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Mean State Dependence of ENSO Atmospheric Feedbacks in Climate Models

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We present a detailed analysis of the ENSO atmospheric feedbacks in a perturbed atmospheric physics ensemble with the Kiel Climate Model (KCM) and for the CMIP5 data base. We further untangle the interaction between perturbed physics and the mean state differences in the KCM ensemble by conducting additional atmospheric only simulations. The results show that the atmospheric part of the amplifying Bjerknes Feedback (the zonal wind feedback) and the net heat flux damping feedback are strongly, linearly linked with each other via the mean state sea surface temperature (SST) and perturbed model physics play only a minor role.

In observations, strong wind and heat flux feedbacks are caused by a convective response in the Niño4 region during ENSO events, resulting from an eastward shift of the raising branch of the Walker Circulation during El Niño (vice versa for La Niña). Coupled General Circulation Models (CGCM), with an equatorial SST cold bias in the Niño4 region and accompanied La Niña-like mean state, yield a too westward raising branch of the Walker Circulation (by up to 30°) and hence only a weak convective response, explaining the too weak wind and heat flux feedback. Thus the position of Walker Circulation determines the strength of the wind and heat flux feedback and explains the compensating error between these two feedbacks, seen in KCM and many CGCM of the CMIP5 data base.

Furthermore, improved atmospheric feedbacks lead to a substantial improvement of important ENSO properties as phase locking of ENSO to the annual cycle and asymmetry between El Niño and La Niña. In order to successfully represent atmospheric ENSO dynamics in CGCM a correct mean state of the Walker Circulation is important and this serves as an explanation for the too diverse simulated ENSO in current CGCM.