Introduction

We outline a framework for identifying and quantifying regional errors and their global impacts in climate models by forcing the model with analysis increments (either instantaneous or a long term mean) over limited regions. An example is given based on MERRA-2 (Gelaro et al. 2017) and the NASA/GMAO GEOS AGCM (Molod et al. 2015), with a focus on JJA.

Methodology and Experiments

Replay (RPL): takes advantage of the incremental analysis update procedure employed in the GEOS data assimilation system to force a model to track a pre-existing analysis (Figure 1). The equations governing replay have the form:

\[
\frac{\Delta x}{\Delta t} = f(x) + \Delta x
\]  

(1)

Where \( \Delta x \) = (analysis-forecast)/6hours is the instantaneous analysis increment, and \( f(x) \) consists of all the dynamics and physics terms of the model.

Figure 1: Overview of “replay”. The blue arrows indicate that the replay is essentially a continuous model simulation that is driven by a sequence of IAU (Incremental Analysis Update) forcing terms (updated every 6 hours). See equation 1.

Tendency Bias Correction (TBC): Following Chang et al. (2018), the governing equations for the TBC approach have the same form as (1), except that the forcing term is a long term mean of the increments. In particular,

\[
\frac{\Delta x}{\Delta t} = f(x) + \Delta x
\]  

(2)

where the \( \Delta x \) are the instantaneous \( \Delta x \), averaged over the years 1980-2017 (denoted by the overbar).

The RPL & TBC experiments consist of two sets of GEOS AGCM simulations in which the correction terms (either TBC: \( \Delta x \) or RPL: \( \Delta x \)) are applied in various regions (Figure 2) that together span the globe.

Conclusions

- regional TBC, as an extension of the global TBC examined in Chang et al. (2018), provides a powerful tool for identifying the sources of model bias, and quantifying their global impacts in global weather and climate models
- regional RPLY quantifies what is possible if one could track the analysis exactly in that region. As such, it provides an upper bound to how much of the long-term bias that can be corrected by TBC. More generally, we consider regional RPLY to be a tool for quantifying a model’s climate sensitivity
- our results indicate that the TBC impacts tend to be linear in the summer hemisphere (the sum of the results of the sub-regions add up to the results for the corresponding larger region). That does not appear to be true for the winter hemisphere (suggesting, in that case, some limitations in the interpretation of the regional results)

Chang, Y., S. Schubert, R. Koster, A. Molod and H. Wang, 2018: Tendency Bias Correction in Coupled and Uncoupled Global Climate Models with a focus on impacts over North America. Accepted in J. Climate.
