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ENSO in CMIP5 models from an energy budget perspective

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Vast amounts of energy are exchanged between ocean, atmosphere, and space in association with the primary mode of global climate variability, El Niño-Southern Oscillation (ENSO).
Energy budgets of all tropical (30S-30N) ocean basins and the atmosphere are assessed separately to depict anomalous energy flows associated with ENSO in a consistent budget framework.
First, state-of-the art atmospheric and oceanic reanalyses are employed to robustly quantify changes in ocean heat storage, anomalous ocean-atmosphere energy exchanges and atmospheric energy transports during ENSO.
Variability of area-averaged tropical Pacific ocean heat content (OHC) to a large extent is modulated by energy flow through the ocean surface. While redistribution of OHC within the tropical Pacific is an integral part of ENSO dynamics, variability of lateral ocean heat transport out of the tropical Pacific region is found to be small. The only noteworthy contributions arise from the Indonesian Throughflow (ITF), which is anti-correlated with ENSO at a few months lag.
Regression analysis reveals that atmospheric energy transport and RadTOA (radiation at top-of-the-atmosphere) almost perfectly balance the OHC changes and ITF variability associated with ENSO. Only a relatively small fraction of El Niño-related heat lost by the Pacific ocean is radiated to space (mainly in the Pacific subtropics), whereas the major part of the energy is transported away by the atmosphere. Ample changes in tropical atmospheric circulation lead to enhanced surface fluxes and consequently to an increase of tropical Atlantic and Indian OHC that to very large degree compensates tropical Pacific OHC loss. This signature of energy redistribution is robust across the employed datasets for all three tropical ocean basins and explains the small observed ENSO signal in global mean RadTOA.
These results are then used as a benchmark to evaluate the energy pathways during ENSO as simulated by an ensemble of coupled climate model runs from the CMIP5 archive.
Significant differences are found between the results from reanalyses and climate models.
In contrast to reanalyses and satellite data, radiative energy input at TOA strongly increases during El Nino in most of the climate models. Furthermore, tropical Pacific ocean heat content variability is too small in the models: While the upper 300m of the tropical Pacific cool during El Nino, deeper layers tend to warm, leading to a very small ENSO signal in full-depth OHC. Moreover, teleconnections to the tropical Atlantic exist in the models as well, but they are weaker than found from reanalyses.
To a large degree, the found differences between models and reanalyses can be attributed to biased mean states in the models, which then project on the variability.