Omens of coupled model biases in the CMIP5 AMIP simulations: role of the surface evaporation

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Abstract: Significant improvements in the representation of several aspects of the climate system have been made in the coupled global atmosphere-oceanic model over the last decade. However, systematic biases in sea surface temperature (SST) have been barely reduced between the CMIP3 and CMIP5 phases of the Coupled Model Intercomparison Project (CMIP) exercise separated by 7 years. These SST errors affect all tropical oceans and are mainly characterized by an overly pronounced equatorial cold tongue and a warm bias over the eastern tropical oceans. Most recent studies attributed the latter to an insufficient oceanic cooling or to an underestimation of shadowing of the surface by stratocumulus clouds while the equatorial cold tongue is attributed to errors in the wind field and cloud representation.
We show here that surface evaporation contributes as much as clouds to the warm bias. This is first demonstrated by considering the relationship between latent heat flux (LH) biases in forced atmospheric simulations and the SST biases models developed in coupled ocean-atmosphere simulations with the same atmospheric model. 22 pairs of forced atmospheric and coupled ocean-atmosphere simulations from the CMIP5 database are analysed showing up a systematic, negative correlation between the spatial patterns of these two biases.
The models with the largest warm biases in coupled mode are those with the highest surface heating by radiation and lowest evaporative cooling over eastern tropical oceans in atmospheric simulations with prescribed sea surface temperatures. Two sets of dedicated sensitivity experiments with the IPSL-CM5A-LR model (wind-nudged simulations and test on heat exchange coefficient) confirm this link between forced and coupled bias patterns. The analysis of the sources of the atmospheric LH bias patterns reveals that the near-surface wind speed bias dominates the zonal structure of the LH bias and that the near-surface relative humidity dominates the east-west contrasts.