Geophysical Research Abstracts
Vol. 20, EGU2018-3275-2, 2018
EGU General Assembly 2018

Mean-State Dependence of ENSO atmospheric feedbacks and ENSO dynamics in climate models

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ENSO atmospheric feedbacks are strongly underestimated in state-of-the-art climate models (Bellenger et al. 2014). Therefore we investigate in a perturbed atmospheric physics ensemble with the Kiel Climate Model (KCM) and in CMIP5 models how ENSO atmospheric feedbacks depend on the mean state of the tropical Pacific. Additionally, uncoupled simulations are conducted with the atmospheric component of the KCM to obtain further insight into the mean state dependence. It is found that the strengths of the positive zonal wind feedback and the negative heat flux feedback are both strongly linearly related equatorial sea surface temperature (SST) bias, while at least in the KCM differences in model physics seem to be less important (Bayr et al. 2017). In observations, strong zonal wind and heat flux feedbacks are caused by a convective response in the western central equatorial Pacific (Niño4 region), resulting from an eastward (westward) shift of the rising branch of the Walker Circulation (WC) during El Niño (La Niña). Climate models with a La Niña-like mean state, i.e. an equatorial SST cold bias in the Niño4 region (a common problem in many state-of-the-art climate models), simulate a too westward located rising branch of the WC (by up to 30°) and only a weak convective response. Thus, the position of the WC determines the strength of both the wind and heat flux feedback, which also explains why biases in these two feedbacks partly compensate in many climate models. Furthermore, a too eastward position of the WC leads to a fundamental change in ENSO dynamics, as ocean-atmosphere coupling shifts from a predominantly wind-driven to a more solar radiation-driven mode. On the other hand, enhanced atmospheric feedbacks lead to a substantial improvement of the non-linearity of ENSO. Differences in the mean state SST are suggested to be a major source of ENSO diversity in current climate models.

References:
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