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Using an ensemble data set of turbulent air-sea fluxes to evaluate the IPSL climate model in tropical regions

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Low-latitude turbulent ocean-atmosphere fluxes play a major role in the ocean and atmosphere dynamics, heat distribution and availability for meridional transport to higher latitudes, as well as for the global freshwater cycle. Their representation in coupled ocean-atmosphere models is thus of chief importance in climate simulations. Despite numerous reports of important observational uncertainties in large-scale turbulent flux products, only few model flux evaluation studies attempt to quantify and directly consider these uncertainties. To address this problem for large-scale, climatological flux evaluation, we assemble a comprehensive database of 14 climatological surface flux products, including in situ-based, satellite, hybrid and reanalysis data sets. We develop an associated analysis protocol and use it together with this database to offer an observational ensemble approach to model flux evaluation.

We use this approach to perform an evaluation of the representation of the intertropical turbulent air-sea fluxes in a suite of CMIP5 historical simulations run with different recent versions of the IPSL model. To enhance model understanding, we consider both coupled and forced atmospheric model configurations. For the same purpose, we not only analyze the surface fluxes, but also their associated meteorological state variables and inter-variable relationships. We identify an important, systematic underestimation of the near-surface wind speed and a significant exaggeration of the sea-air temperature contrast in all the IPSL model versions considered. Furthermore, the coupled model simulations develop important sea surface temperature and associated air humidity bias patterns. Counterintuitively, these biases do not systematically transfer to significant biases in the surface fluxes. This is due to a combination of compensation of effects and the large flux observational spread. Our analyses reveal several inconsistencies in inter-variable relationships between the different model versions and the observations, which could represent process-oriented constraints for future model development. Furthermore, the parallel assessment of coupled and forced atmospheric simulations leads to a new hypothesis linking atmospheric wind and latent heat flux biases to the development of the sea surface temperature bias in the IPSL coupled model. The observational ensemble and analyses presented in this study thus offer a good framework for large-scale model surface flux evaluation and provide a potentially rich source of information for model development.