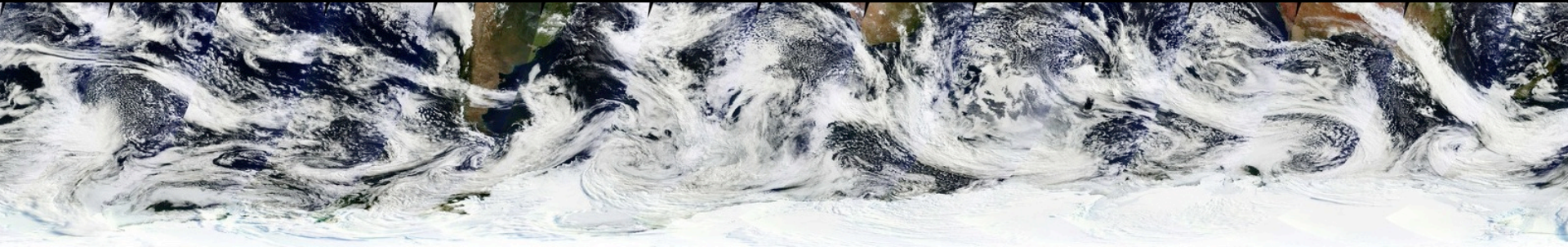




How does “fixing” the Southern Ocean absorbed shortwave radiation bias impact climate sensitivity?



NASA MODIS

William Frey, Jennifer Kay
Atmospheric and Oceanic Sciences
University of Colorado, Boulder
22 June 2016



Overview

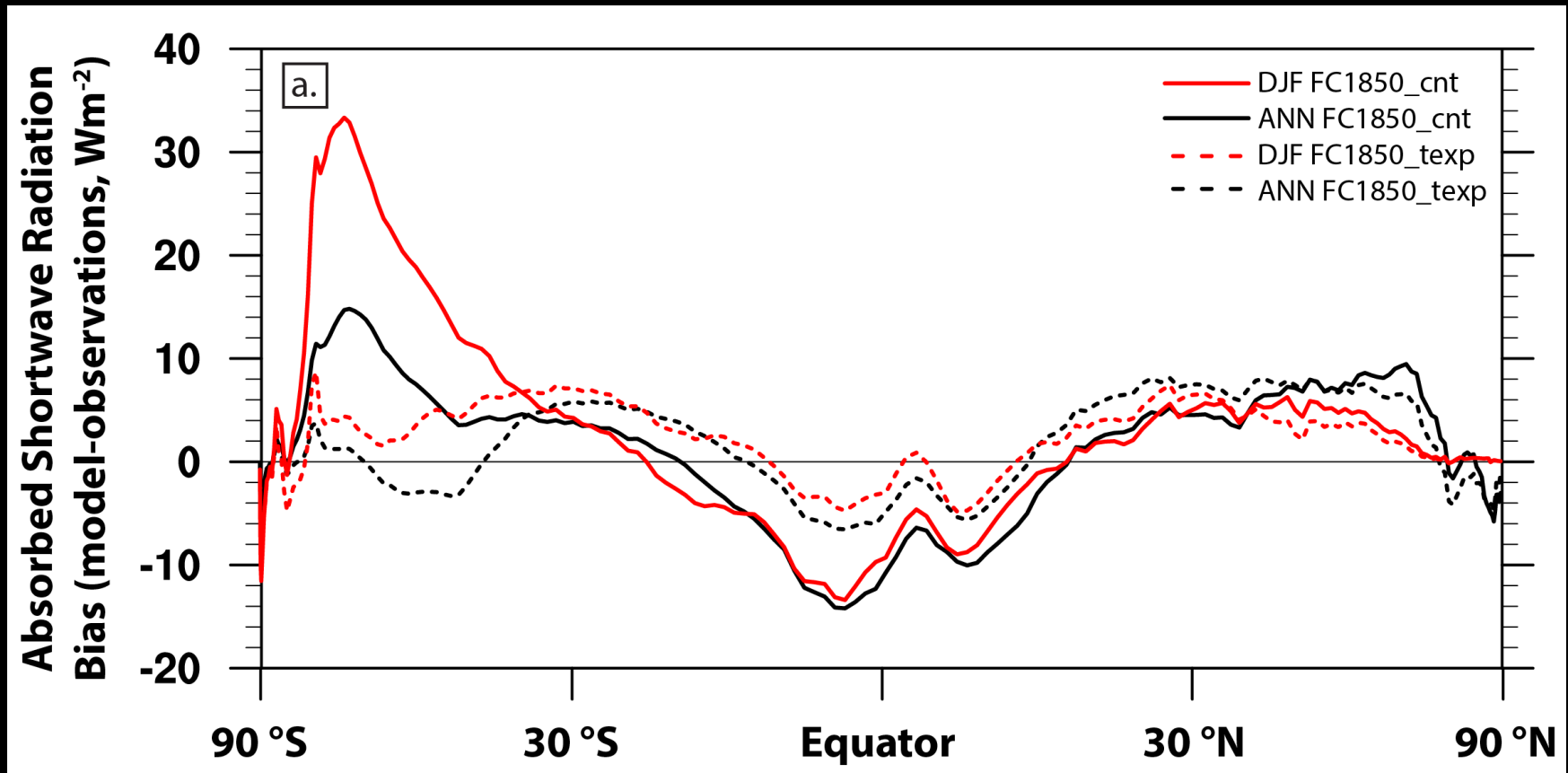
- What is the bias and how was it fixed?
- Result: Increase in Climate Sensitivity
- Mechanisms: Cloud Feedbacks
- The Role of the Ocean
- Conclusions



“Fixing” the Southern Ocean ASR Bias

1. Brighten clouds by Increasing supercooled liquid

2. Tune by changing RH threshold for low cloud formation

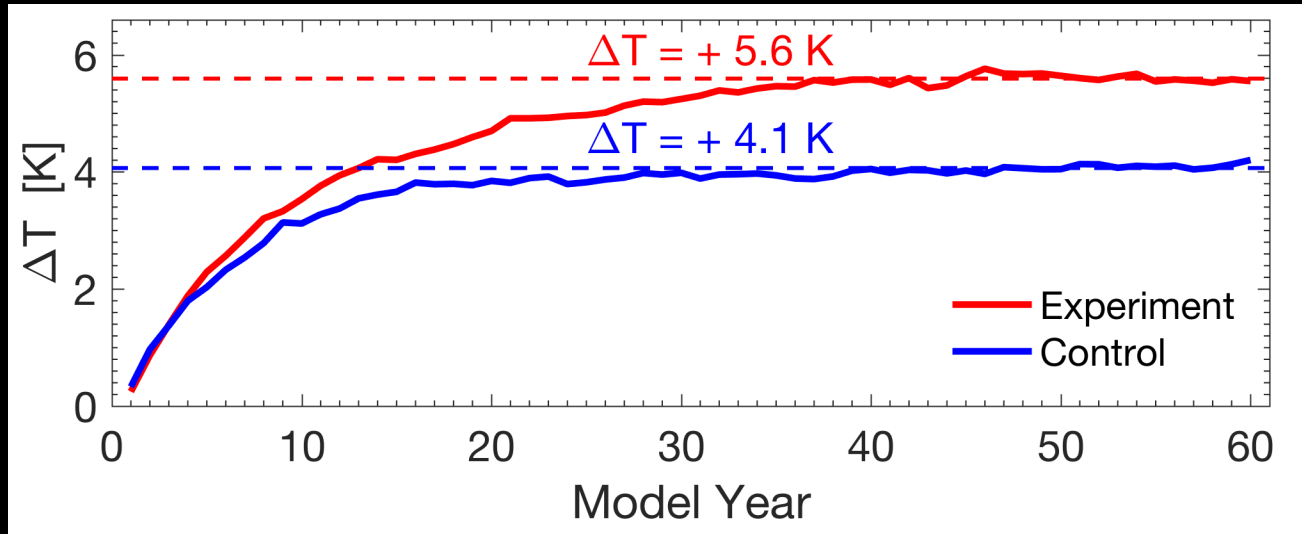


Jen Kay., *et al.* (2016), Global climate impacts of fixing the Southern Ocean shortwave radiation bias in the Community Earth System Model, *J. Climate*, [doi:10.1175/JCLI-D-15-0358.1](https://doi.org/10.1175/JCLI-D-15-0358.1)

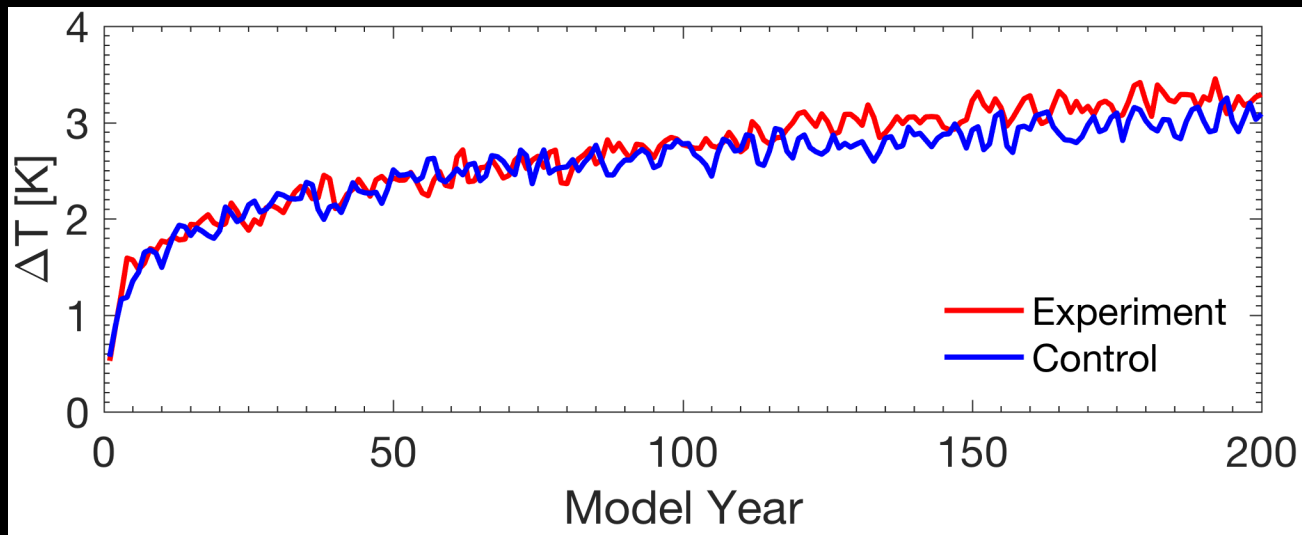


Increased Climate Sensitivity

Slab
Ocean

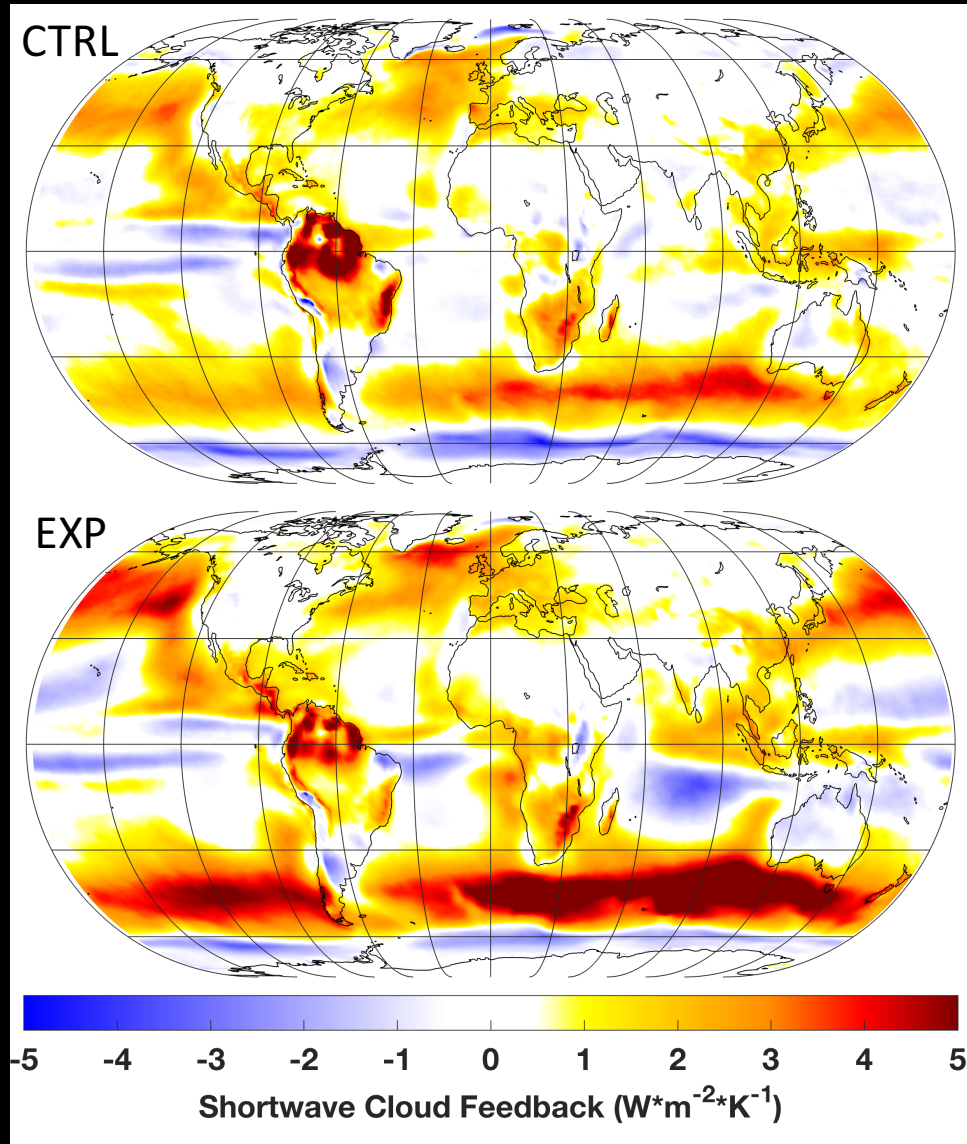


Fully
Coupled



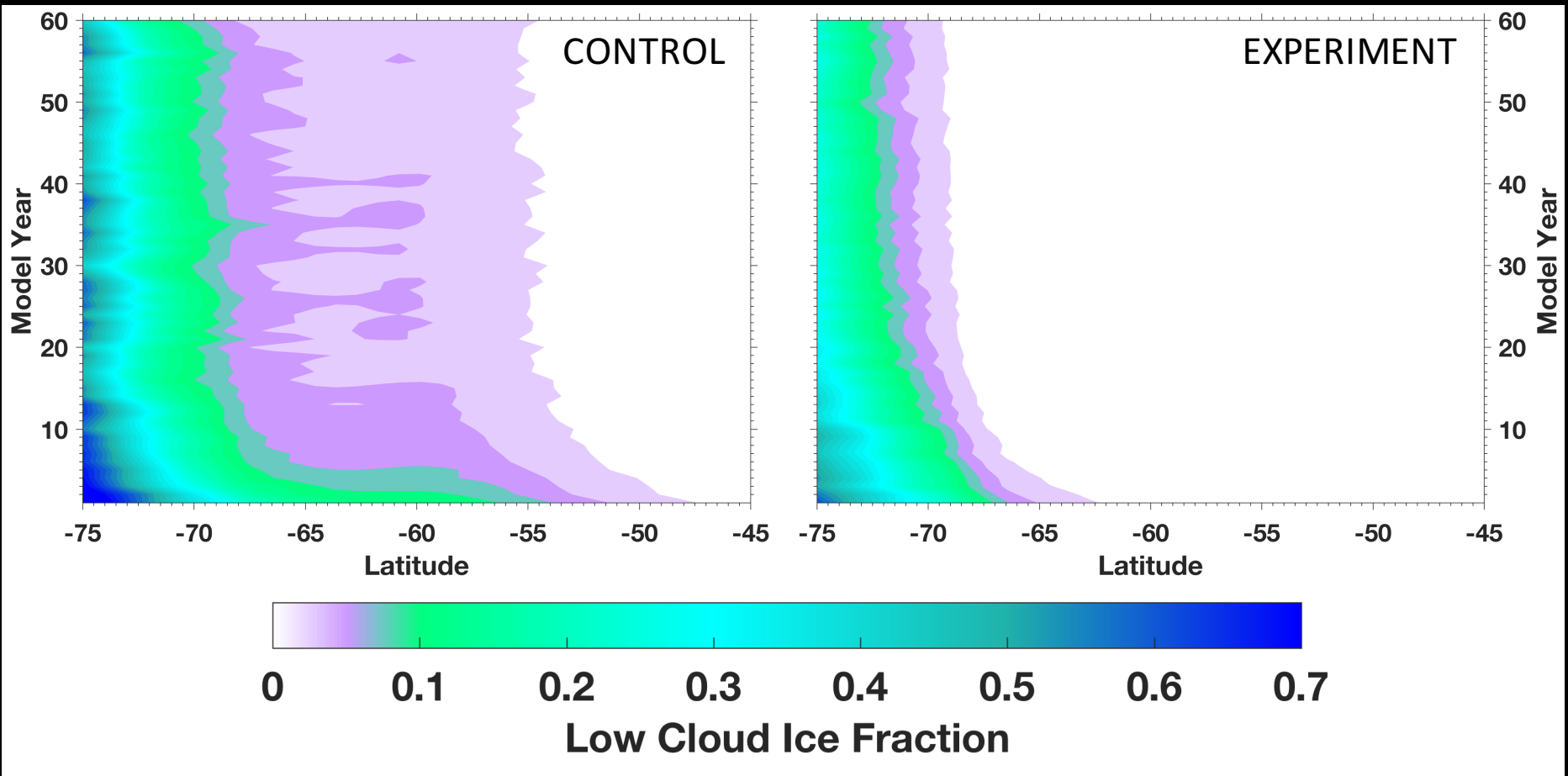


Shortwave Cloud Feedbacks Increase Warming



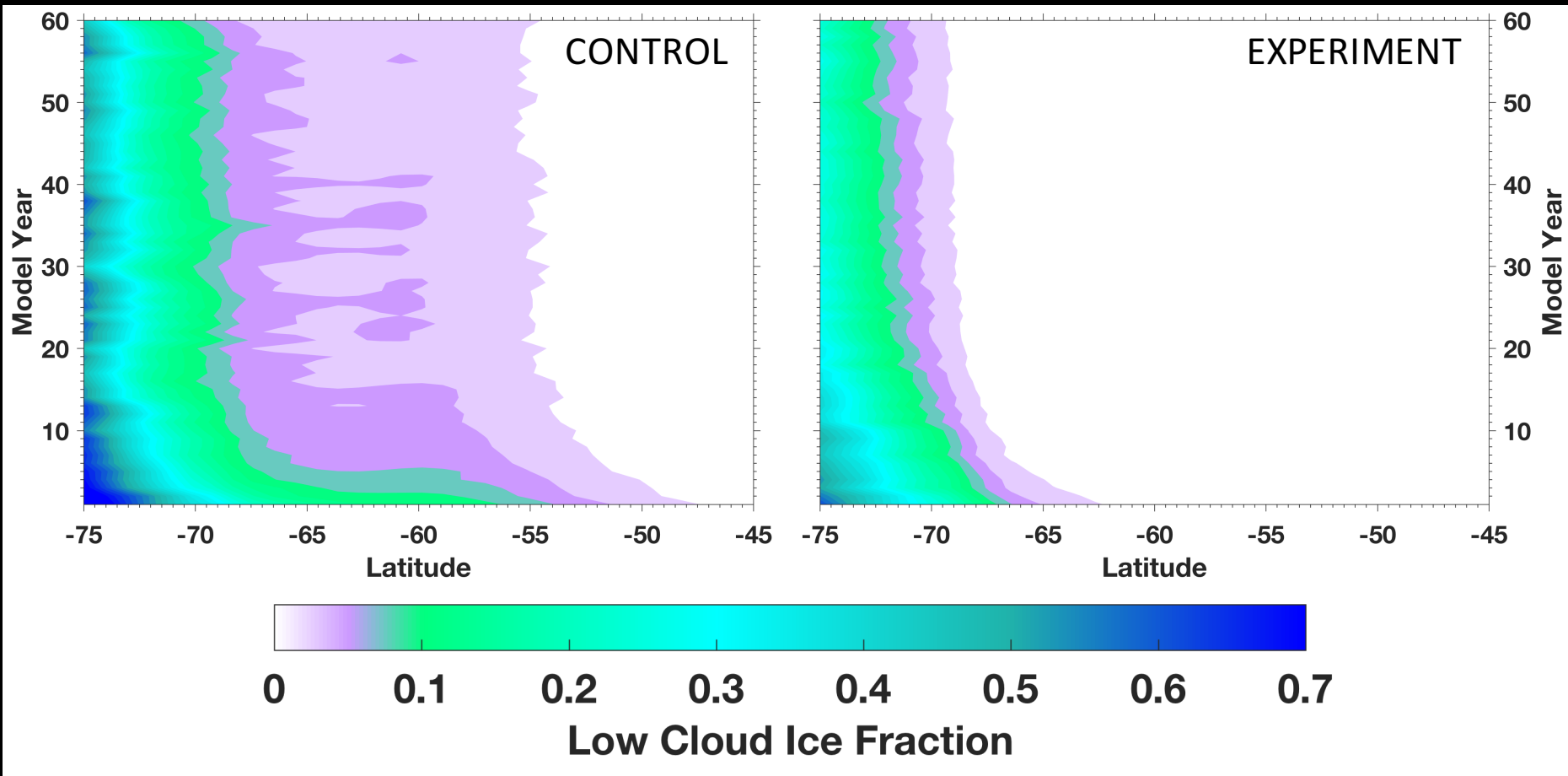


Negative Feedback Driven by Phase Change





Negative Feedback Driven by Phase Change

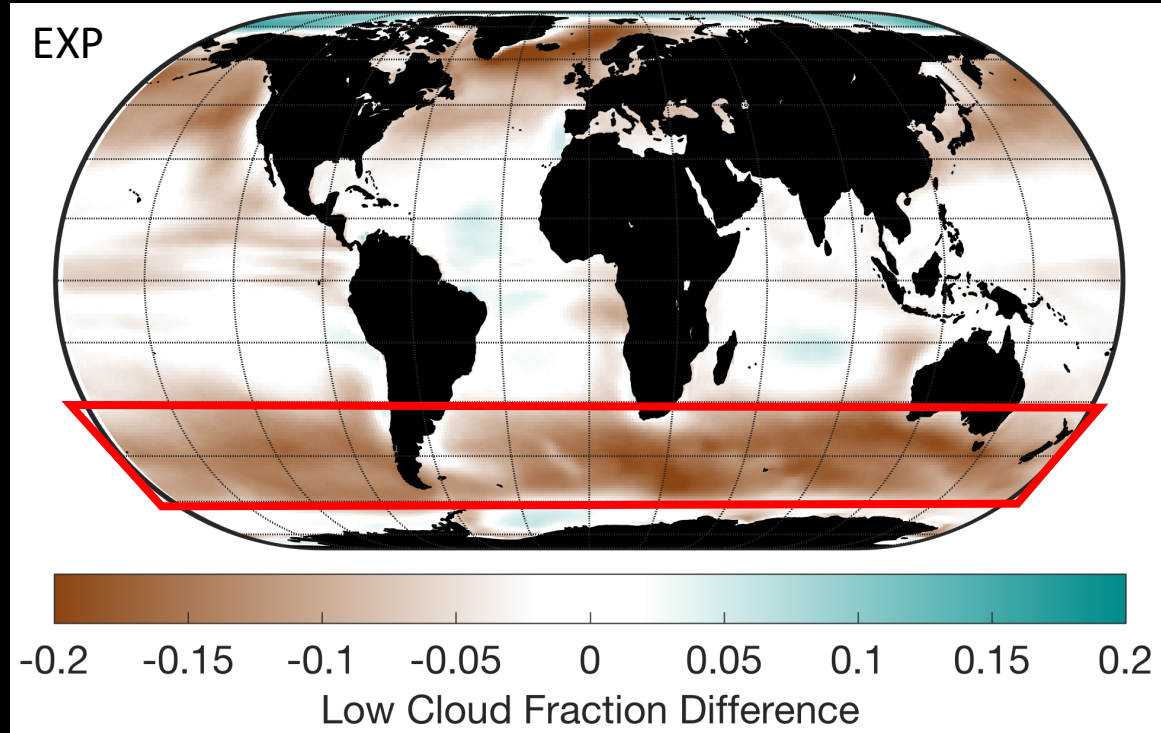


Negative Shortwave Feedback caused by Ice-to-Liquid Conversion with warming

- "Fixed Model" has smaller feedback due to smaller initial ice fraction
- What Causes Continued Warming after Year 20?

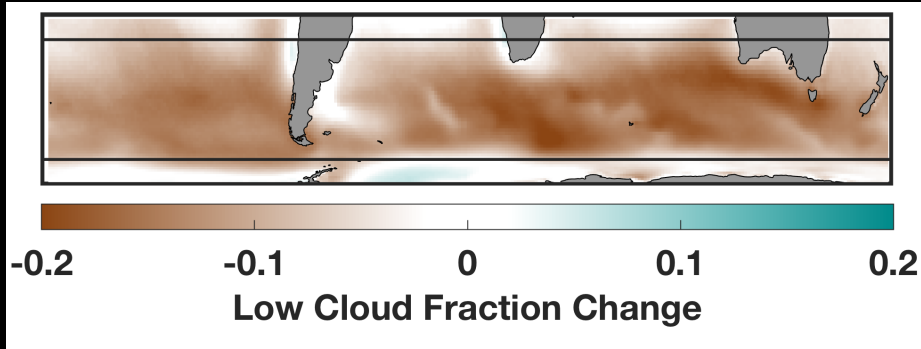


Cloud Fraction Decrease Causes Positive Feedback



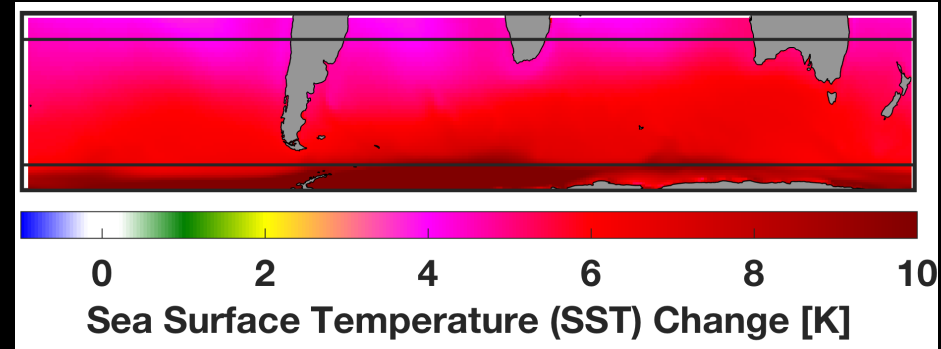
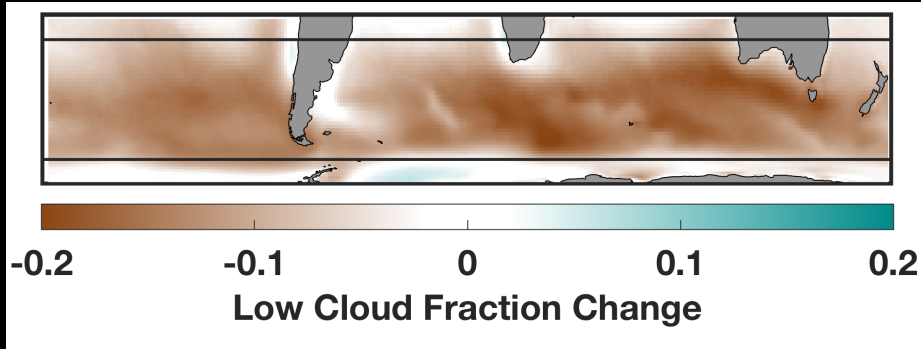


What Causes Mid Latitude Low Cloud Decrease?



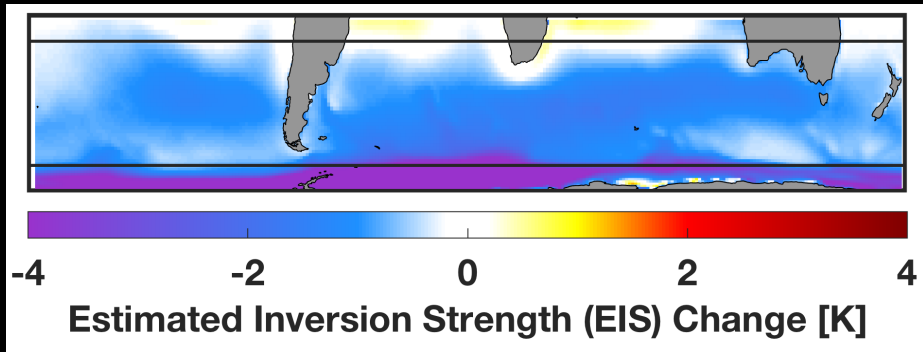
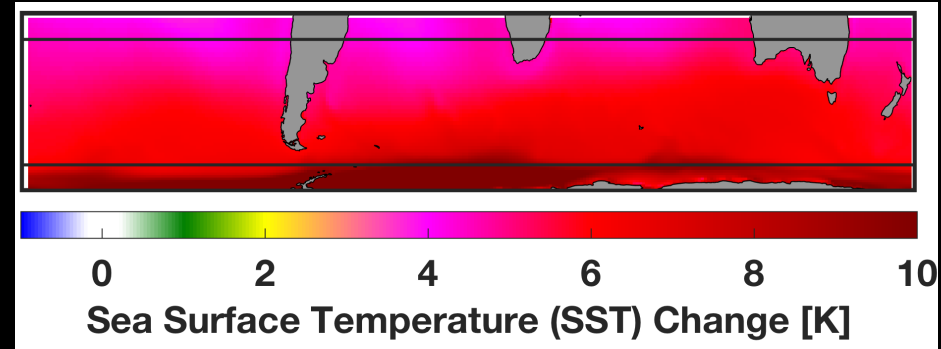
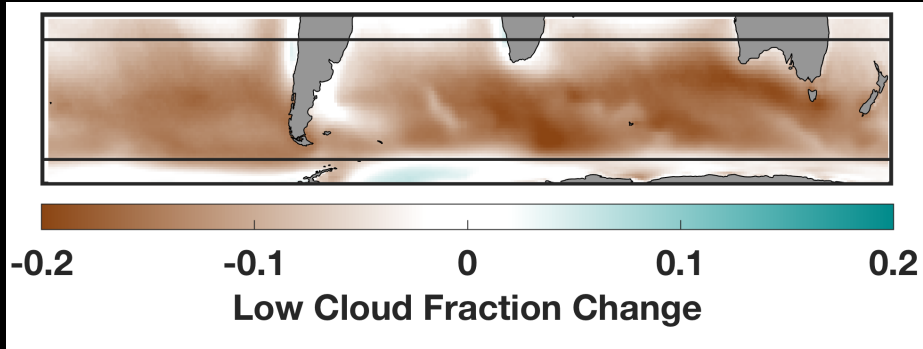


What Causes Mid Latitude Low Cloud Decrease?



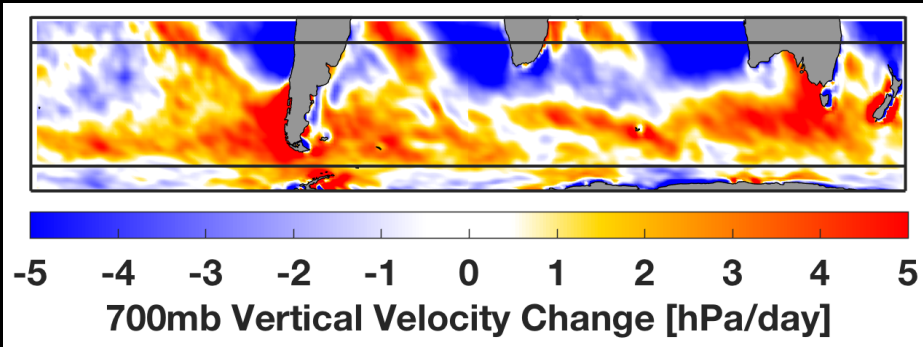
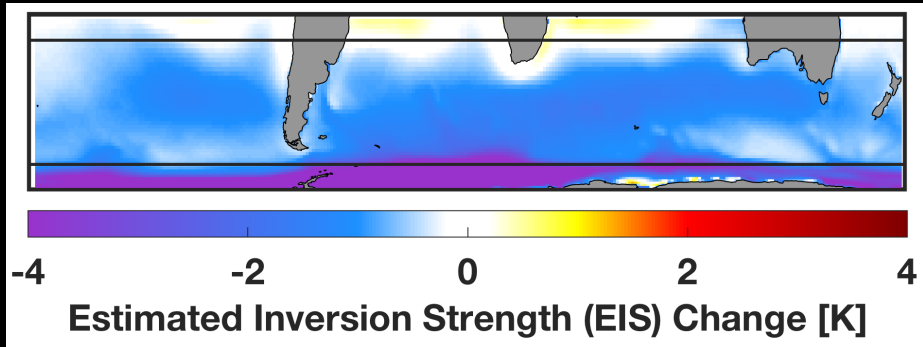
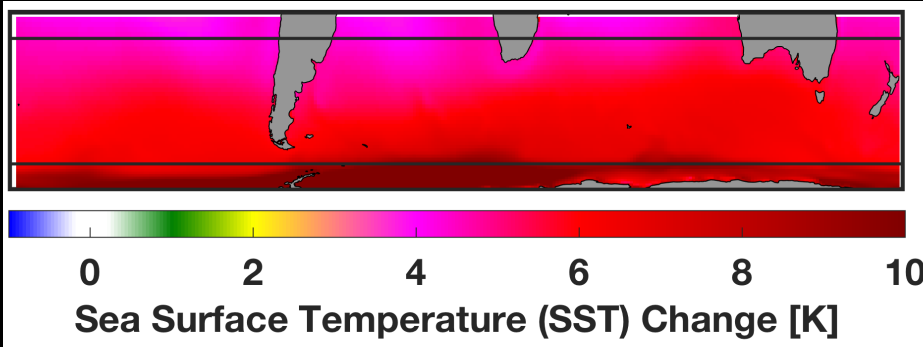
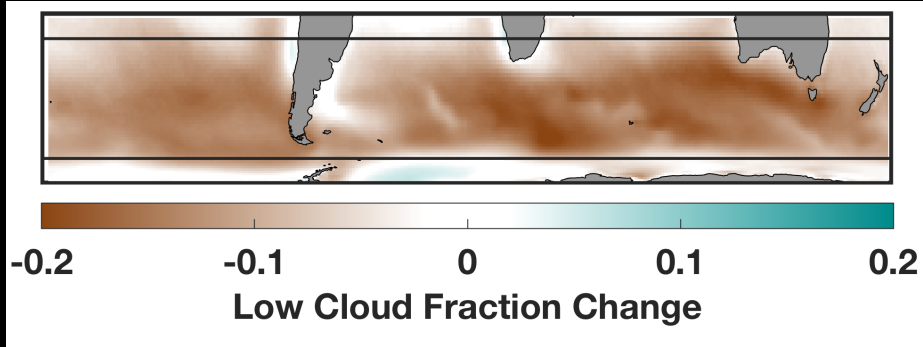


What Causes Mid Latitude Low Cloud Decrease?



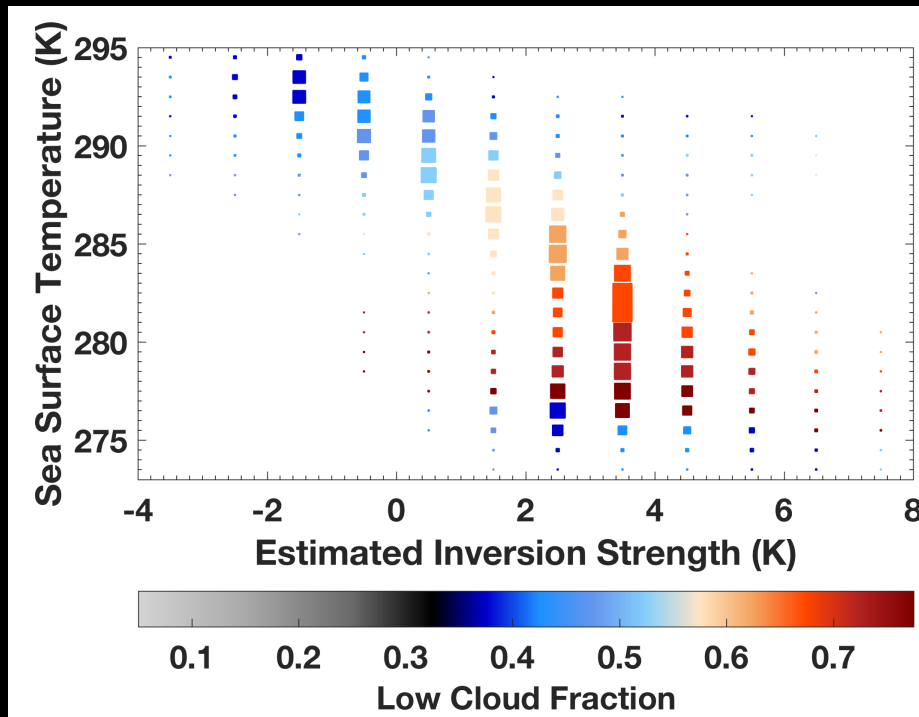


What Causes Mid Latitude Low Cloud Decrease?



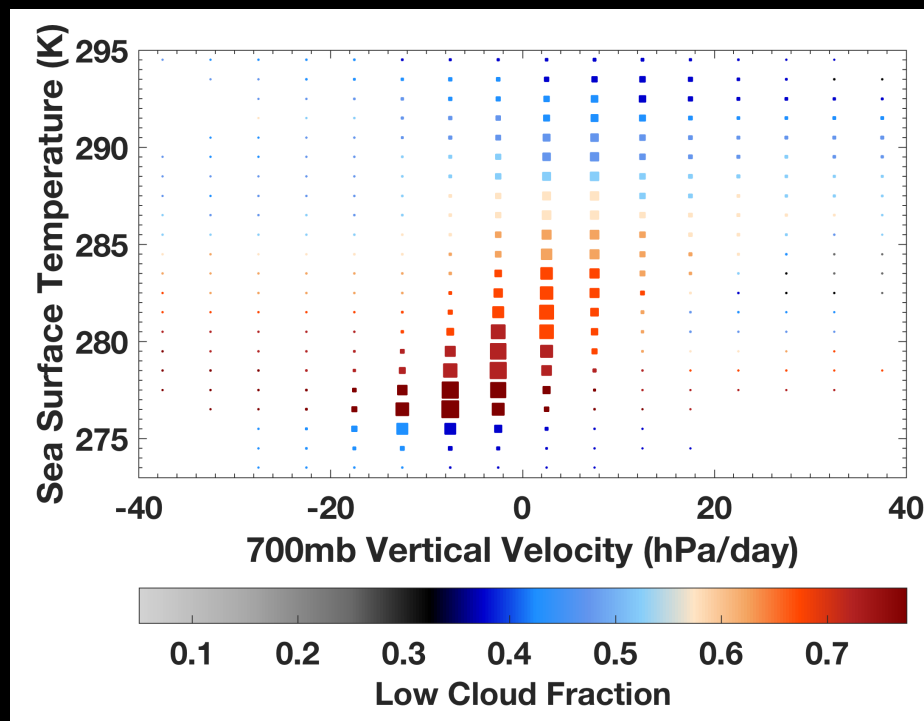
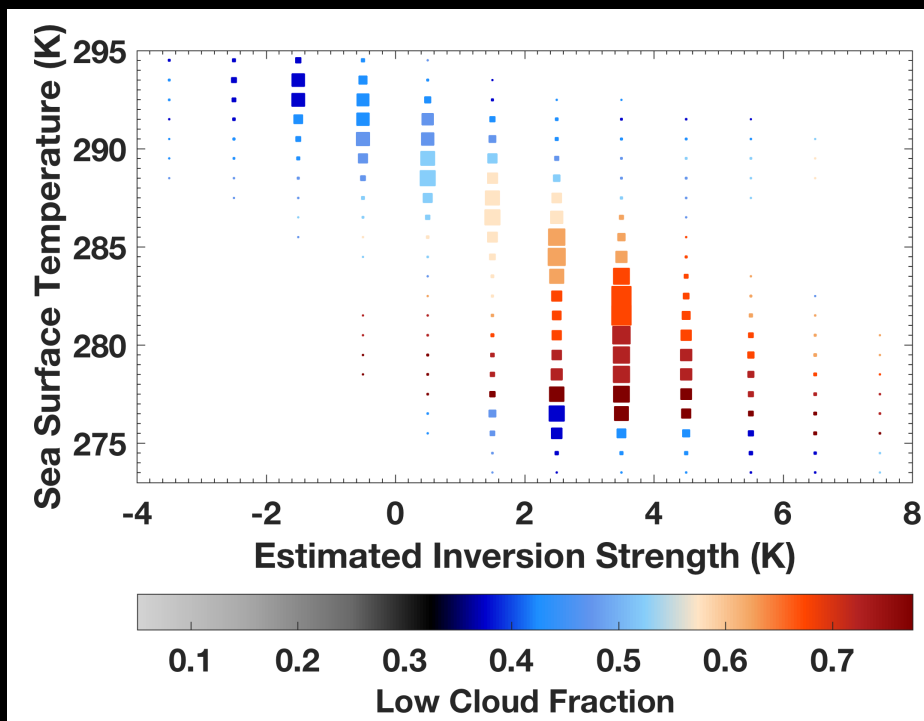


What Can Internal Variability Tell Us?



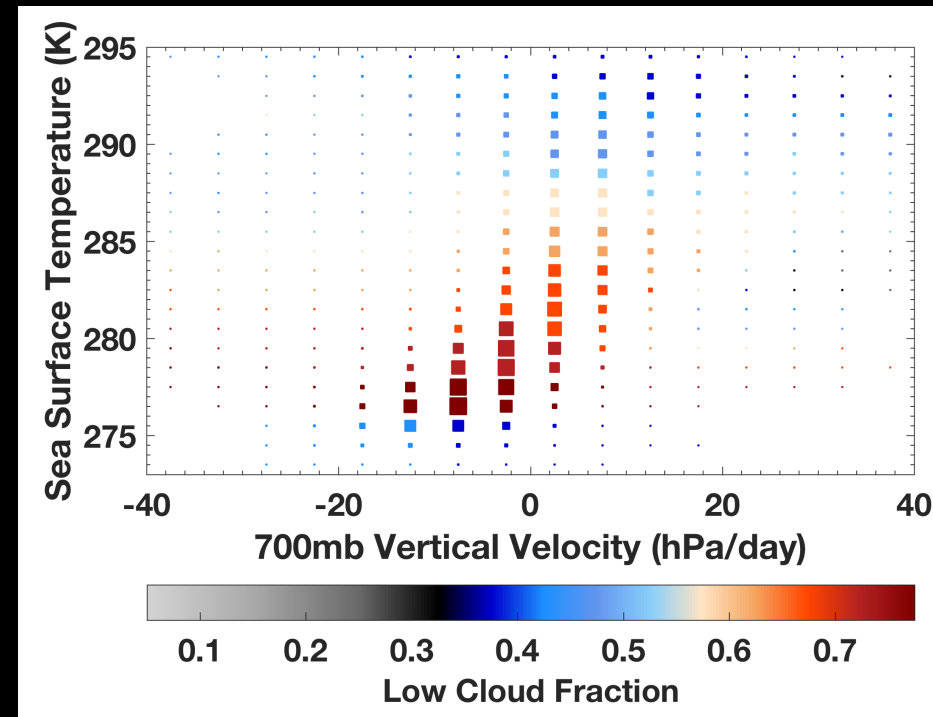
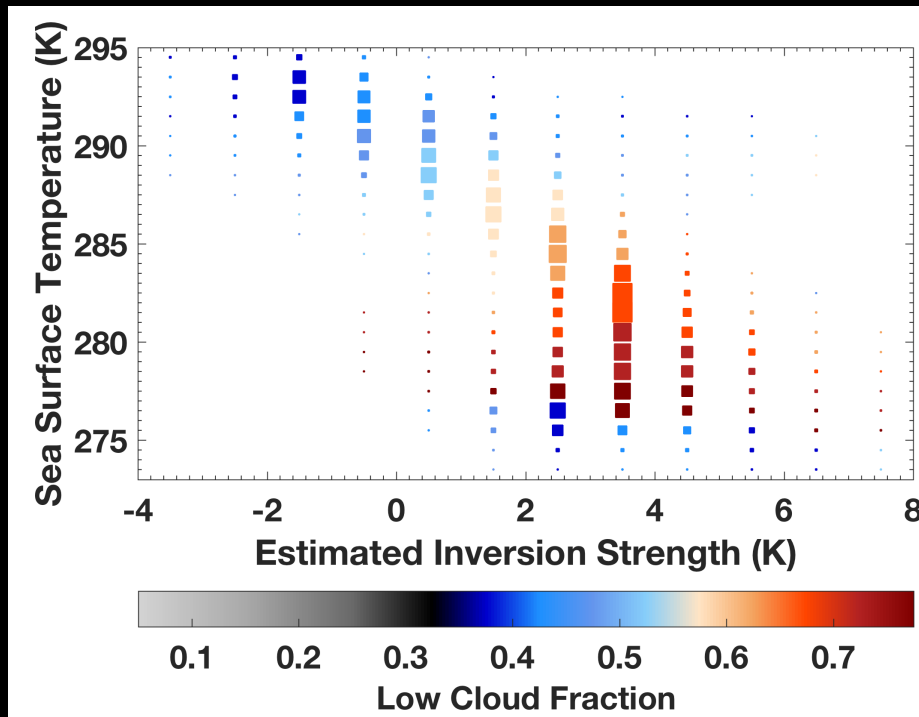


Increasing SSTs Decrease Low Cloud Fraction





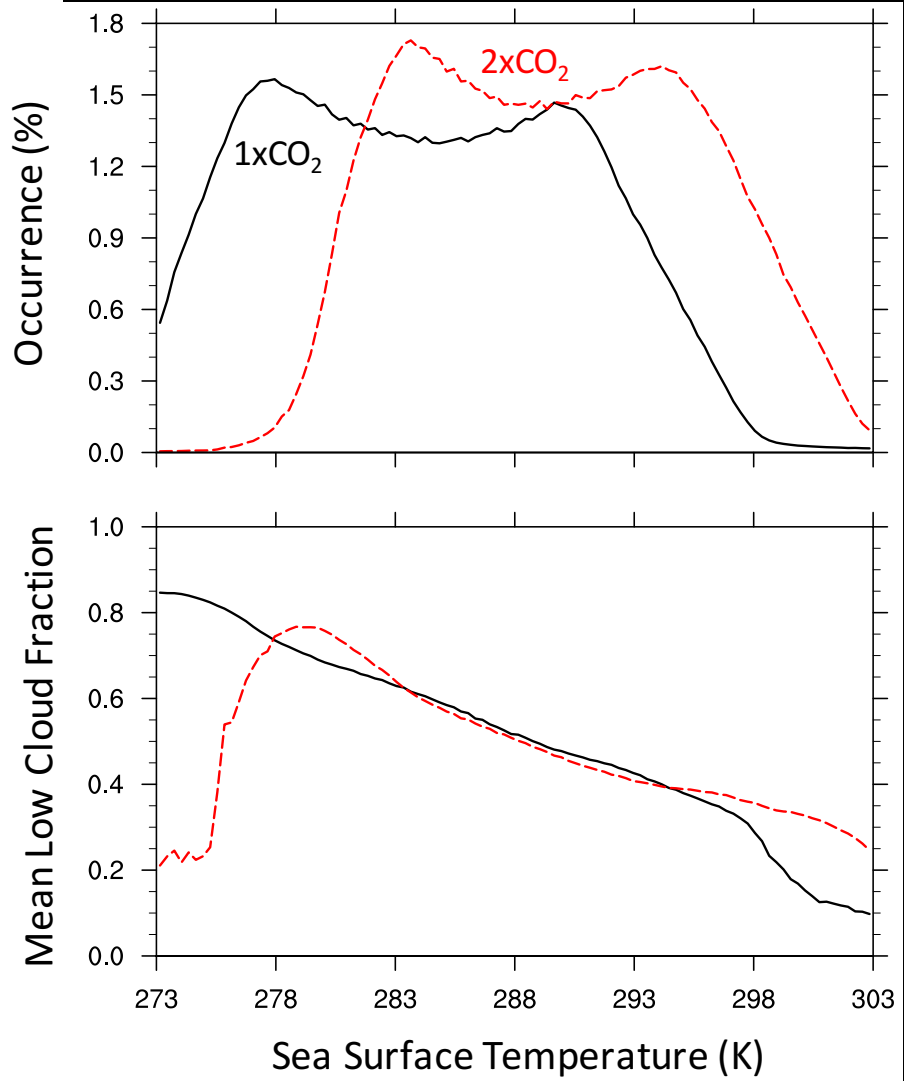
Increasing SSTs Decrease Low Cloud Fraction



- How do increased SST decrease low cloud fraction?

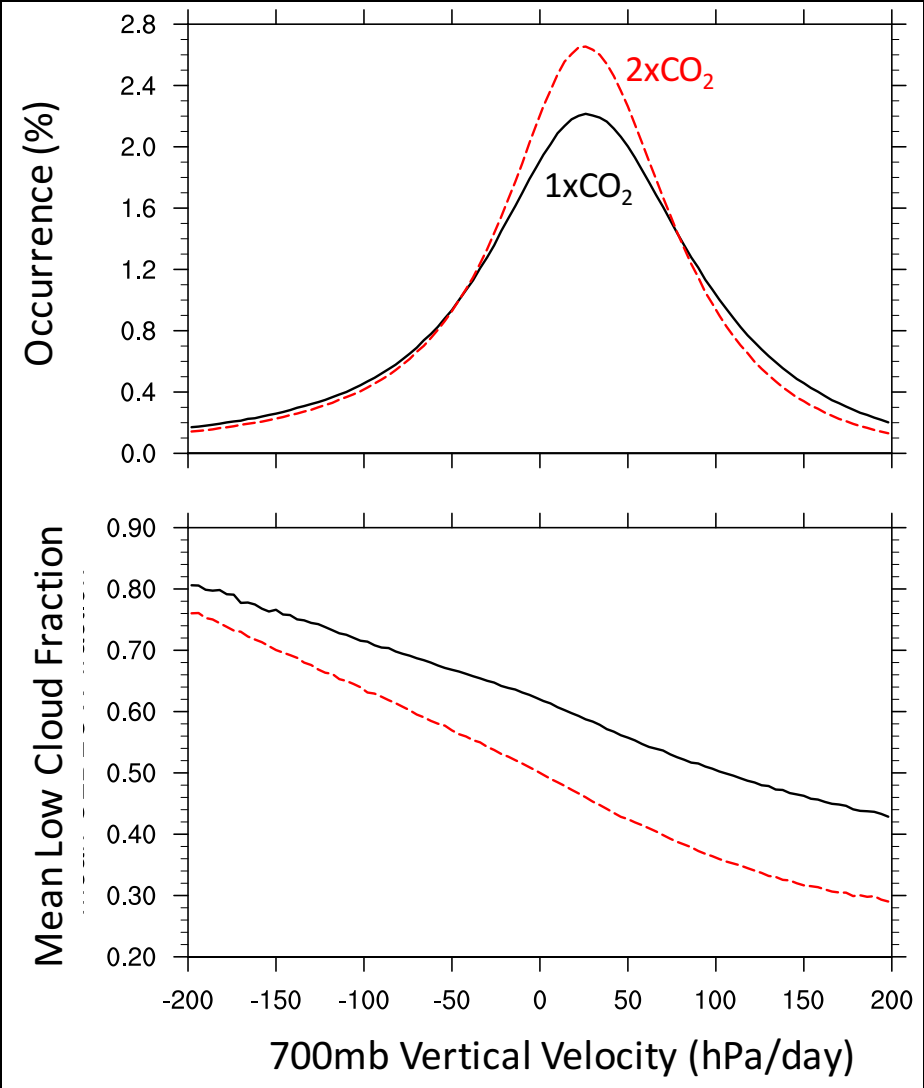
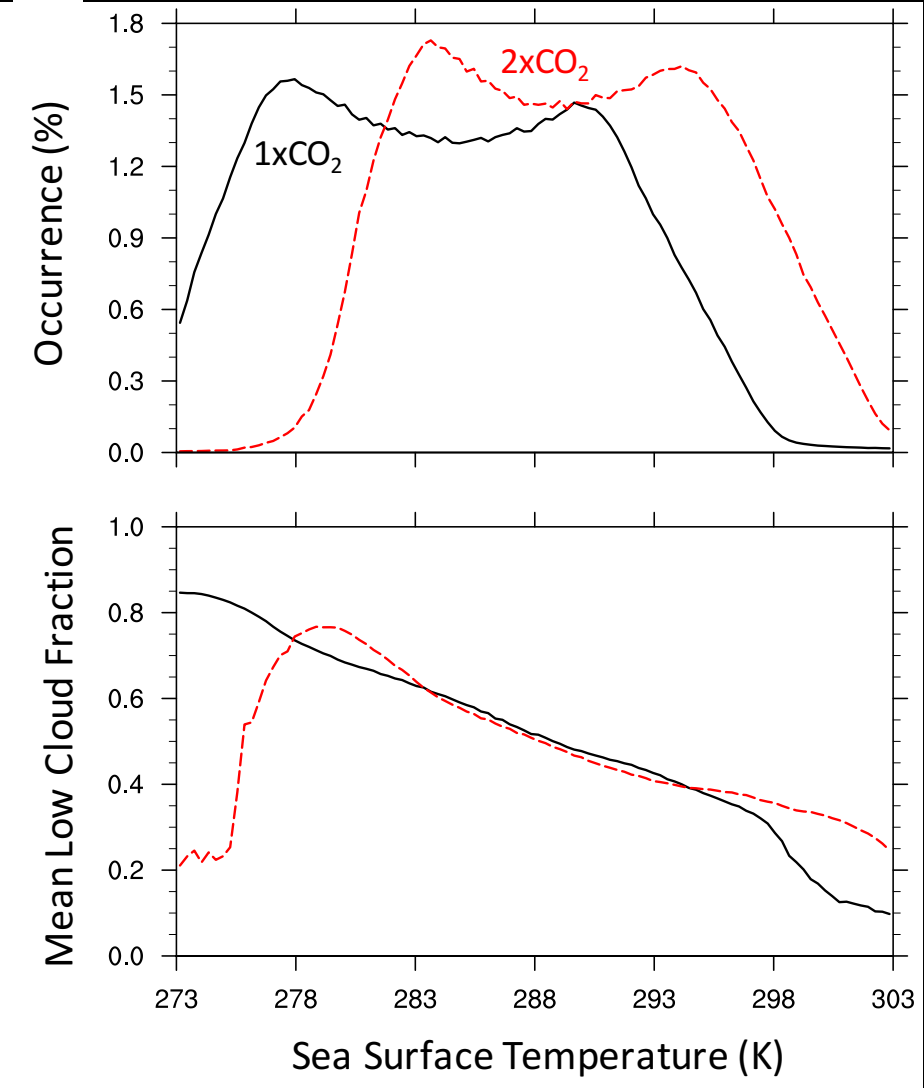


Comparing SST and Vertical Velocity Changes



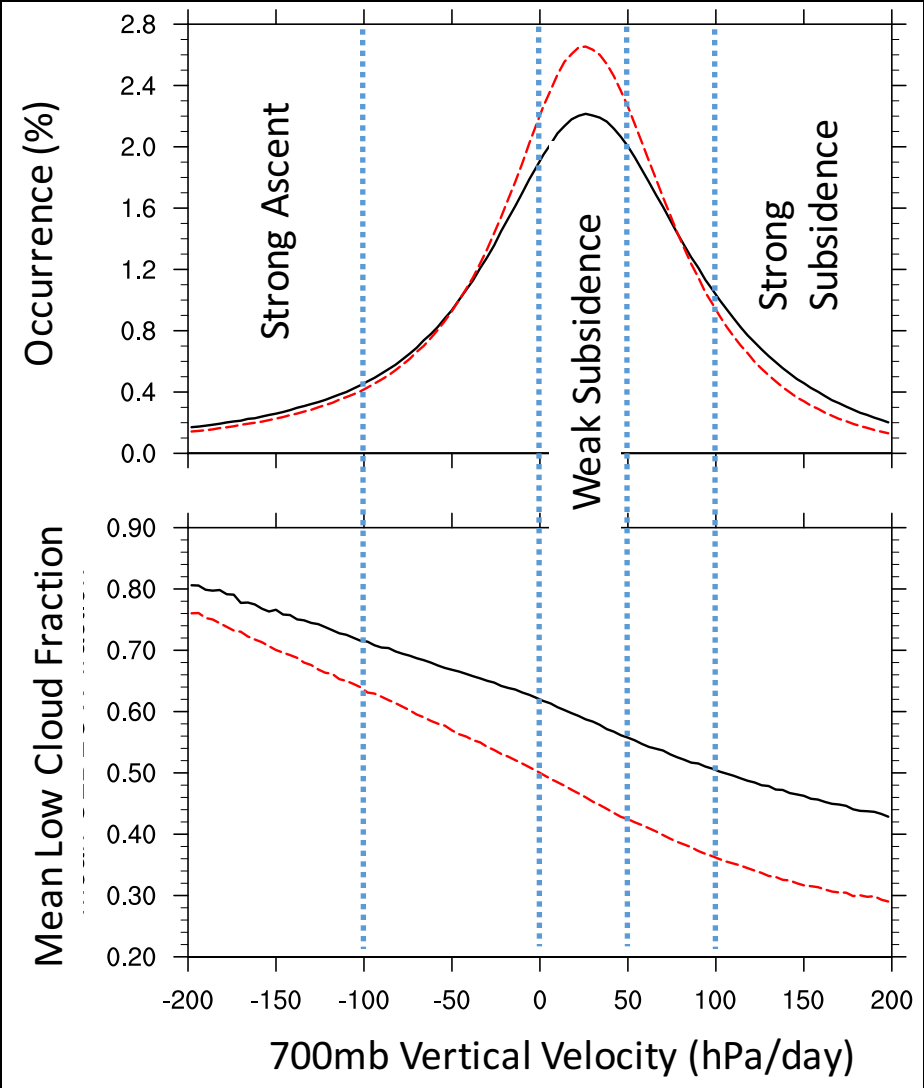
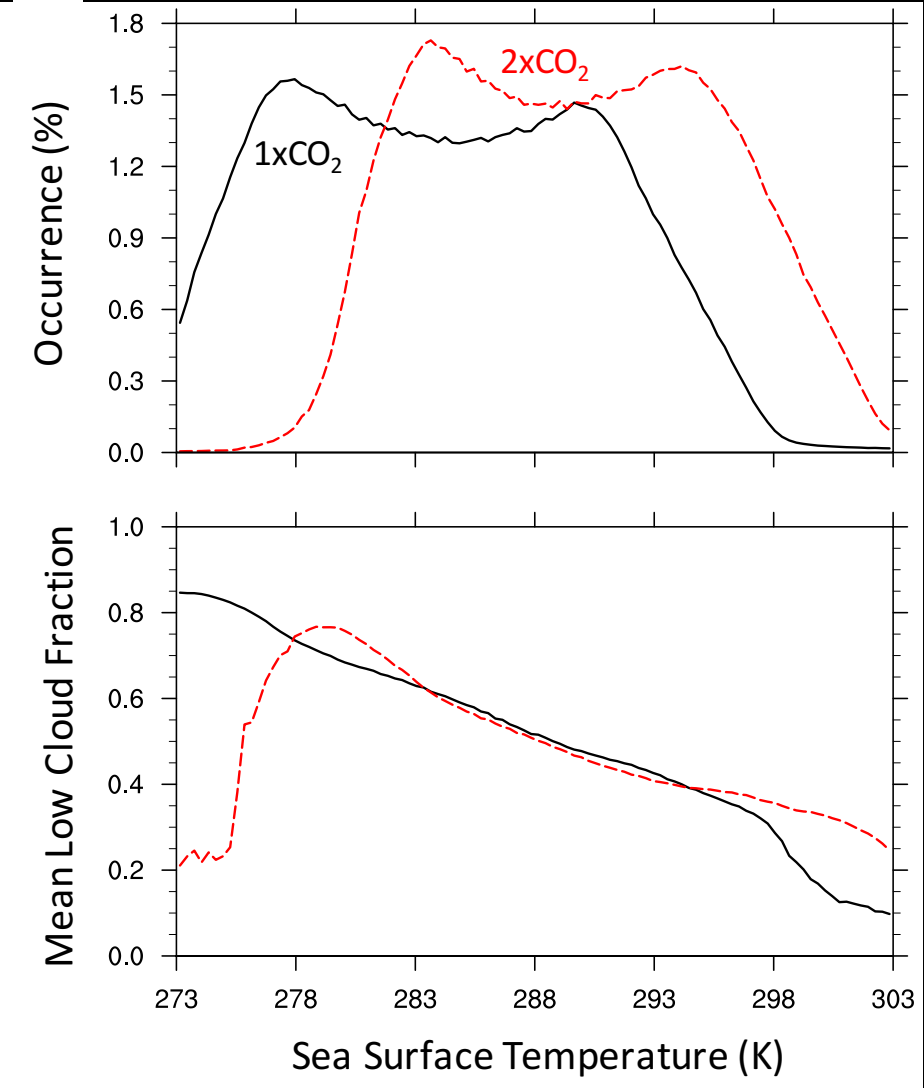


Comparing SST and Vertical Velocity Changes



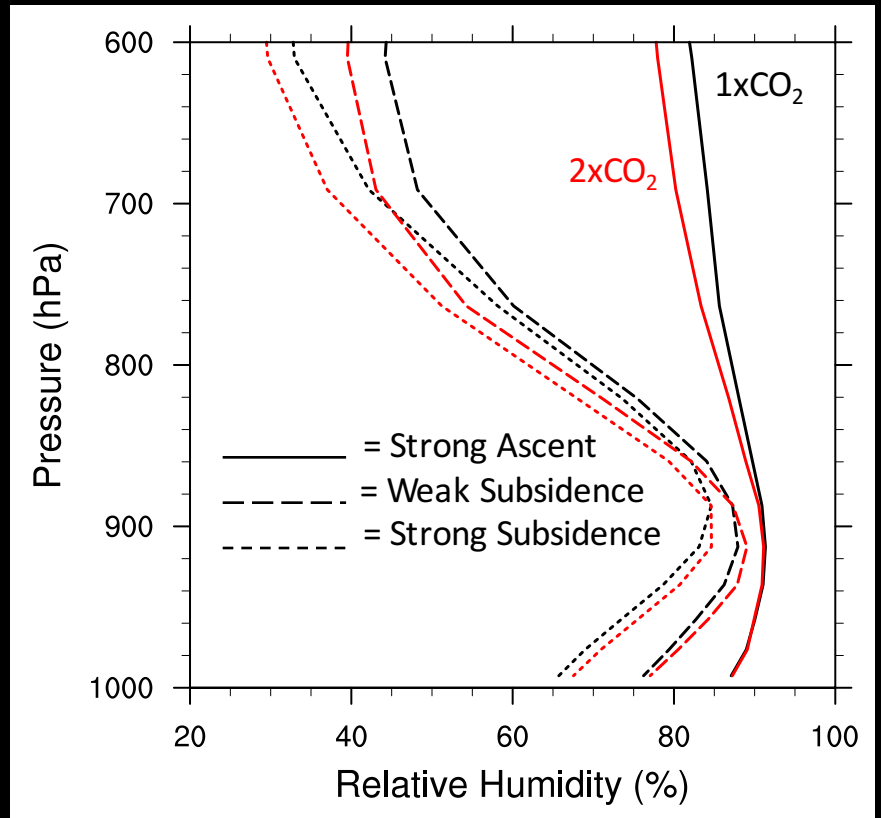
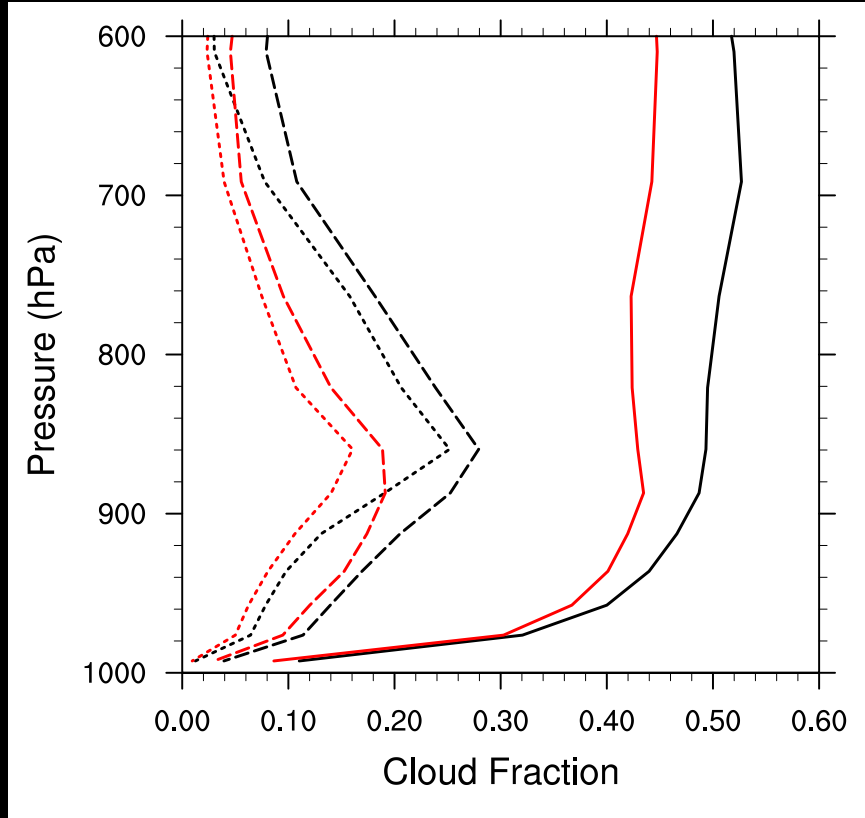


Comparing SST and Vertical Velocity Changes



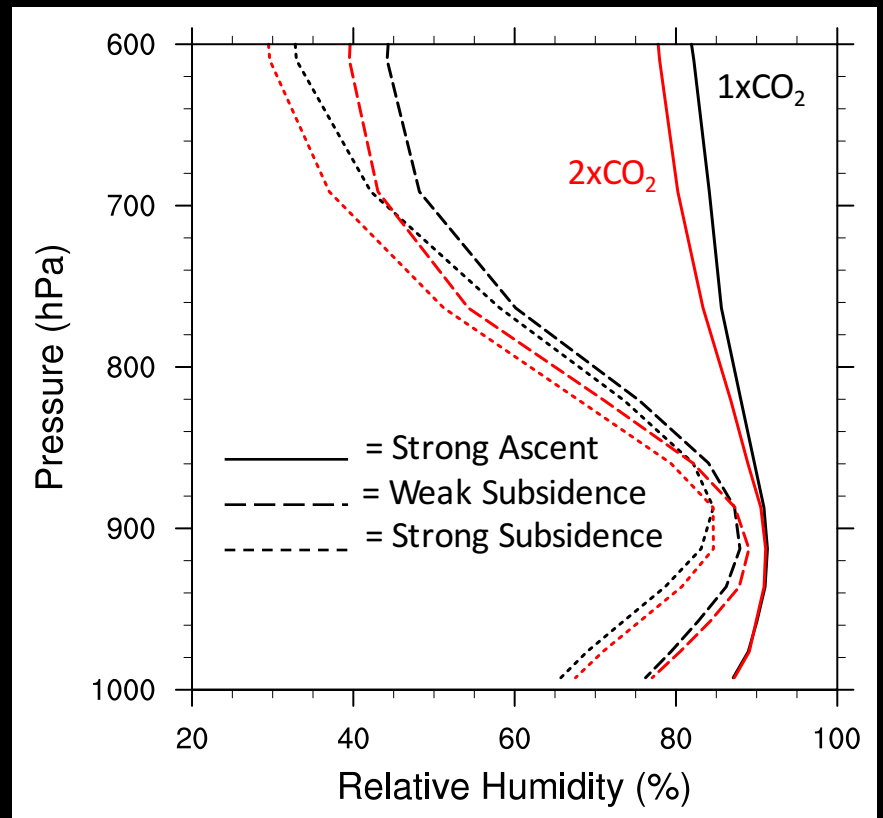
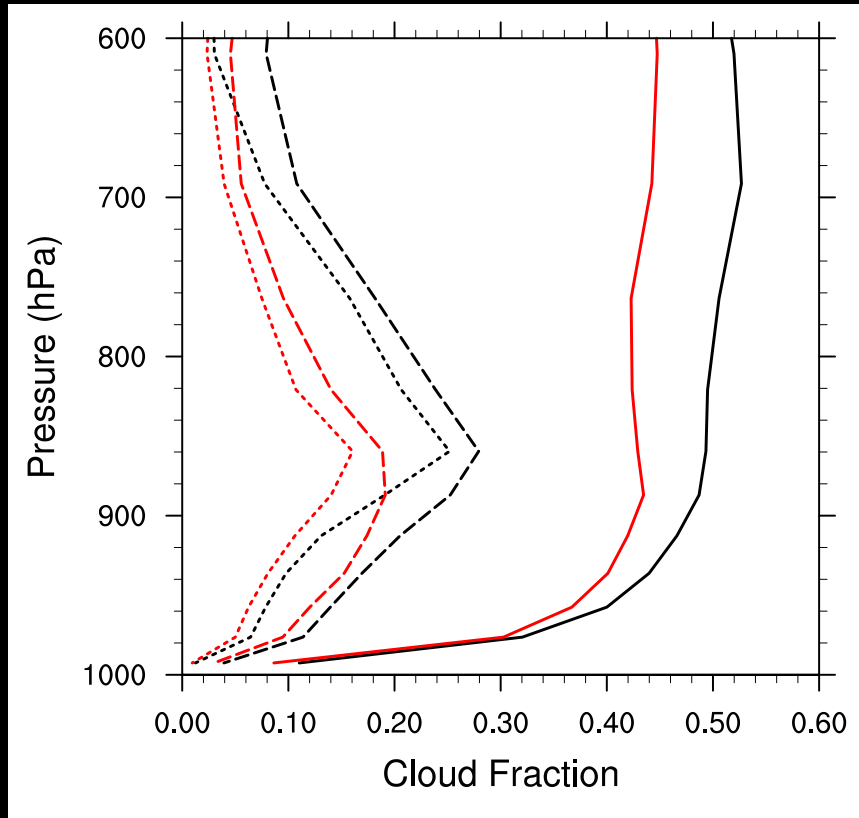


Mixing Decreases Cloud Fraction





Mixing Decreases Cloud Fraction

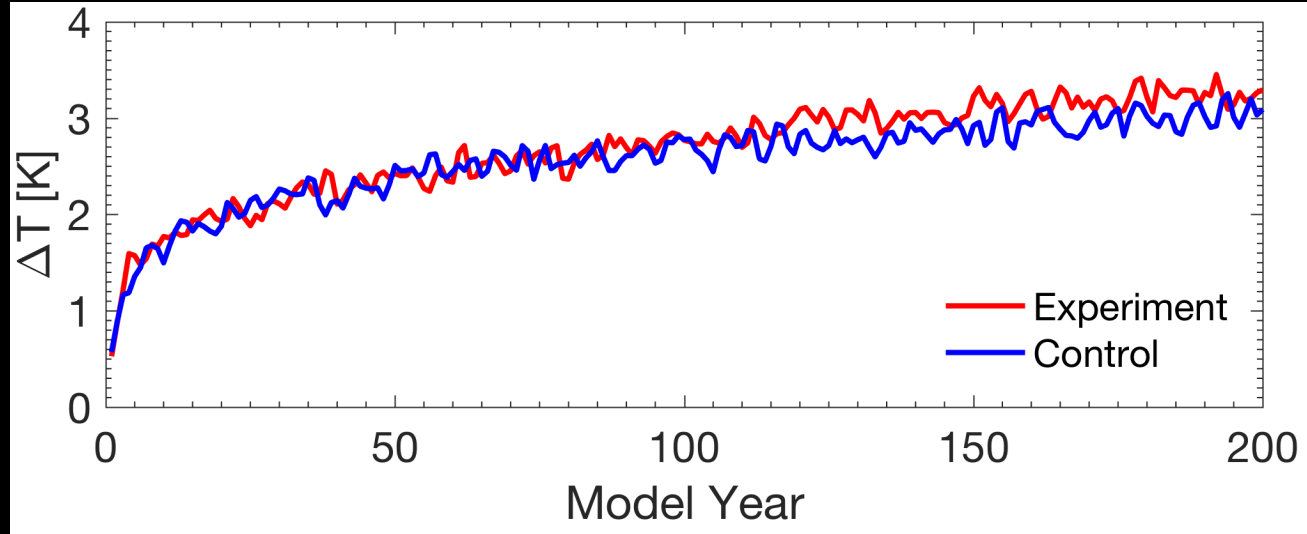


- Positive Shortwave Feedback caused by decreased cloud fraction
 - Higher SSTs cause relatively dryer air to be mixed into boundary layer, decreasing cloud fraction



The Ocean's Role

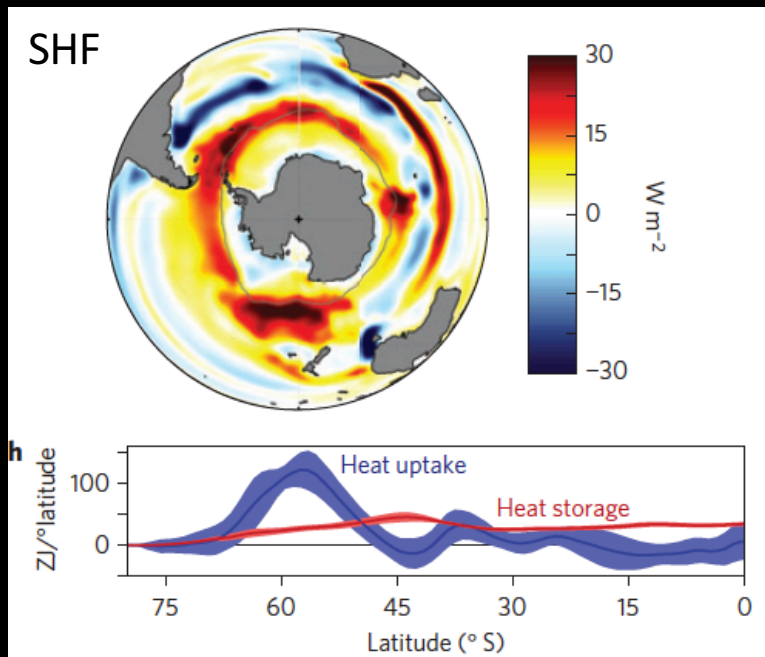
**Fully
Coupled**



- How does Southern Ocean Circulation delay warming?



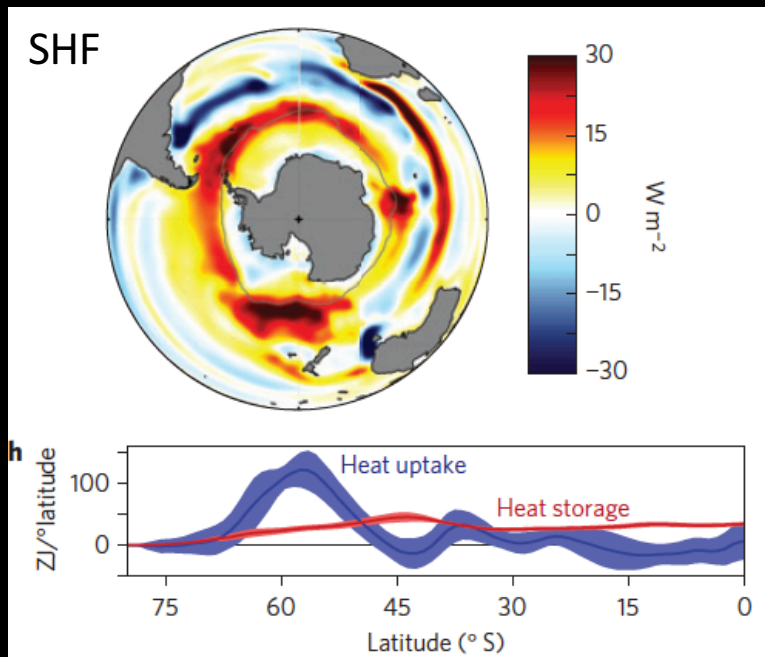
The Ocean Redistributes Heat



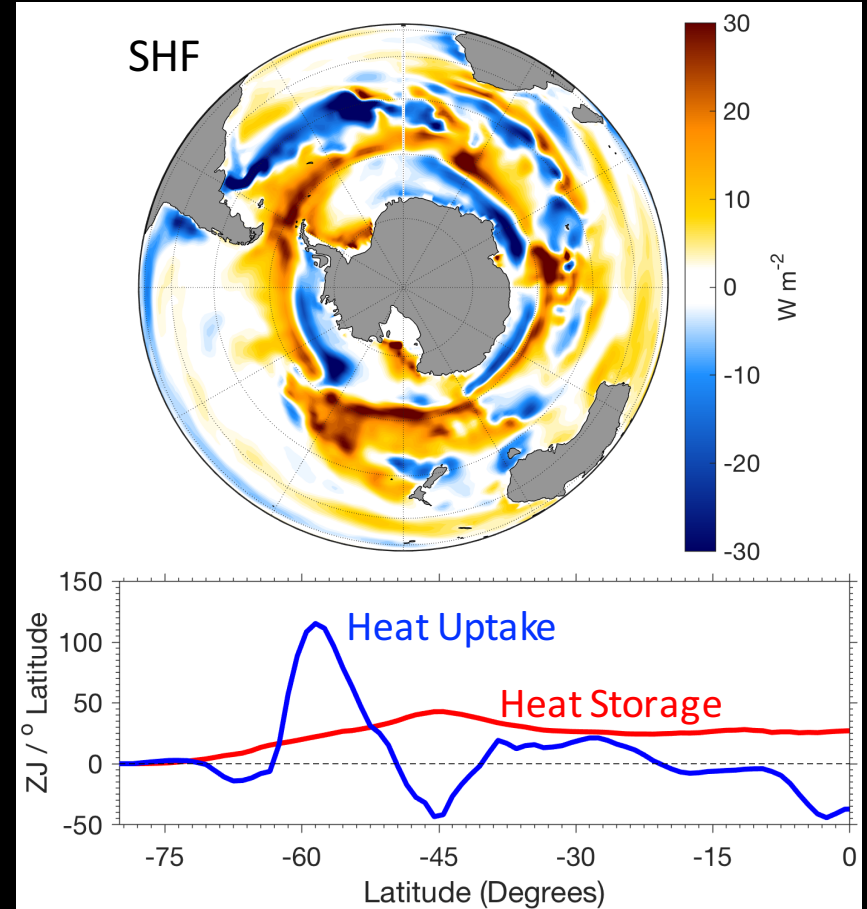
Armour, et al., 2016



The Ocean Redistributes Heat

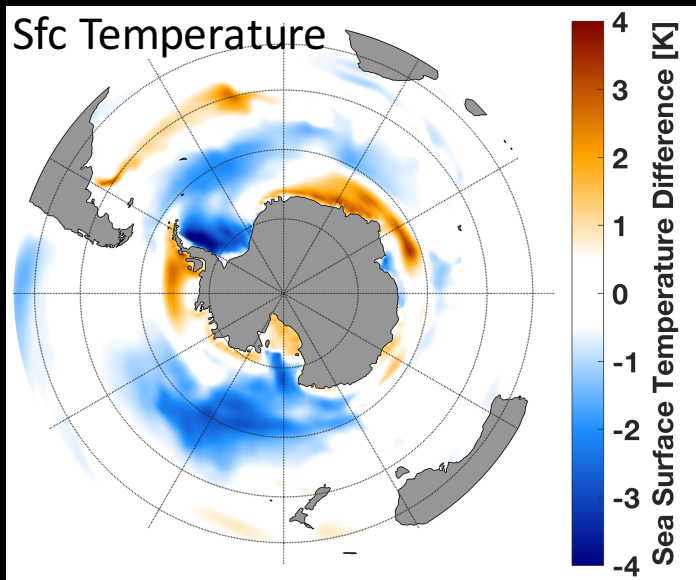
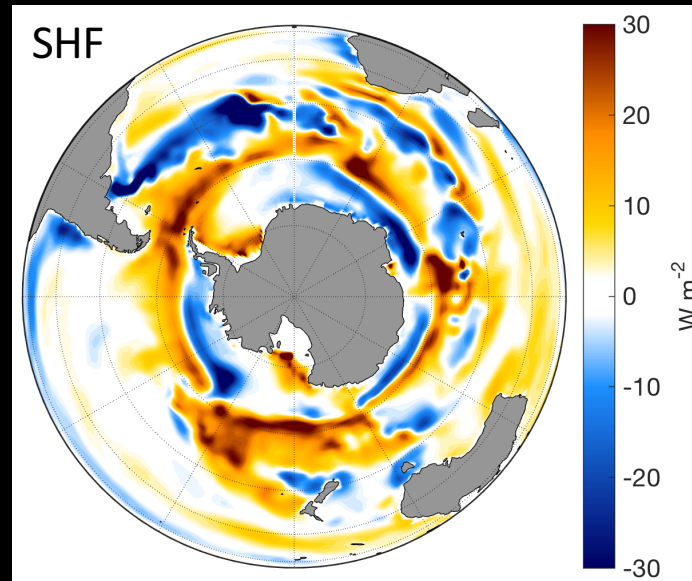


Armour, et al., 2016



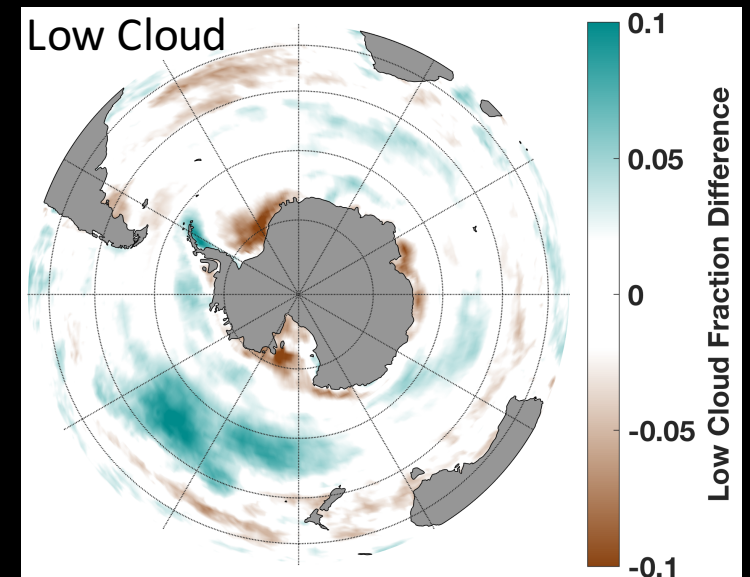
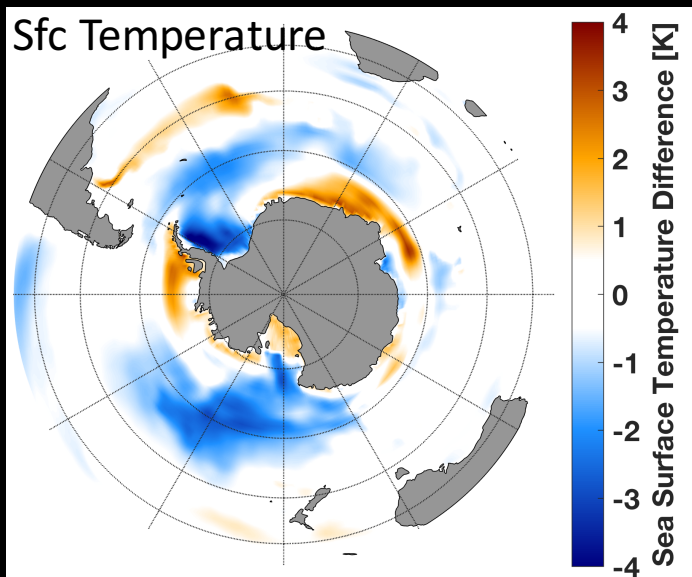
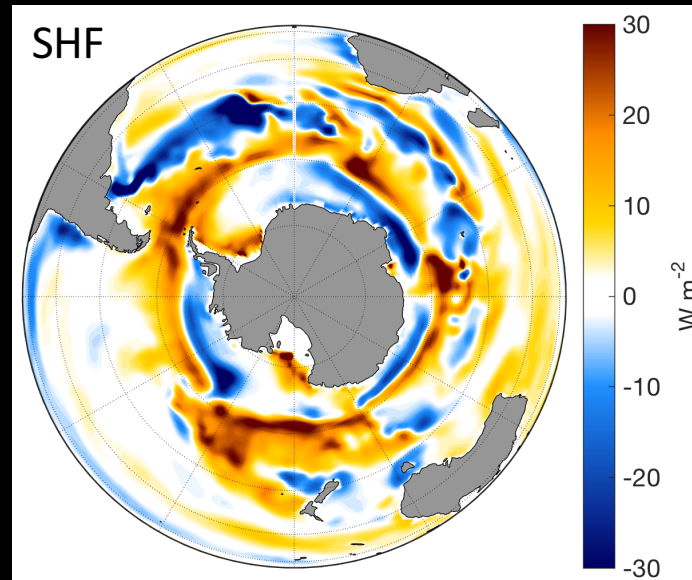


Ocean Heat Transport Modifies Cloud Response





Ocean Heat Transport Modifies Cloud Response





Conclusions

- Decreasing the absorbed shortwave radiation bias in CESM increases climate sensitivity.
- Initial warming is driven by a smaller negative cloud phase feedback and amplified by a positive SST – cloud fraction feedback in the mid latitudes.
- Deep ocean circulation delays surface warming over the Southern Ocean which delays the SST– cloud fraction Feedback.

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