Effects of mean state of climate models on the response to prescribed forcing: Sensitivity experiments with the SPEEDY general circulation model.

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Introduction

Understanding how the general circulation of the atmosphere is affected by global warming is one of the grand challenges in climate science. Despite the use of large ensembles of continuously improving climate models, uncertainty is still considerable. For example, climate models exhibit non-negligible biases in simulating the extra-tropical circulation, as can be seen from results of the Climate Model Intercomparison Projects (CMIP3-5-6). It is therefore important to understand processes driving the variability of the circulation in climate models and how these processes are affected by the bias of the model. In this framework, to characterize the effect of the bias of the models on the response to a given forcing, several simulations were performed with the atmospheric general circulation model Simplified Parameterizations, primitivE - Equation DYnamics (SPEEDY)forced by climatological SST. Each simulation is characterized by a different atmospheric mean state at mid-latitudes, obtained by altering the height of the Rocky Mountains. We use these different versions of the SPEEDY model to mimic differnt models' biases and study how the response of the model to a given forcing changes when the mean state changes. The chosen forcing, for the response analysis, is the Atlantic Multidecadal Variability (AMV). AMV is a slowly evolving sea surface temperature (SST) anomaly pattern in the Atlantic Ocean, it is related to the heat content and/or heat transport in the ocean and it plays a relevant role in the Decadal Climate Prediction Project (DCPP) because it is considered one of the possible cause of the hiatus found in the global temperature time series.

The Model

SPEEDY is a primitive equations intermediate Atmospheric general circulation model. The resolution is T30 (4̃50 Km at equator) with 8 vertical levels and a gaussian grid of 96 x 48. Despite its "simplicity" and the "low" resolution, SPEEDY is able to reproduce several key aspects of the real atmosphere.[1][2] This model is a powerful resource; its speed and the required modest computational effort make SPEEDY a convenient tool when the numbers and /or the length of the simulations reach a 4-digit figure thousands of simulation.

Methodology

Six simulations are performed with a modified orography to obtain an atmospheric circulation at mid-latitudes characterized by different mean states. A control climate simulation carried in standard configuration is used as baseline (CTL). The six modified orography simulation have the height of the Rocky Mountains, or Rockies, increased or decreased by a given factor. The experiments are: -60% (minus60), -40% (minus40), -20% (minus20), +20% (plus20), +40% (plus40) and +60% (plus60). The modified orography is then smoothed with a weighted average over nine grid points. Each simulation is 200 years long and starts with the atmosphere at rest.

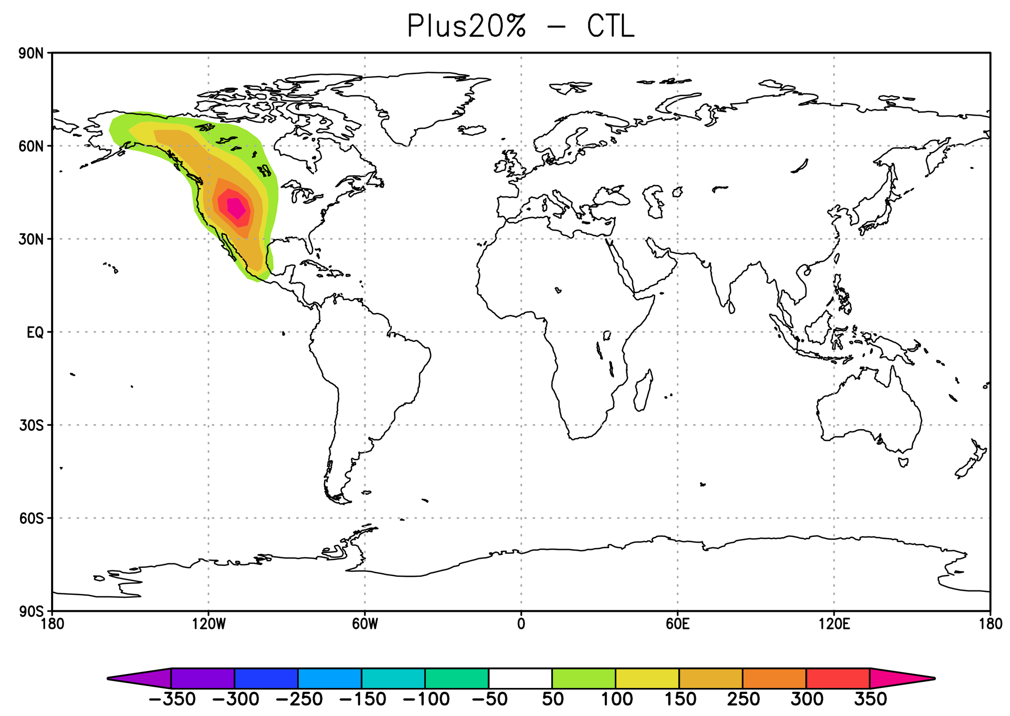

Figure 1: Orography, difference between the experiment with Rockies increased by 20% and the control experiment.

To study the effect of the bias of the models on the response to external forcing, the SST pattern of the AMV, both the positive (AMV+) and negative (AMV-) is imposed all the seven simulations. The positive AMV SST pattern is the pattern provided by DCPP component C, to obtain the negative phase it is sufficient to invert the sign of the anomaly.

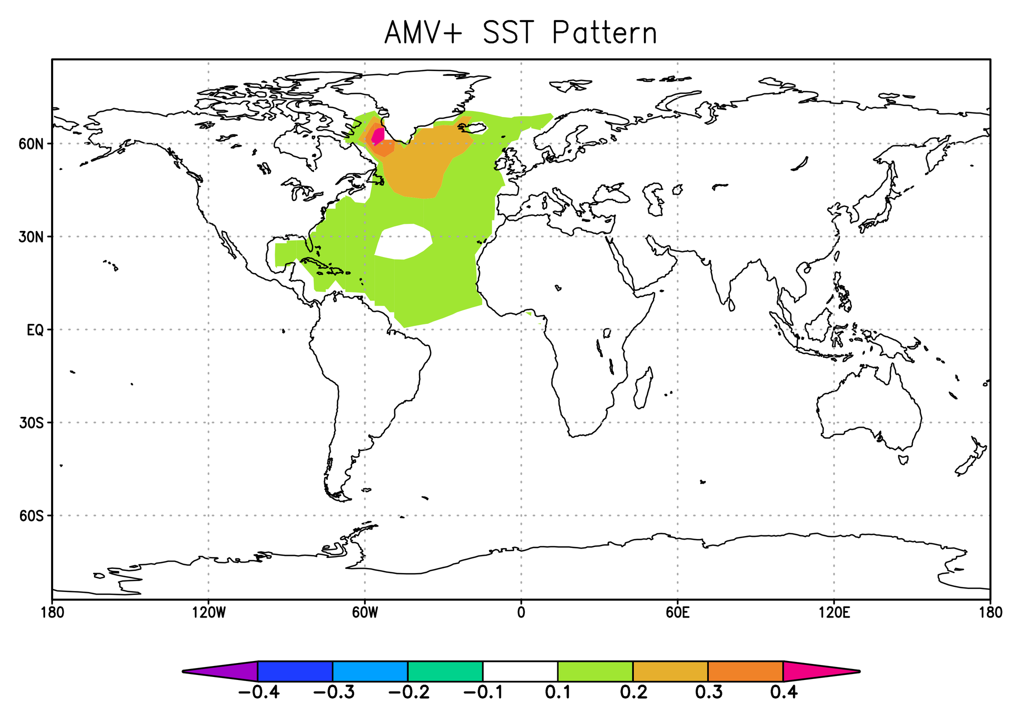

Figure 2: . SST anomaly pattern for the positive phase of AMV.

Preliminary Results

Each panel in Figure 3 shows the difference between the "Perturbed-Rockies" simulation and the control for the 500hPa geopotential height in DJF. The effect of the orography is to increase the geopotential height upstream when the Rockies are elevated and to reduce it when the orography is diminished. The intensity of the anomalies scales quite linearly with the magnitude of the factor applied to the Rockies.

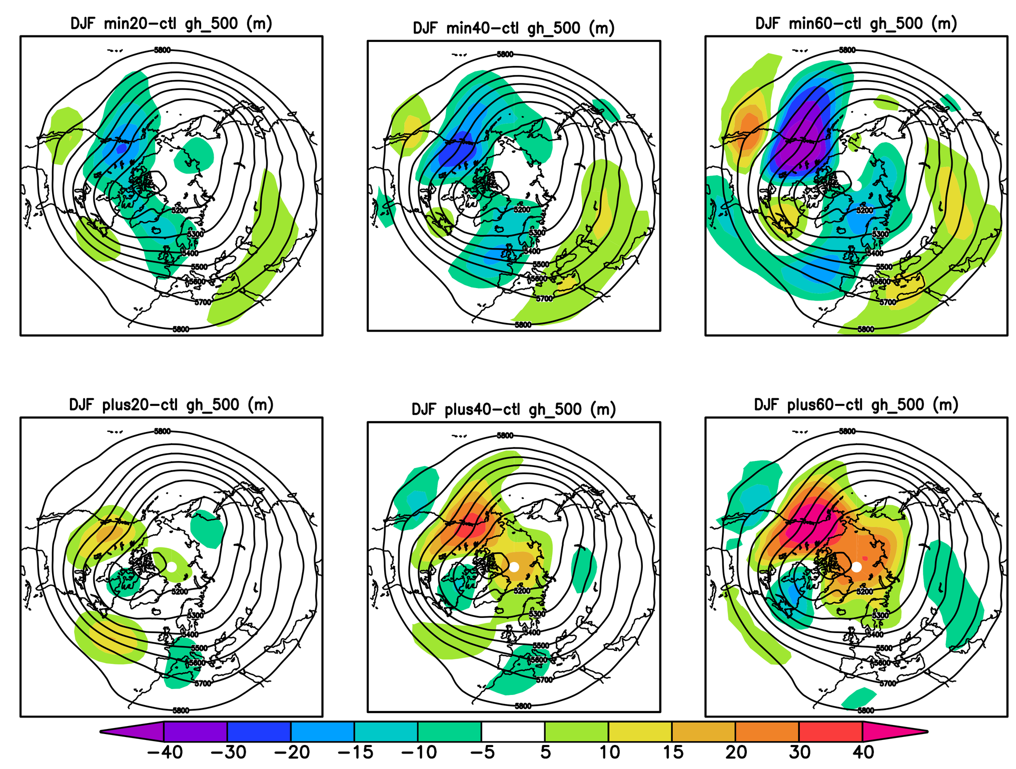

Figure 3: . Difference between experiments and CTL, DJF average of geopotential height at 500 hPa. Contours are the full field of CTL.

Figure 4 shows the the geopotential height at 500 hPa for all the AMV experiments. Each panel contains the difference between the experiment with the positive phase of the AMV minus the negative phase of the AMV. The geopotential height, for some of the experiments, shows a NAO- like pattern, but not all the simulation exhibit the same behavior and the same intensity.

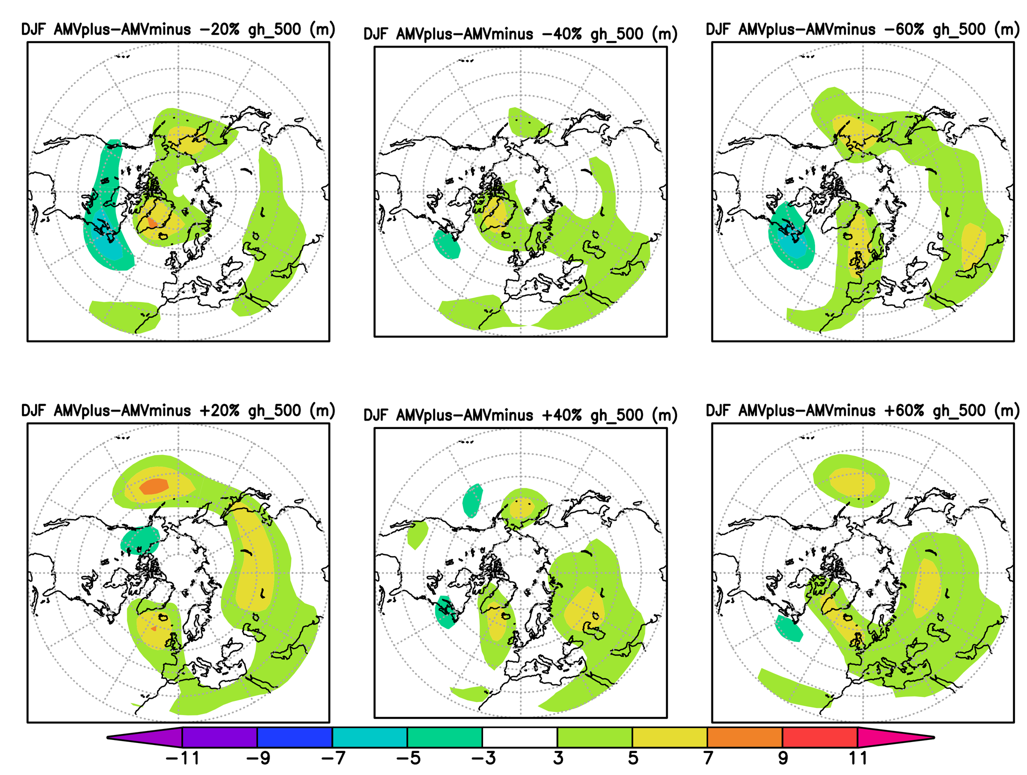

Figure 4: . Difference between AMV+ and AMV-, DJF average of geopotential height at 500 hPa.

Conclusions Remarks

The response to AMV of several simulation with different mean states were studied. Preliminary results show that the effect of the mean state on the response to external forcing is non negligible, moreover, the response appear to be complex and somehow non linear. Future experiments will test the response to stronger forcing like 2xAMV (i.e. applying a 2 times stronger anomaly) or the El Niño Southern Oscillation.

References

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[2] Kucharski F, Molteni F, and Bracco A (2006) Decadal interactions between the western tropical Pacific and the North Atlantic Oscillation. Clim Dyn 26: 79-91