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Interdecadal variability of atmospheric teleconnections and simulation skills of climate models

A. Alice M. Grimm (1), B. Atul K. Sahai (1,2) and C. Chester F. Ropelewski (3)

(1) Department of Physics, Federal University of Paraná, Curitiba, Brazil, (2) Permanent Affiliation: Indian Institute of Tropical Meteorology, Pune, India, (3) International Institute for Climate Prediction, Palisades, New York, USA.

grimm@fisica.ufpr.br / Fax: 55 41 361-3418 / Phone 55 41 361-3097

Global climate models forced by sea surface temperature (SST) are the standard tools in seasonal climate prediction and in projection of future climate change caused by anthropogenic emissions of greenhouse gases. Assessing the ability of these models to reproduce observed atmospheric circulation given the lower boundary conditions, and thus its ability to predict climate, has been a recurrent concern. Several assessments have shown that the performance of models is seasonally-dependent, but there has always been the assumption that, for a given season, the model skill is constant throughout the period being analyzed. Is the long-term variability of the atmosphere and the oceans prone to influence the performance of models, as is the seasonal variability?

Here, we demonstrate that there are periods when these models perform well and periods when they do not capture observed climate variability. The variations of the model performance have temporal scales and spatial patterns consistent with decadal/interdecadal climate variability. These results suggest that there are unmodeled climate processes that affect seasonal climate prediction as well as scenarios of climate change, particularly regional climate-change projections. The reliability of these scenarios may depend on the time slice of the model output being analyzed.

We compare the seasonal responses of two AGCMs (ECHAM3 and NCEP-MRF9) to prescribed observed SST with observed seasonal fields (from the NCEP/NCAR Reanalysis) during the period 1950-1994, to verify whether their performance is affected by long-term climate variations. The model performance is assessed through analy-

sis of simultaneous correlation coefficients (CCs) between the reanalysis data and the model output, averaged over every 20º latitude $\times$ 40º longitude region over the globe. Seasonal correlations are computed for winter and summer in 11-year sliding periods. The overall temporal variation of these CCs is a measure of interdecadal variation of the models' skill all over the globe. We also examined the long-term variations of the models´ performance by comparing the temporal variability of the observed response of the atmosphere to El Niño/Southern Oscillation (ENSO) with the temporal variability of the models´ response to ENSO.

The relationships between the interdecadal variations of the models' skill and known interdecadal modes of SST variability are examined through Empirical Orthogonal Function analyses of the sliding correlations between observed and modeled fields. To understand possible physical mechanisms behind the variability of the models´ performance, the first and second Principal Components were correlated with SST averaged over $10^{\circ} \times 10^{\circ}$ latitude-longitude regions. The statistical significance of the correlations is assessed through a Monte Carlo procedure. The patterns of correlation indicate regions where SST varies coherently with the modes of models´ performance. These patterns resemble closely those associated with well-known modes of non-ENSO low-frequency variability, as the Pacific Decadal Oscillation and the North Atlantic Oscillation.

The long-term fluctuations of the ability of the AGCMs forced with observed SST in reproducing the variability of the atmosphere seem to reflect fluctuations in the ocean-atmosphere links related to decadal/interdecadal climate variability. The existence of un-modeled interdecadal climate variations is likely due to un-modeled and not-well-understood climate processes. Some causes of the interdecadal variations in model skill are suggested. One of them is the inability of the models in correctly reproducing the interdecadal changes in the basic state of the atmosphere, which may modify their ability to represent well some processes, as the propagation of Rossby waves generated by tropical heat sources into the extratropics. An Influence Function analysis shows that the efficiency of anomalous tropical heat sources in producing rotational circulation anomalies in the extratropics is different when using the observed atmospheric basic states before and after the mid 70s. However, when the models´ basic states in these two periods are used, the influence functions are almost the same. This analysis suggests that models do not adequately reproduce the interdecadal changes in the basic state and their consequences. Probably they also do not reproduce well the anomalous tropospheric heat sources associated with interdecadal variability.

Given the use of these models in seasonal climate predictions and similar models in projections of future climate change, the long-term variations in their performance should be taken into account in their evaluation. As interdecadal variability is inherent to the climate system, even in the presence of increasing greenhouse-gases, the long-term variations of model skill indicate that the regional reliability of long climate model runs may depend on the time slice in which the output of the model is analyzed.

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