Importance of marine boundary layer clouds for the mean climate and interannual variability over the Atlantic Ocean

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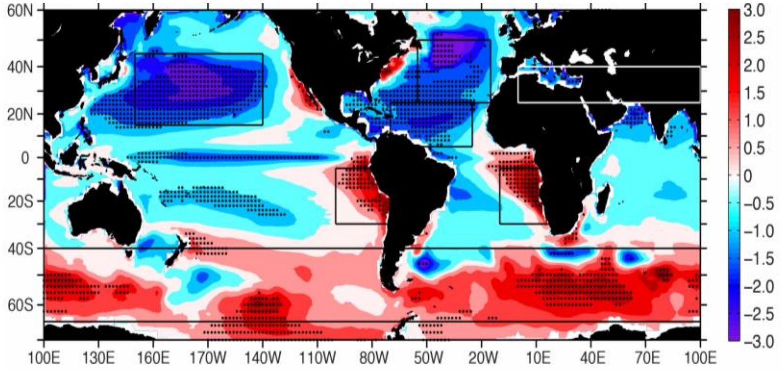
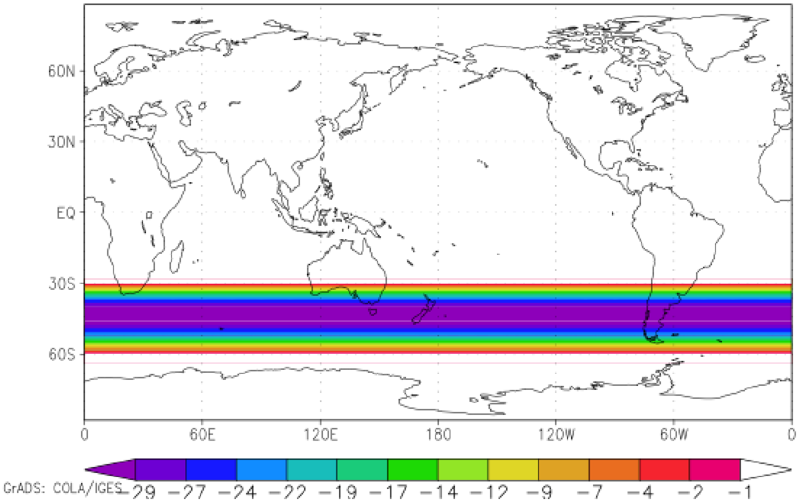
SST biases averaged in CMIP5 models



Wang, Zhang, Lee, Wu, and Mechoso (2014, *Nature CC*)

Reduction in Incident SW at TOA



Questions and Approaches

Question 1: Can reducing the incoming energy flux over the southern ocean in a CGCM improve its simulation of tropical climate?

Approach: Contrast the effects of reducing SW incident at TOA over the Southern Ocean in two different models: **UCLA CGCM** and **NorESM**

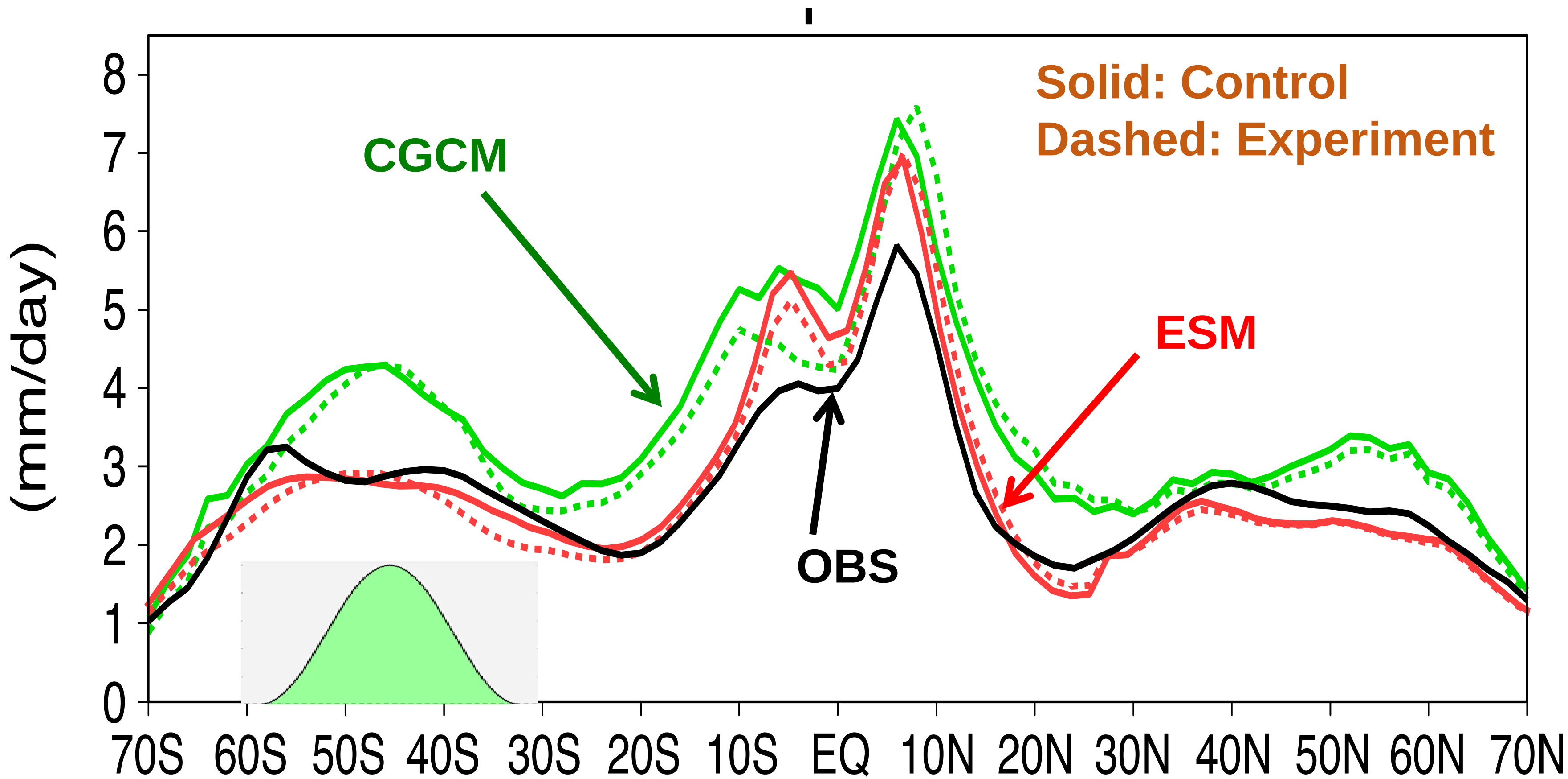
(Hereafter CGCM and ESM)

Question 2: Is SST variability over Atlantic Ocean amplified by positive cloud feedbacks?

Approach: Examine the regression of detrended seasonal anomalies in SW cloud radiative effect and in SST onto mean SST anomalies in the Scu regions of the eastern Atlantic.

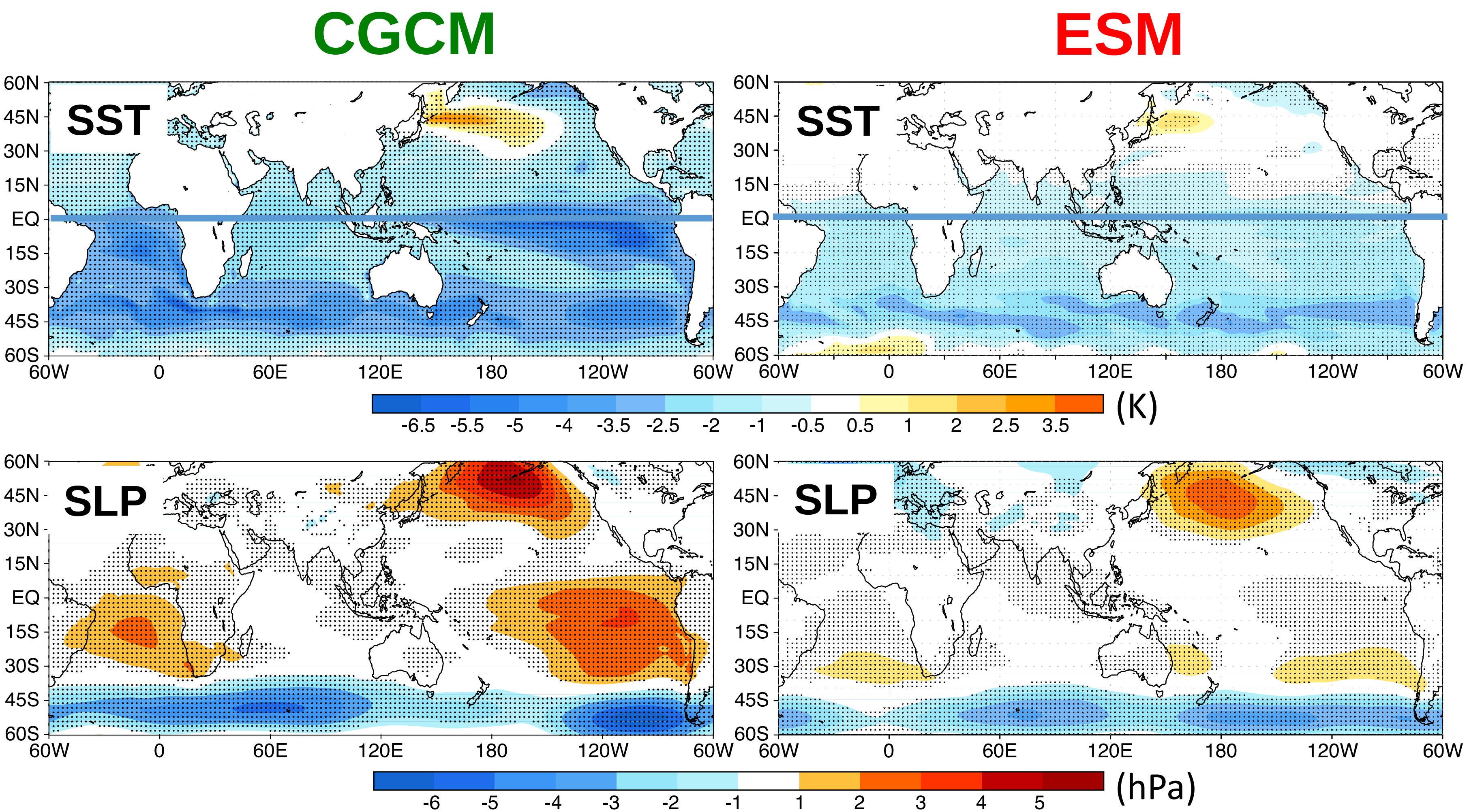
(Use ISCCP, CERES, ERA-Interim and CMIP5 data)

Annual and zonal mean precipitation show less double ITCZ

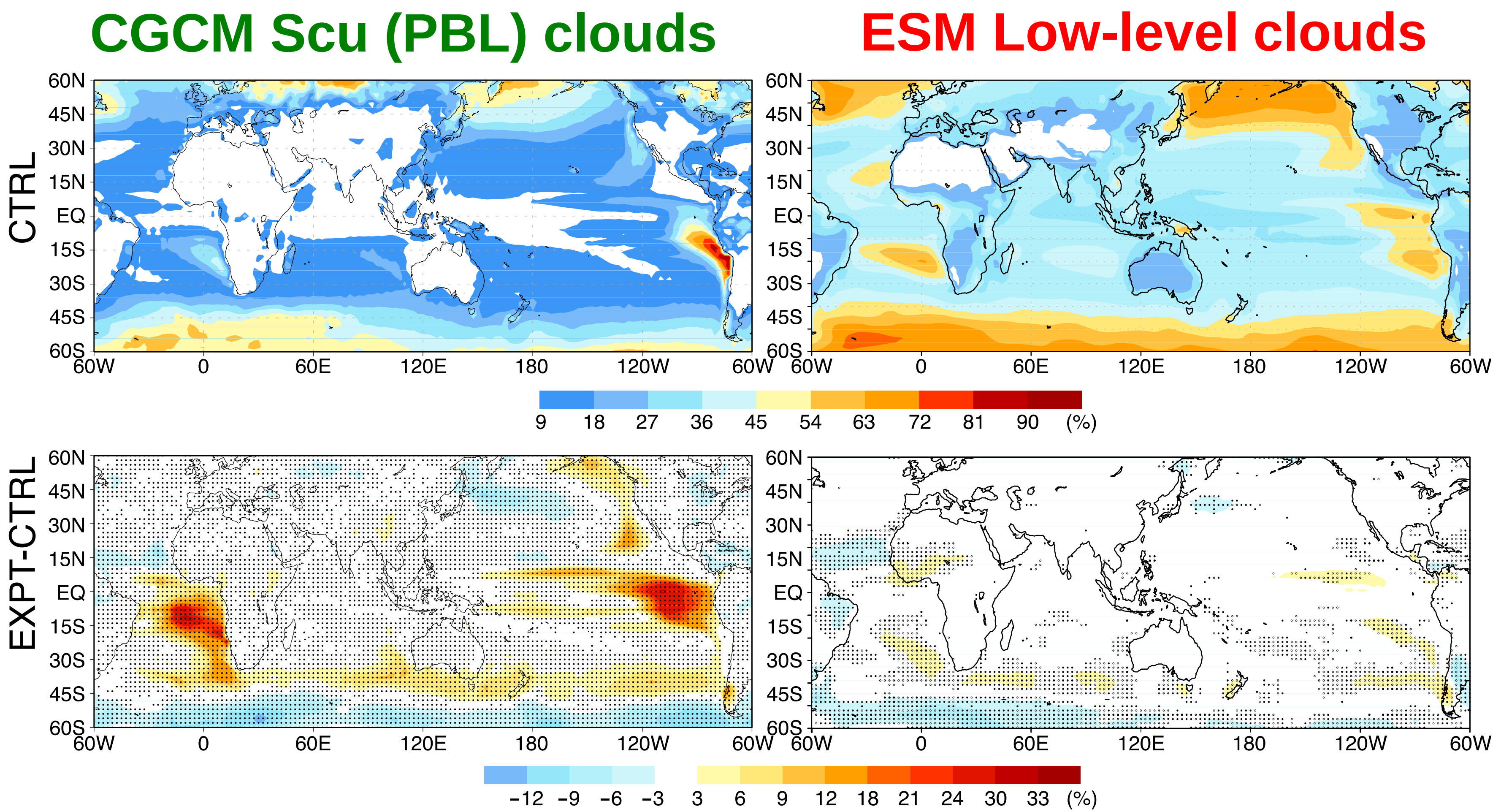


Short-Wave Incident at TOA is decreased between 30S-60S ~ 3.7% rad received between 20S and 90S

SSTs cool down and the southern subtropical highs are enhanced



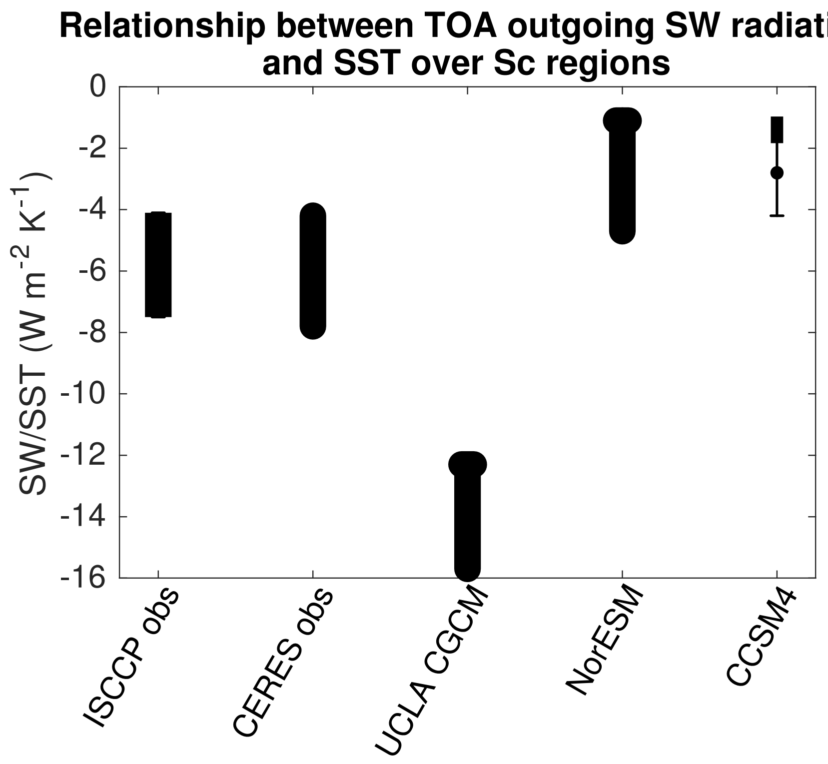
Changes in TOA radiation are consistent with changes in low-level clouds



Top: Control

Bottom: Experiment-Control

Slope of regression of monthly anomalies of outgoing SW radiation on SST over the five major stratocumulus regions over the global oceans.



Errorbars denote 95% confidence bounds, taking into account temporal and spatial autocorrelation

Data

Cloud radiative effect (CRE) = clear-sky minus all-sky outgoing radiation at top of atmosphere

Cloud fraction

ISCCP 1985-2000

CERES 2001-2014

SST

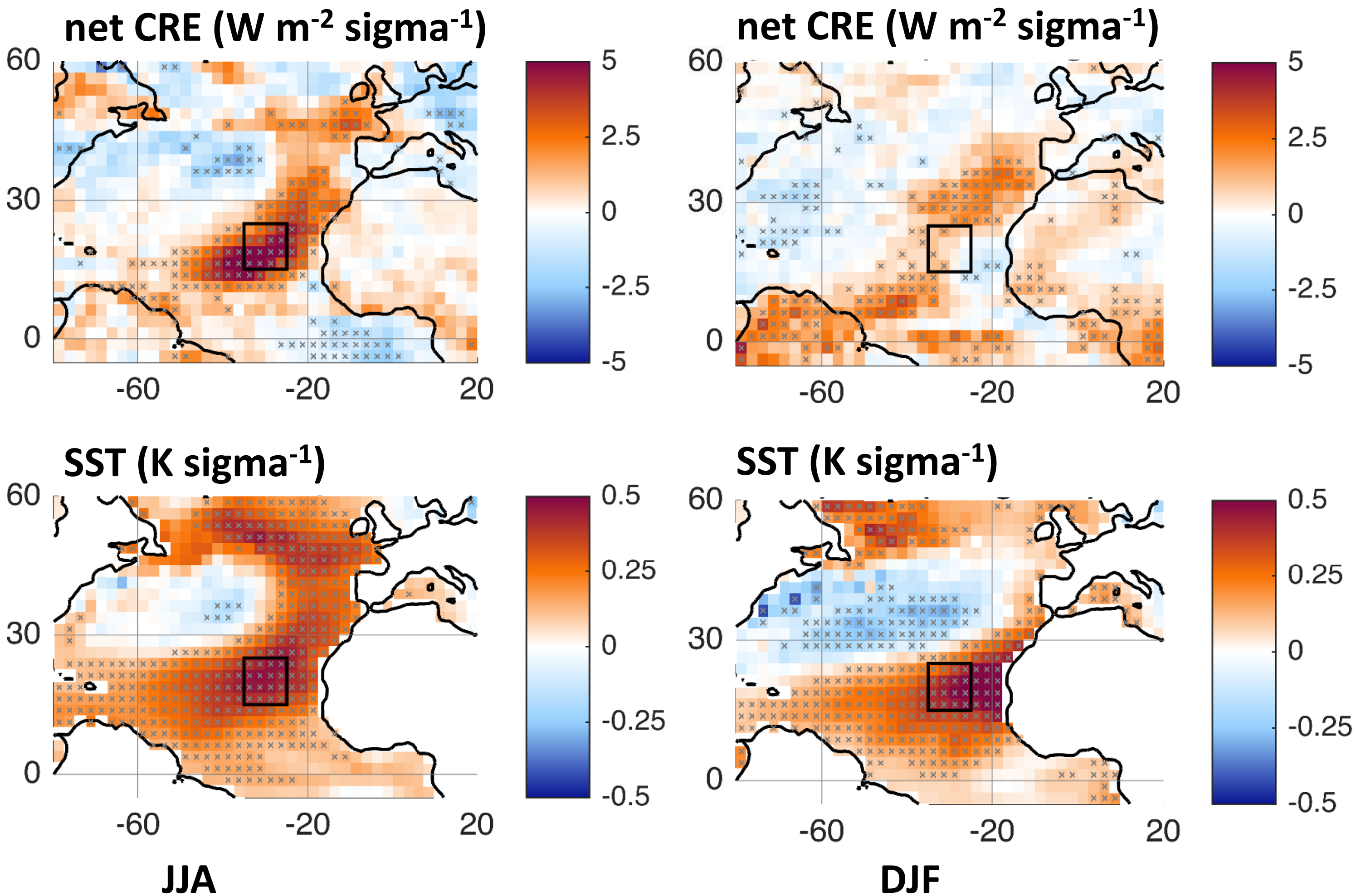
Sea-level pressure (SLP), winds

ERA-Interim reanalysis

(same results using NOAA Optimum Interpolation SST V2)

CMIP5 historical runs 1976-2005

Patterns associated with dominant mode of North Atlantic SST variability

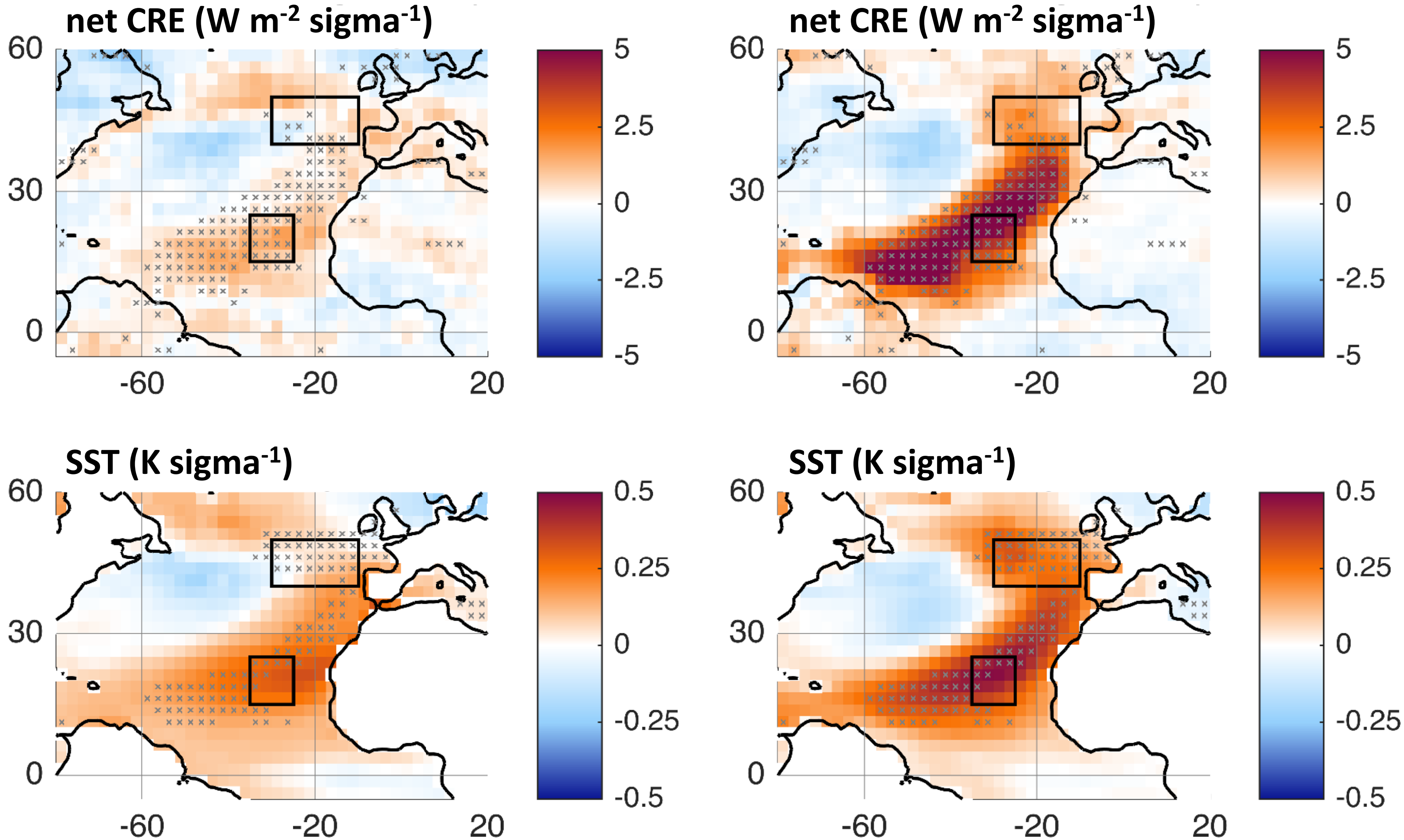


Summer JJA: Consistent w/positive cloud feedback

Winter DJF: Inconsistent w/positive cloud feedback

Slopes of regression of **net cloud radiative effect (CRE) and SST** seasonal anomalies onto 1985-2014 SST anomalies averaged over boxed region of max boundary layer cloud amount.

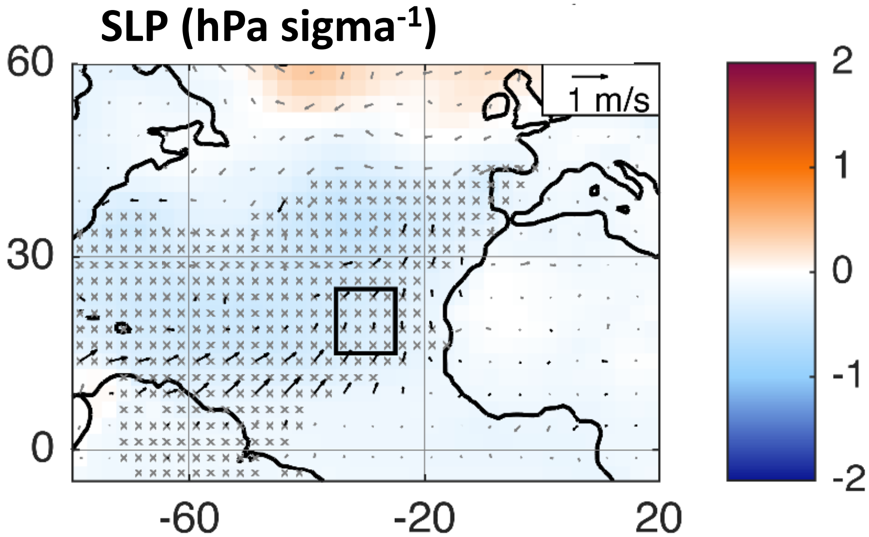
Patterns of dominant mode of summertime North Atlantic SST variability in models with weak/strong cloud feedback over subtropical NE Atl.



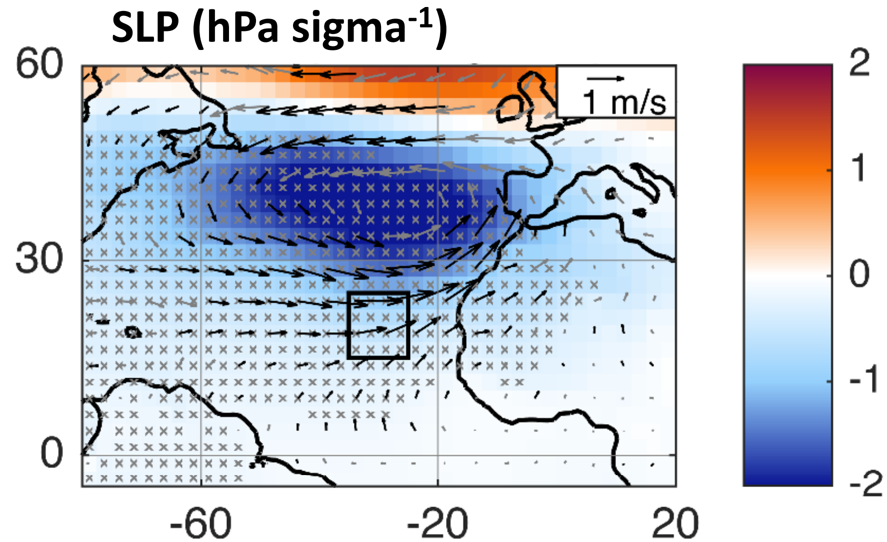
Weak feedback **Strong feedback**

Statistically significant basin-scale difference in net CRE and SST

North Atlantic Oscillation (NAO) emerges in winter but not in summer



JJA



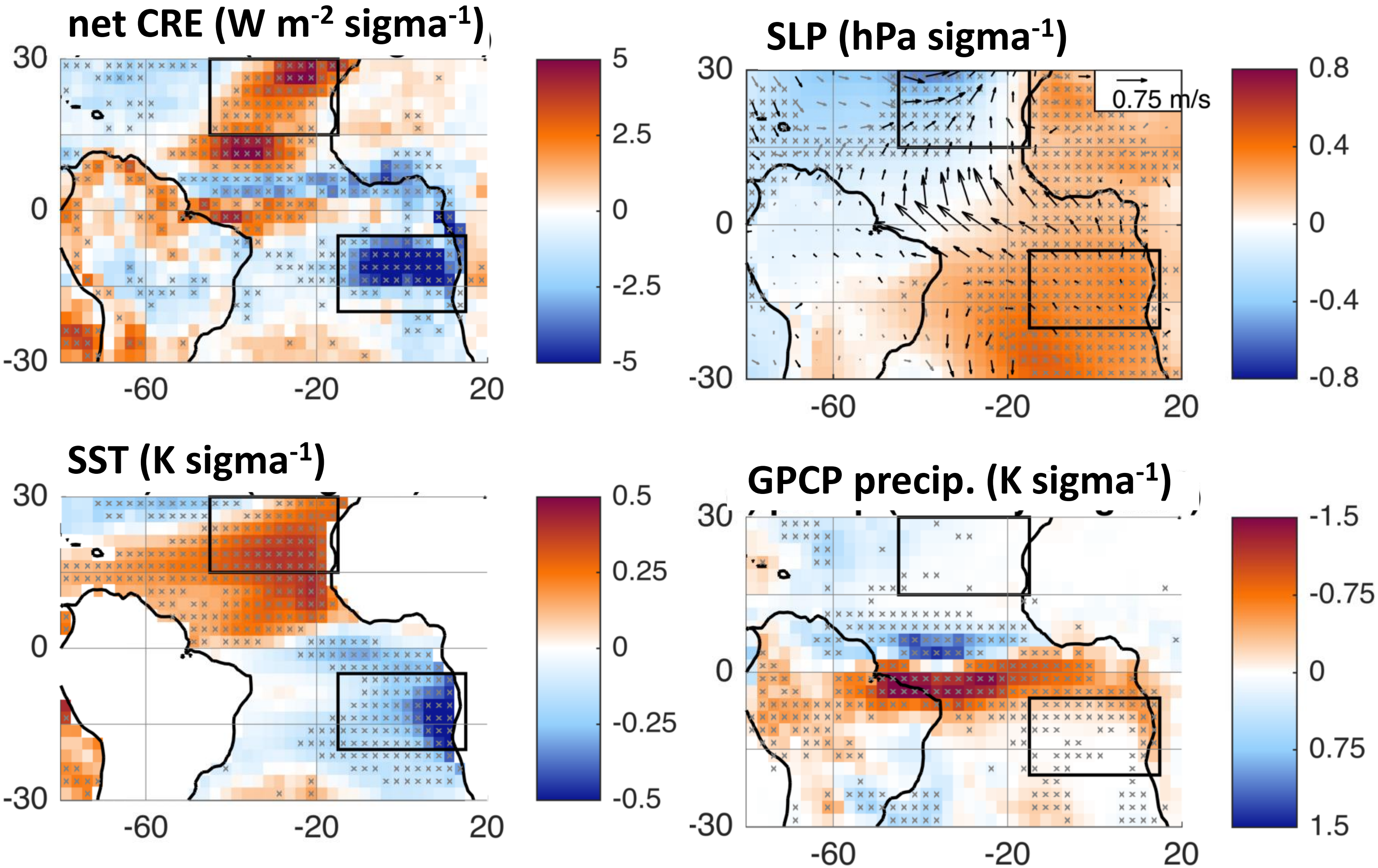
DJF

i) weaker heat flux anomalies
ii) shallower ocean mixed layer
greater role for clouds

Surface winds drive sensible and latent heat fluxes that generate SST anomalies.

Slopes of regression of **sea-level pressure (SLP) and wind** seasonal anomalies onto 1985-2014 SST anomalies averaged over boxed region of max boundary layer cloud amount.

Patterns associated with dominant mode of tropical Atlantic coupled variability during spring



Consistent w/positive cloud feedback

Slopes of regression of climate field MAM anomalies onto 1985-2014 SST anomaly difference between boxes.

Conclusions

Question 1: Can reducing the incoming energy flux over the southern ocean in a CGCM improve its simulation of tropical climate?

Yes. The extent of improvement depends upon the CGCM's success in capturing Scu-SST feedbacks.

Question 2: Is SST variability over Atlantic Ocean amplified by positive cloud feedbacks?

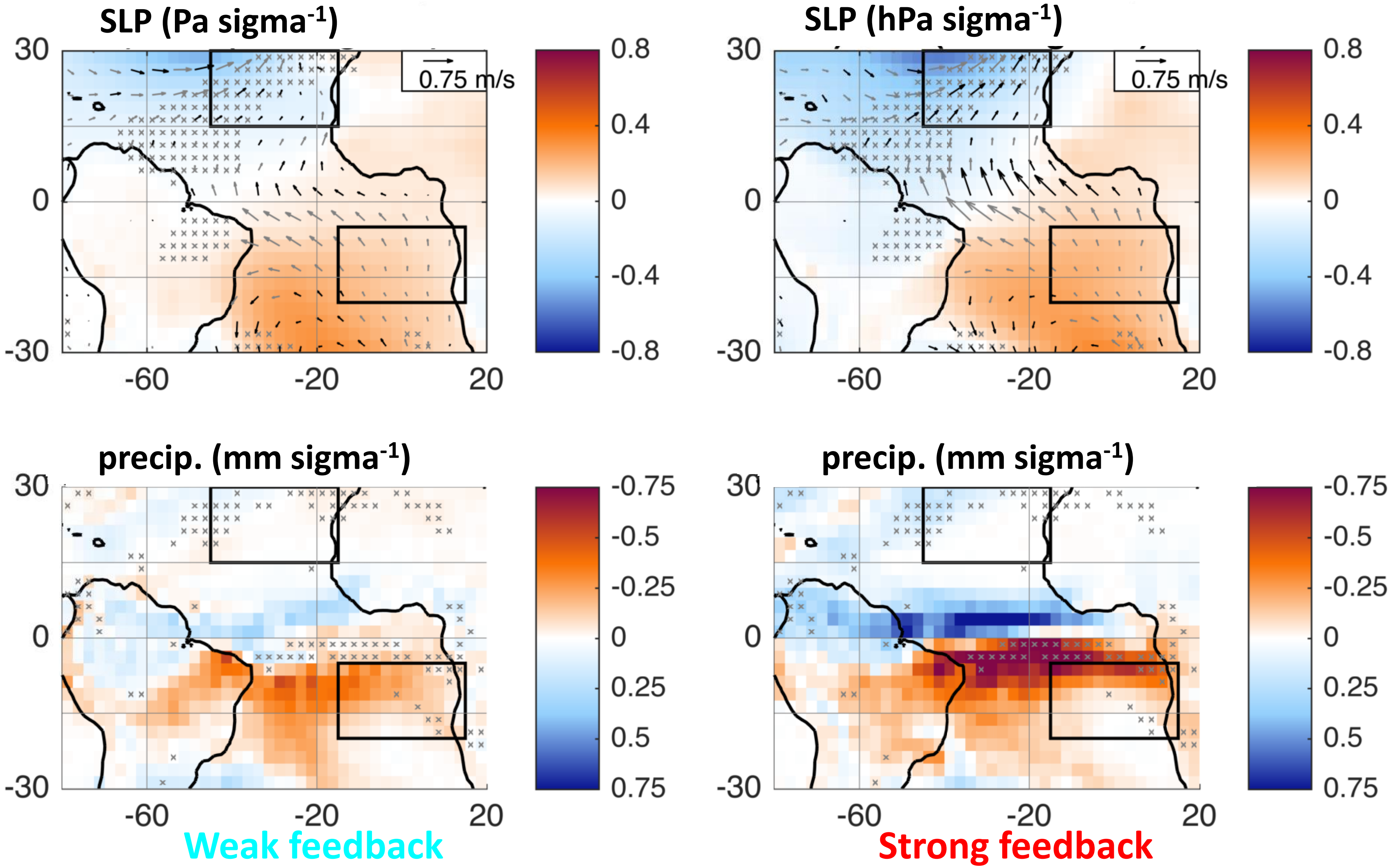
Yes. On the basis of observational data, we find new evidence for linkage between cloud-SST feedback and dominant modes of variability.

Conclusions

Improve marine boundary layer clouds

→more realistic simulation of mean climate and interannual to interdecadal atmosphere-ocean variability

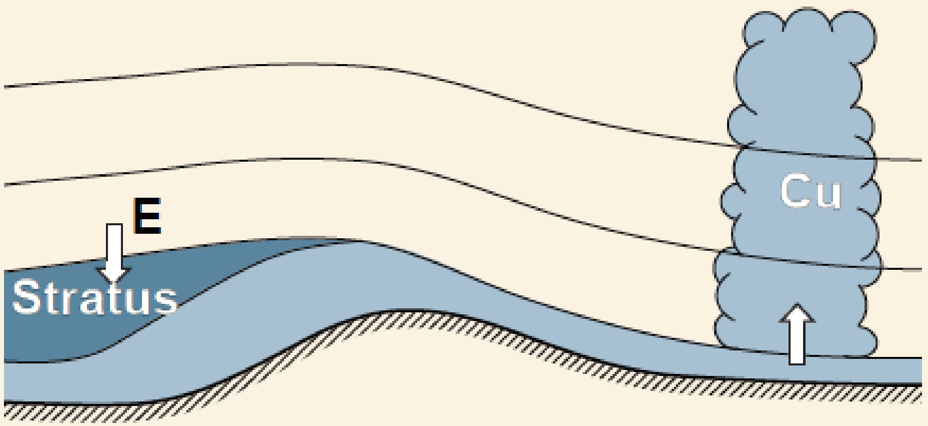
Patterns of dominant mode of springtime tropical Atlantic coupled variability in CMIP5 models with weak/strong cloud feedback over subtropical SE Atlantic



Statistically significant difference in SLP, winds, and precipitation

PBL PARAMETERIZATION IN UCLA AGCM

Suarez, Randall and Arakawa(1983) (Gen IV-V)



Characteristics/assumptions:

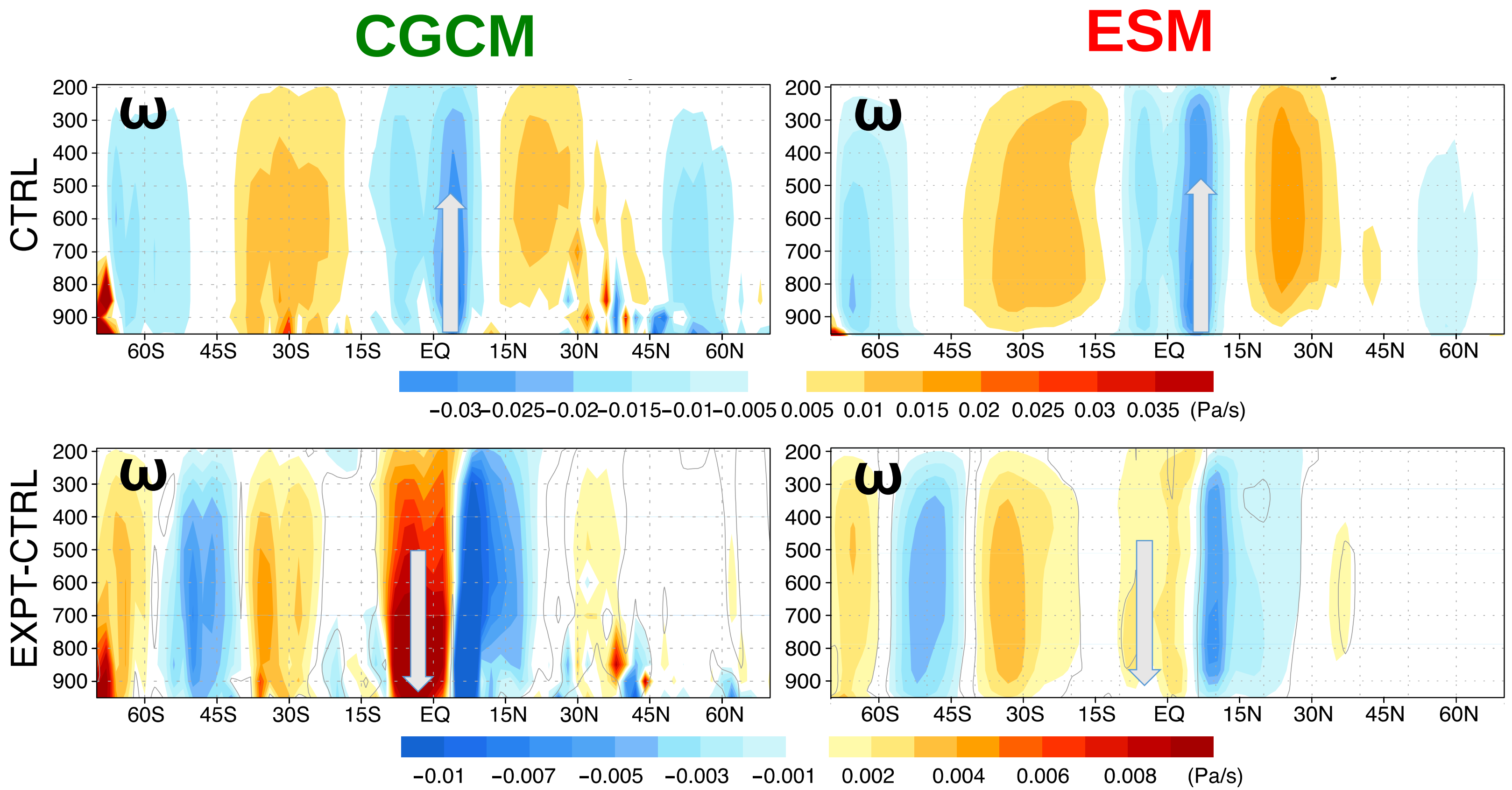
The model's lowest layer is designated as PBL

The PBL depth is predicted

Stratocumulus (PBL-top clouds) are determined implicitly .

The bottom of cumulus clouds is at the PBL-top

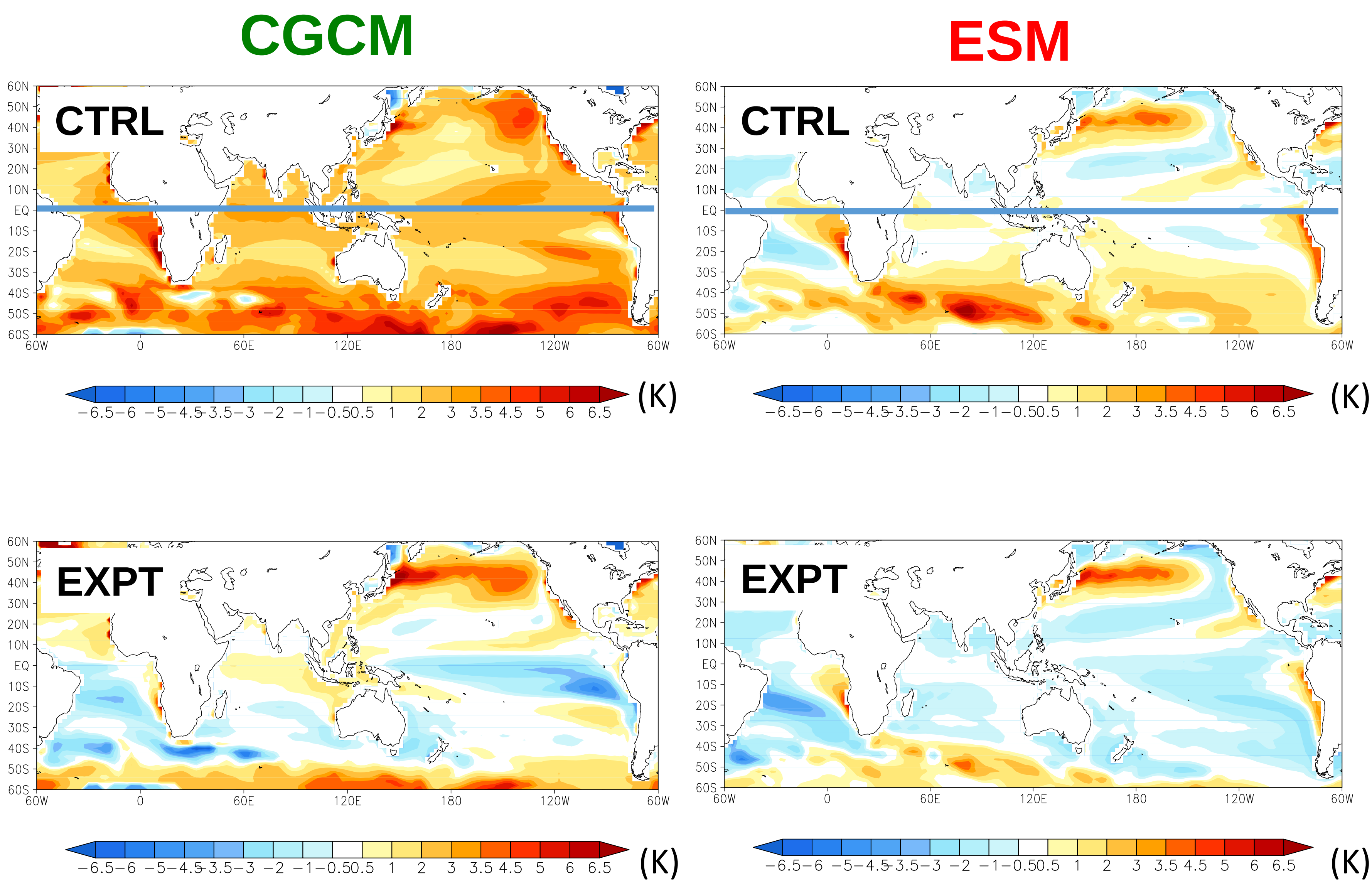
In EXPT subsidence increases in southern tropics, more so in the UCLA CGCM



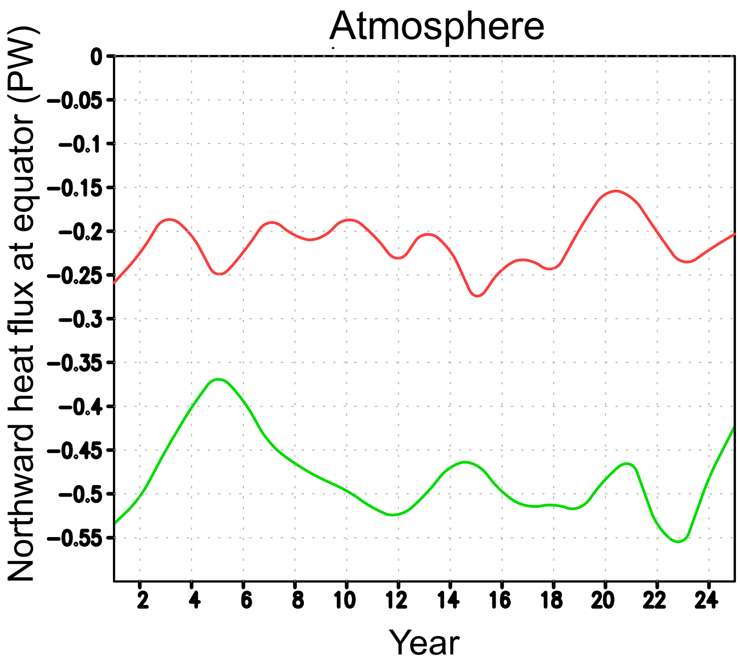
Top: Control Bottom: Experiment-Control

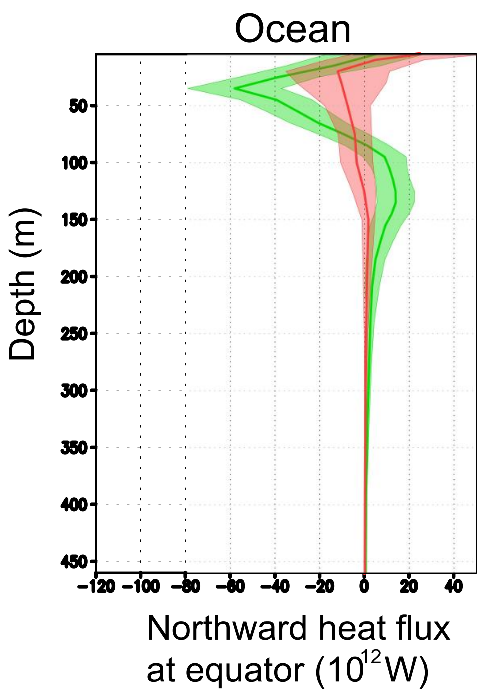
Also, the ITCZ is enhanced in northern tropics

SST biases in EXPT are generally weaker in both models!



Change in northward heat flux at the equator in the atmosphere and ocean in the experiment.





CGCM **ESM**