's talk:

1) How do we "fix" this excessive ASR bias?
2) What are the climate impacts of "fixing it"?

# Cloud phase biases in atmosphere-only CAM5 runs

*(using simulator-enabled comparisons with CALIPSO)*




**Over the Southern Ocean: Not enough Liquid, Too much Ice**

# CAM5's shallow convection scheme controls cloud condensate phase via a temperature ramp…

Let's add more supercooled cloud liquid in shallow convective clouds ("experiment")…

We're off to races!!

# Increasing supercooled liquid in shallow convective clouds dramatically reduces the CAM5 Southern Ocean absorbed shortwave bias

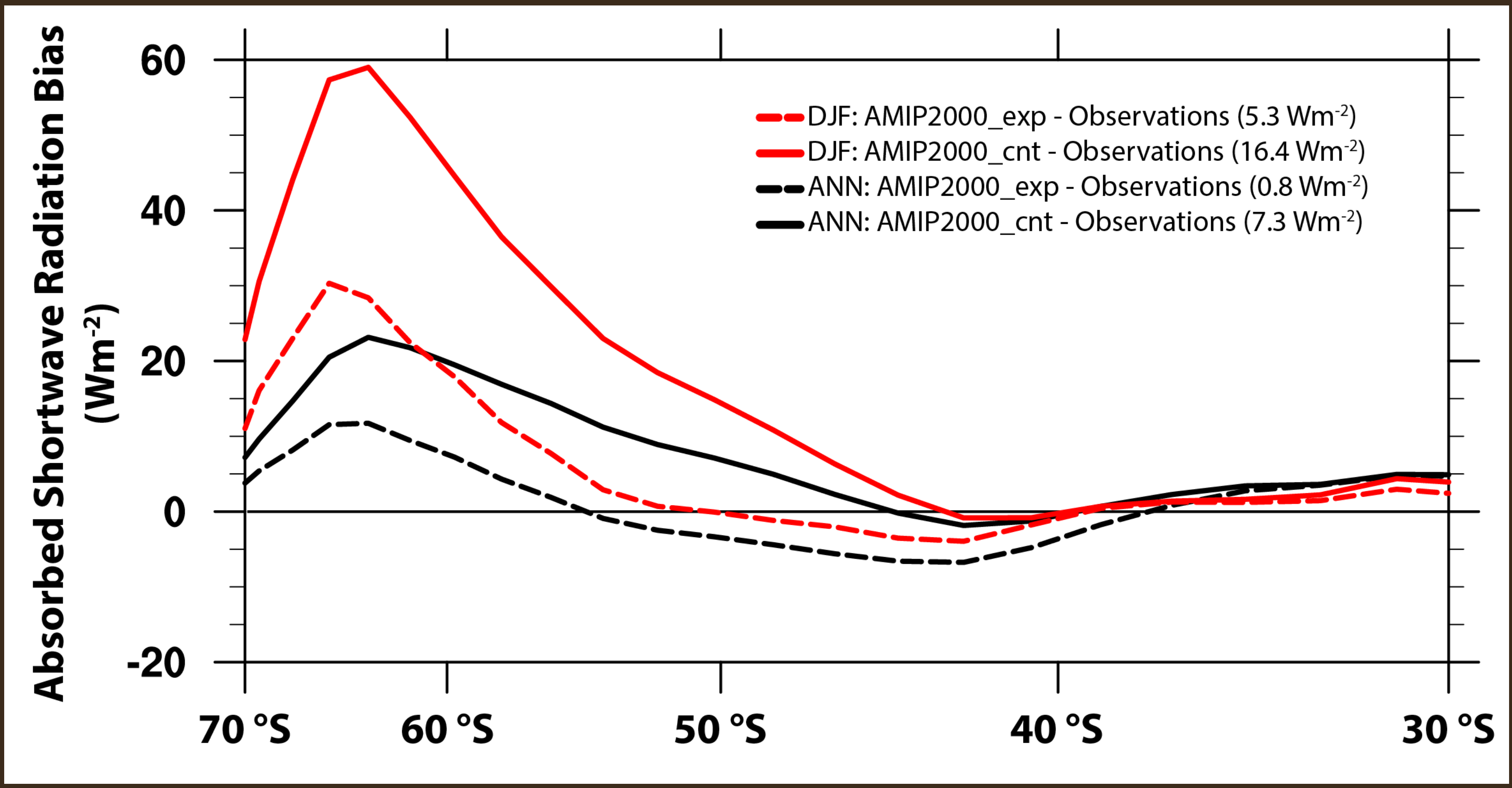
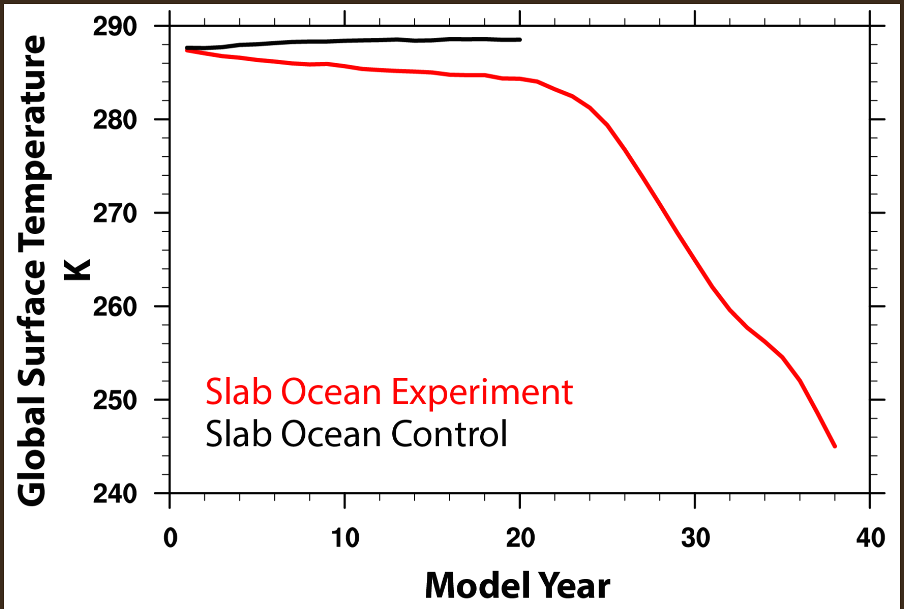



*Figure 4 - Kay et al. submitted*

# Do you remember the happy polar bears at last year's CFMIP meeting?


Runaway global cooling and sea ice expansion with increased supercooled liquid in shallow convective clouds…

# PROGRESS:
# We "fixed" both Southern Ocean and Tropical shortwave radiation biases!

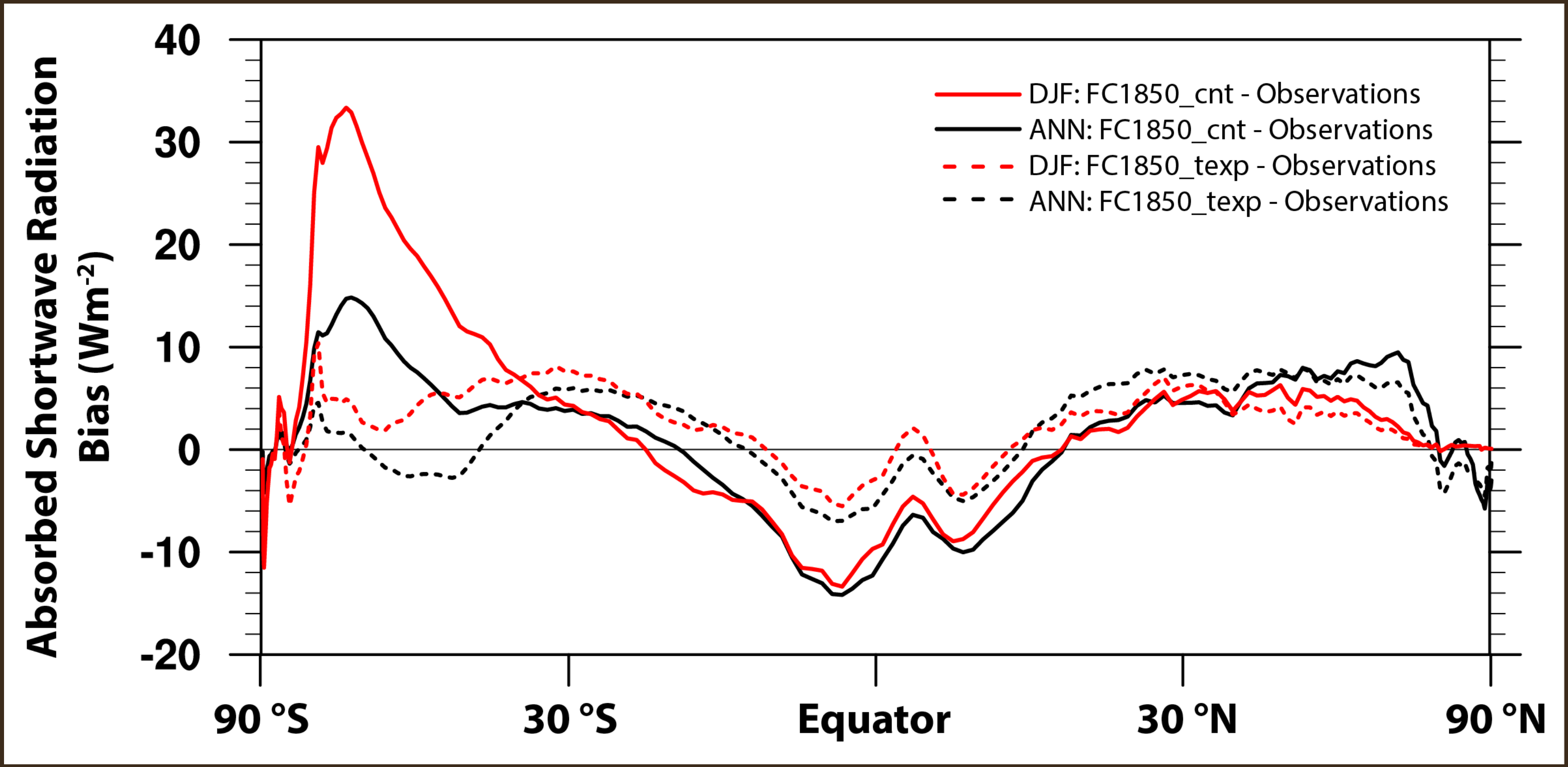
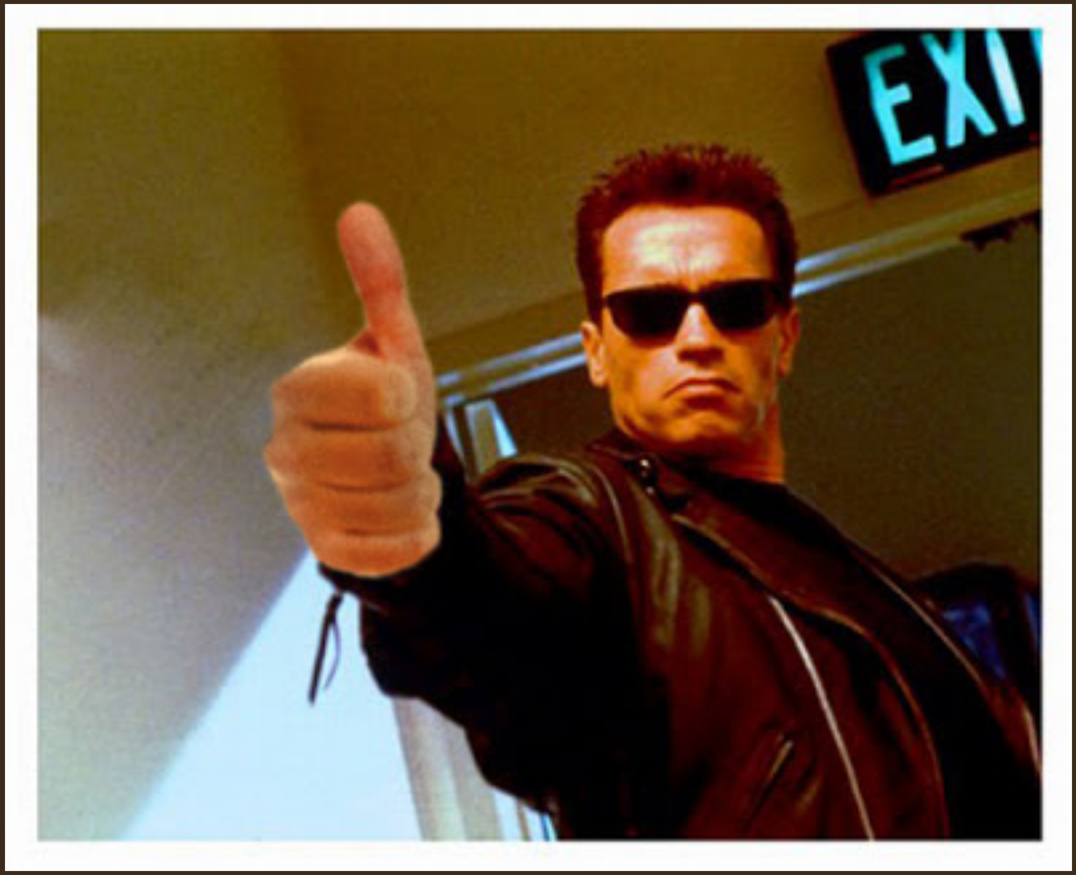



*Figure 5 - Kay et al. submitted*

Hypothesis Verified: Increasing supercooled liquid in CAM5 clouds “fixes” the excessive absorbed shortwave radiation over the Southern Ocean.




We “fixed” it!!

# What are the climate impacts of "fixing" the excessive Southern Ocean absorbed shortwave bias?

***Cooler Southern Ocean?***

***Jet changes?***

***Reduced tropical rainfall biases?***

**Link between the double-Intertropical Convergence Zone problem and cloud biases over the Southern Ocean**

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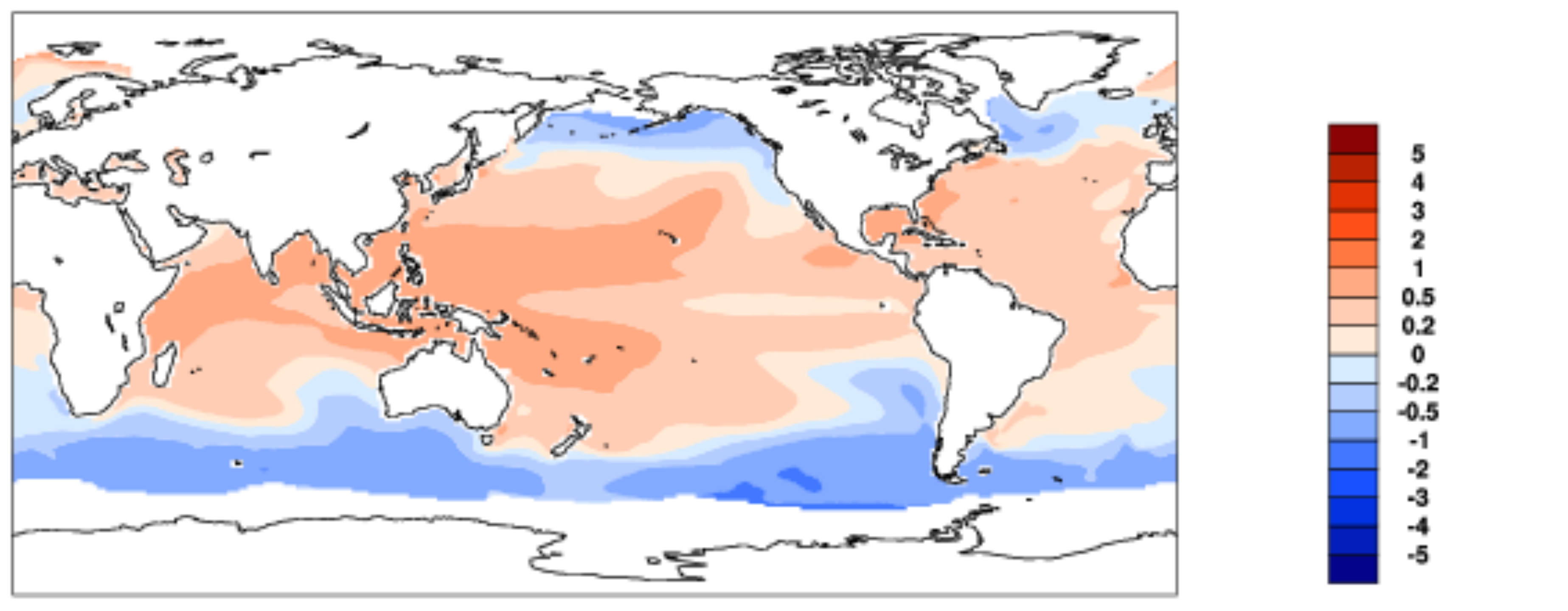
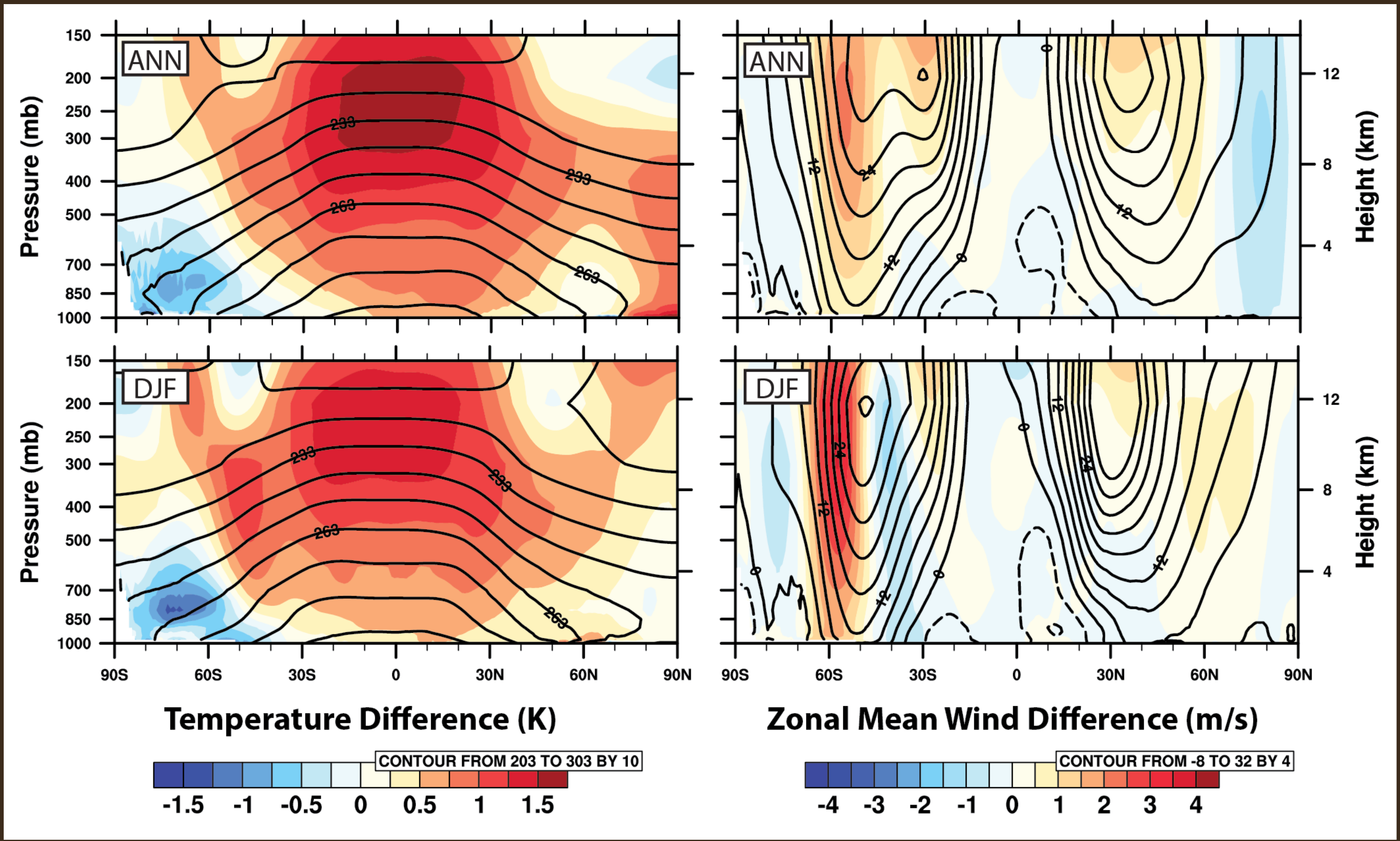
# Sea Surface Temperatures: Cooling in the Southern Ocean, Warming Elsewhere




Fully coupled 1850 runs SST difference (deg C): tuned experiment - control

# Stronger meridional temperature gradients and stronger jet (SH, especially in DJF)




Fully coupled 1850 runs: tuned experiment - control

Does reducing the Southern Ocean shortwave radiation bias also reduce tropical precipitation biases (i.e., the double ITCZ)?

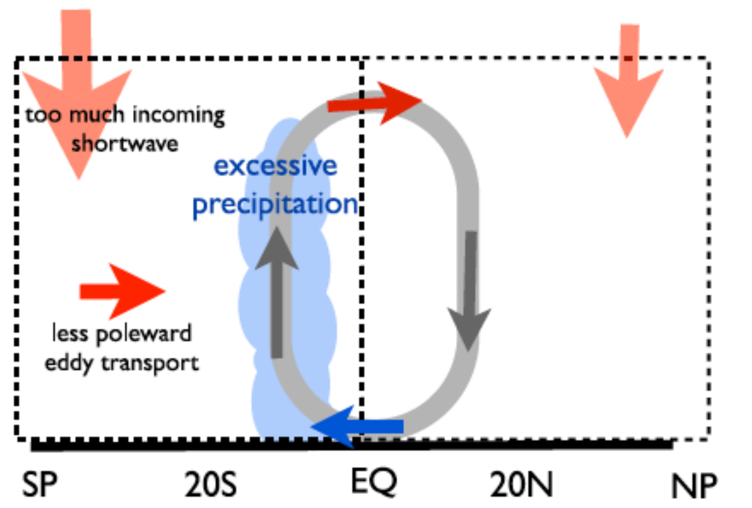
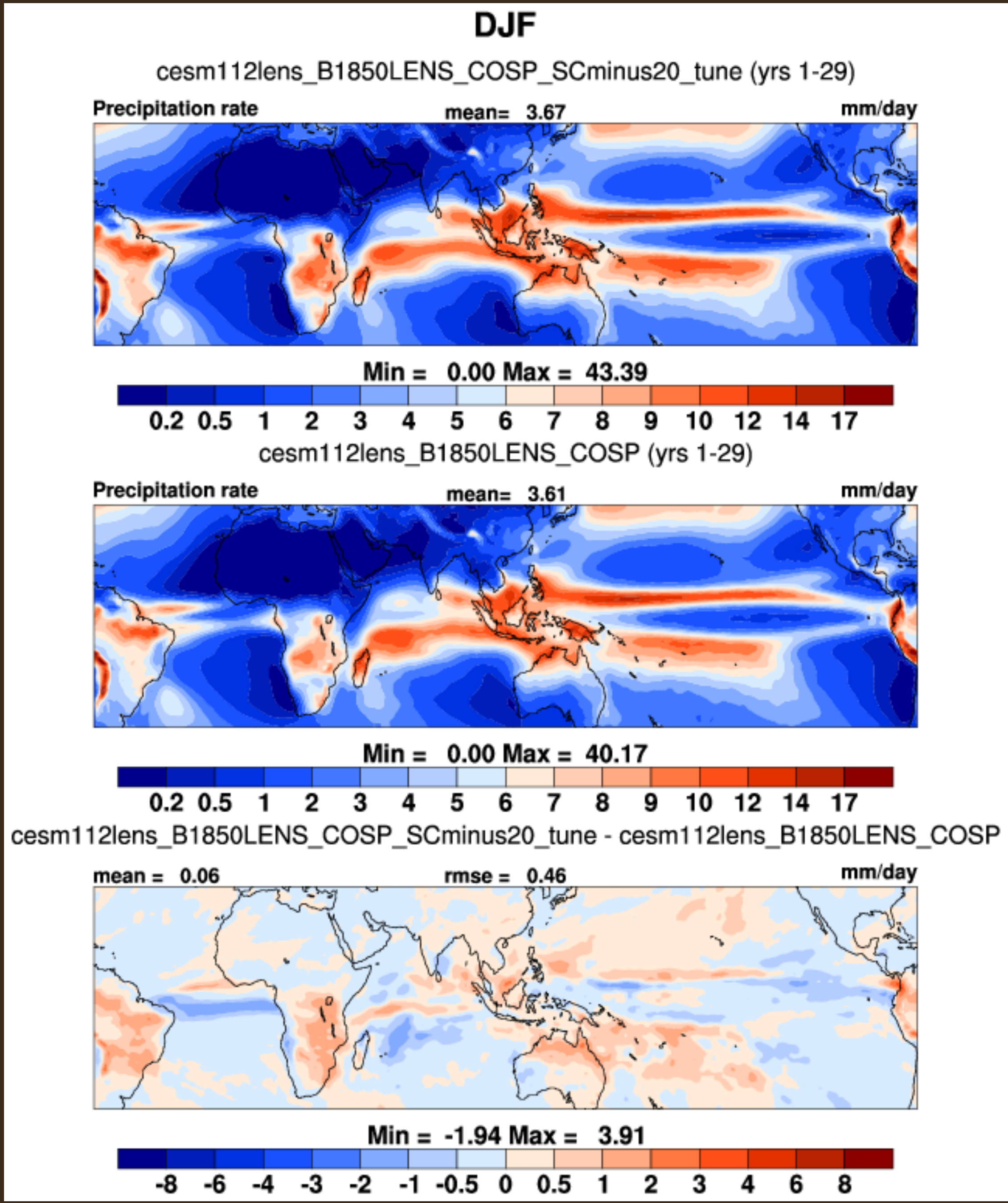



**Fig. 4.** Schematic of the proposed mechanism for the double-ITCZ bias. The anomalous energy fluxes and circulation in multimodel mean relative to observations are plotted. Most models simulate too much incoming shortwave radiation over the Southern Ocean due to cloud biases, which results in anomalously high temperatures in the Southern Hemisphere midlatitudes. Similar cloud biases exist in Northern Hemisphere midlatitudes, but to a much smaller degree. The anomalous heating in the Southern Ocean is spread into the Southern Hemisphere tropics by baroclinic eddies. An anomalous Hadley circulation is induced to transport energy from the Southern Hemisphere to the Northern Hemisphere (the red arrow across the equator), and keep the tropical tropospheric temperatures relatively flat. Because water vapor is concentrated in the lower troposphere, this anomalous Hadley circulation transports moisture southward (the blue arrow across the equator), and results in excessive precipitation in Southern Hemisphere tropics. Other biases in energy fluxes at the top of the atmosphere or at the surface that have hemispheric asymmetry can also affect tropical precipitation through this mechanism.

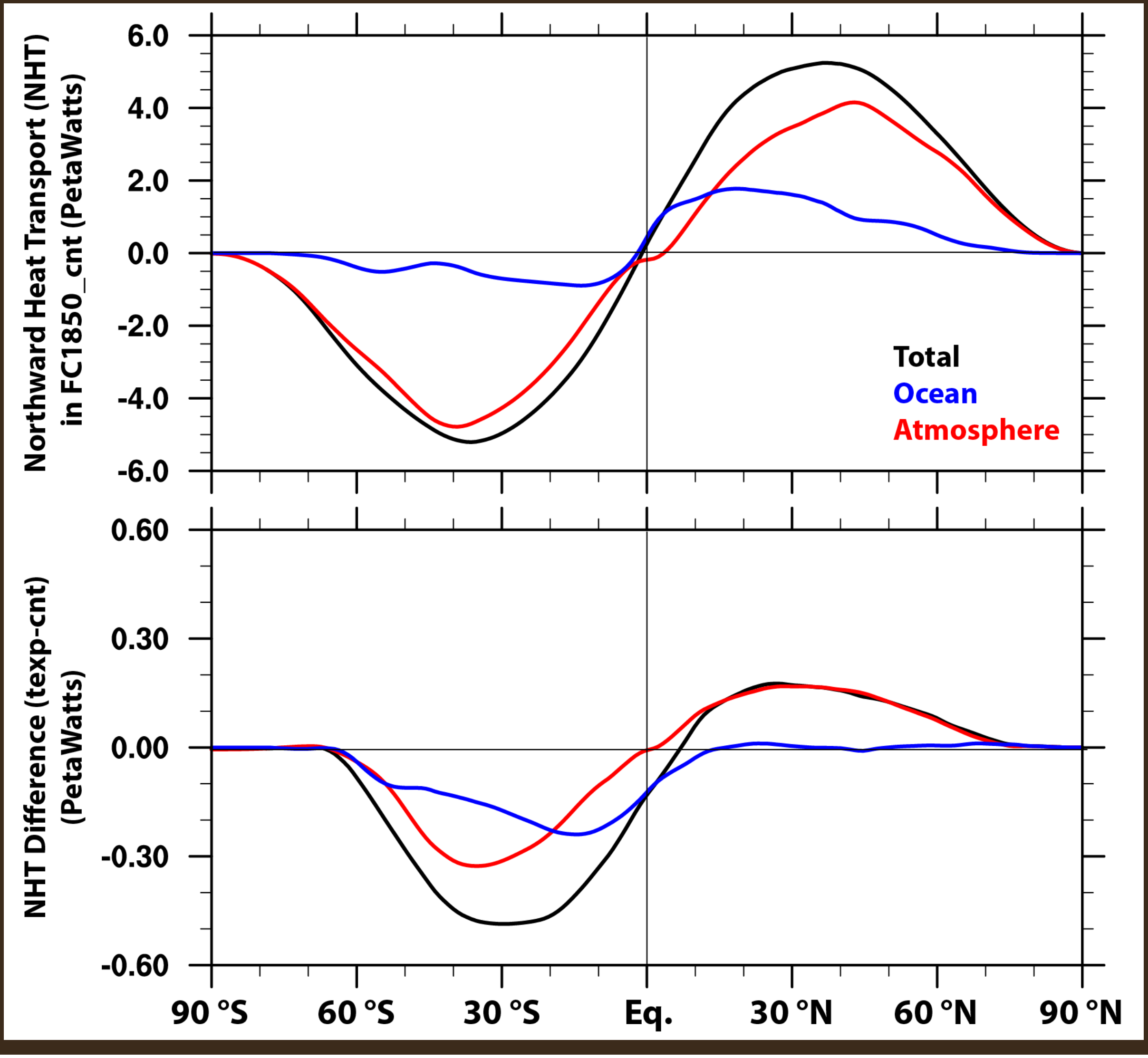
*Hwang and Frierson 2013*

Influence of the Southern Ocean shortwave radiation on tropical precipitation (a la Hwang and Frierson)

Not overwhelming



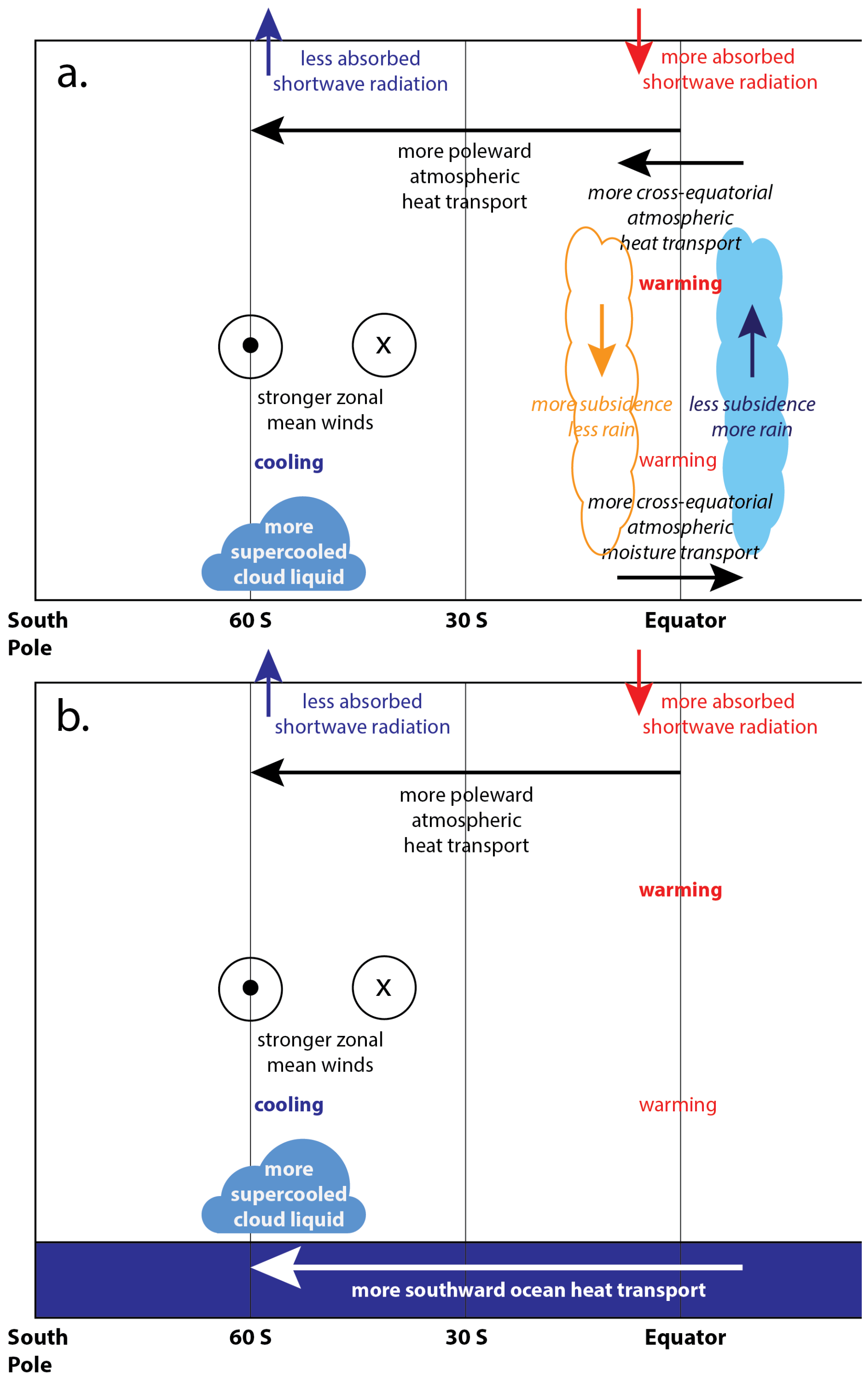
# In the fully coupled tuned experiment, cross-equatorial heat transport changes in the ocean (!), not the atmosphere.



# Original cartoon

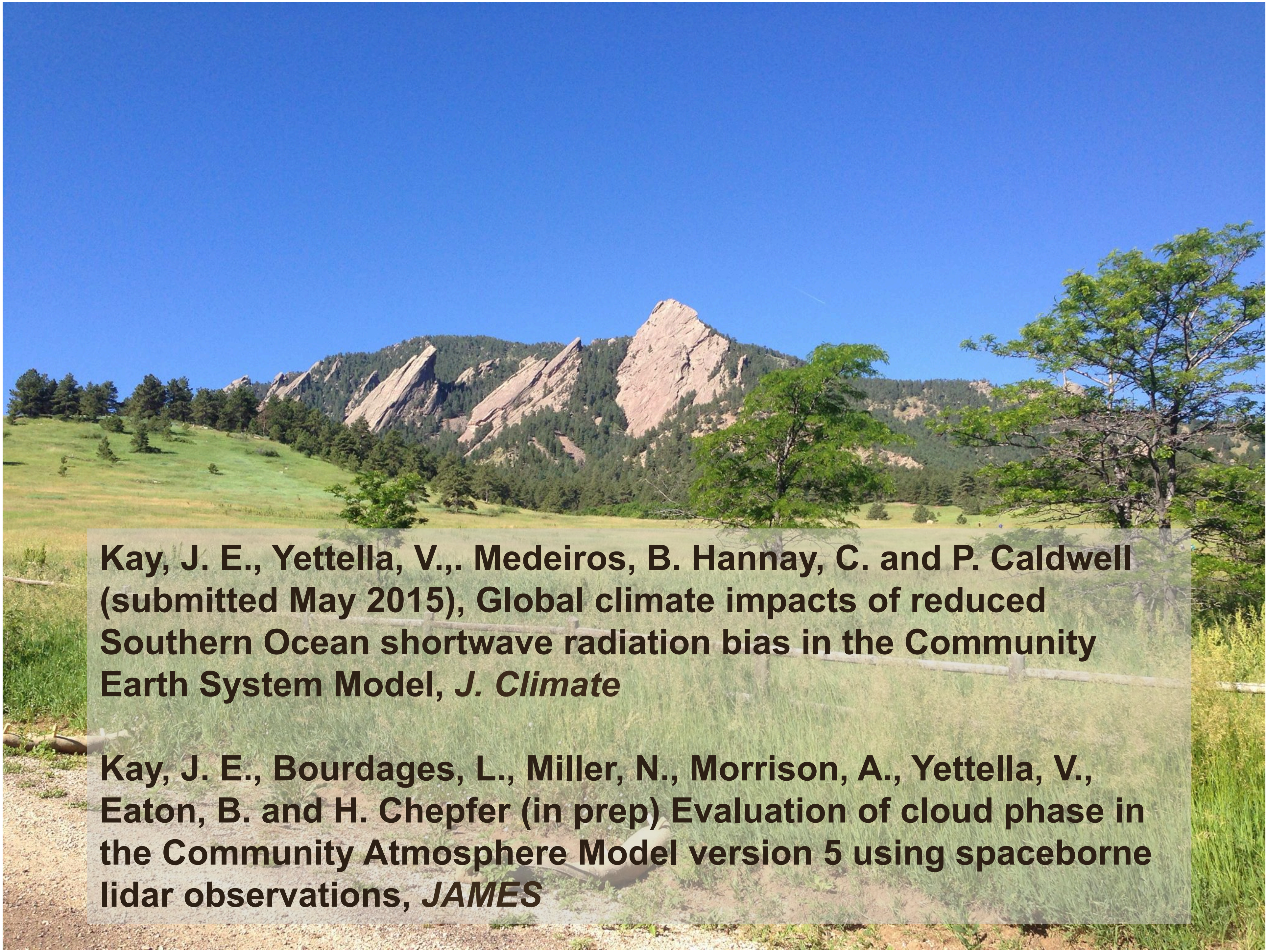
# With Ocean cartoon

Kay et al. (submitted)



# Summary:
# Climate impacts of “fixing”
# Southern Ocean cloud/radiation biases

1. We “fixed” the Southern Ocean shortwave radiation bias by increasing supercooled liquid in shallow convective clouds.
2. First order climate impact = Global cooling, Snowball Earth.
3. Tuned experiment with reduced shortwave bias: brighter/cooler Southern Ocean, dimmer/warmer Tropics, more poleward heat transport, stronger SH jet, and small tropical rainfall changes.
4. **Dynamic ocean heat transport is crucial when assessing the influence of interhemispheric temperature gradients on climate.**




**Kay, J. E., Yettella, V.,. Medeiros, B. Hannay, C. and P. Caldwell (submitted May 2015), Global climate impacts of reduced Southern Ocean shortwave radiation bias in the Community Earth System Model, *J. Climate***

**Kay, J. E., Bourdages, L., Miller, N., Morrison, A., Yettella, V., Eaton, B. and H. Chepfer (in prep) Evaluation of cloud phase in the Community Atmosphere Model version 5 using spaceborne lidar observations, *JAMES***