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Local and Global Views of Systematic Errors of Atmosphere-Ocean General Circulation Models

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Coupled Atmosphere-Ocean General Circulation Models (CGCMs) have serious systematic errors that challenge the reliability of climate predictions. One major reason for such biases is the misrepresentations of physical processes, which can be amplified by feedbacks among climate components especially in the tropics. Much effort, therefore, is dedicated to the better representation of physical processes in coordination with intense process studies. The present paper starts with a presentation of these systematic CGCM errors with an emphasis on the sea surface temperature (SST) in simulations by 22 participants in the Coupled Model Intercomparison Project phase 5 (CMIP5). Different regions are considered for discussion of model errors, including the one around the equator, the one covered by the stratocumulus decks off Peru and Namibia, and the confluence between the Angola and Benguela currents. Hypotheses on the reasons for the errors are reviewed, with particular attention on the parameterization of low-level marine clouds, model difficulties in the simulation of the ocean heat budget under the stratocumulus decks, and location of strong SST gradients.

Next the presentation turns to a global perspective of the errors and their causes. It is shown that a simulated weak Atlantic Meridional Overturning Circulation (AMOC) tends to be associated with cold biases in the entire Northern Hemisphere with an atmospheric pattern that resembles the Northern Hemisphere annular mode. The AMOC weakening is also associated with a strengthening of Antarctic bottom water formation and warm SST biases in the Southern Ocean. It is also shown that cold biases in the tropical North Atlantic and West African/Indian monsoon regions during the warm season in the Northern Hemisphere have interhemispheric links with warm SST biases in the tropical southeastern Pacific and Atlantic, respectively.

The results suggest that improving the simulation of regional processes may not suffice for a more successful CGCM performance, as the effects of remote biases may override them. Therefore, efforts to reduce CGCM errors cannot be narrowly focused on particular regions.