Geophysical Research Abstracts
Vol. 16, EGU2014-9866, 2014
EGU General Assembly 2014

On the evolution of the oceanic component of the IPSL climate models from CMIP3 to CMIP5: a mean state comparison

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We analyse the impact on the oceanic mean state of the evolution of the oceanic component (NEMO) of the climate model developed at Institut Pierre Simon Laplace (IPSL-CM), from the version IPSL-CM4, used for third phase of the Coupled Model Intercomparison Project (CMIP3), to IPSL-CM5A, used for CMIP5. Several modifications have been implemented between these two versions, in particular an interactive coupling with a biogeochemical module, a 3-band model for the penetration of the solar radiation, partial steps at the bottom of the ocean and a set of physical parameterisations to improve the representation of the impact of turbulent and tidal mixing. A set of forced and coupled experiments is used to single out the effect of each of these modifications and more generally the evolution of the oceanic component on the IPSL coupled models family. Major improvements are found in the Southern Ocean, where physical parameterisations such as partial steps and tidal mixing reinforce the barotropic transport of water mass, in particular in the Antarctic Circumpolar Current, and ensure a better representation of Antarctic bottom water masses. However, our analysis highlights that modifications, which substantially improve ocean dynamics in forced configuration, can yield or amplify biases in coupled configuration. In particular, the activation of radiative biophysical coupling between biogeochemical cycle and ocean dynamics results in a cooling of the ocean mean state. This illustrates the difficulty to improve and tune coupled climate models, given the large number of degrees of freedom and the potential compensating effects masking some biases.