Project: 1085

Project title: The response theory as a tool for investigating climate predictability and scale separation

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The MPI-ESM v.1.1 model has been run at its coarse resolution (CR), consisting of T31 spectral resolution (amounting to 96 gridpoints in the longitude dimension, 48 in the latitude dimension) and 31 vertical levels for the atmosphere, a curvilinear orthogonal bipolar grid (GR30) (122 longitudinal and 101 latitudinal gridpoints) with 40 vertical levels for the ocean.

A 4000-years control run has been produced in unforced conditions, representative of present-day atmospheric CO2 concentrations (i.e. 360 ppm). Initial conditions for a 20members ensemble have been sampled from it every 200 years, in order to ensure reasonable oceanic decorrelation (cfr. Ganopolsky et al., 2002; Wunsch and Heimbach, 2008). Two ensembles have been run, one reflecting an instantaneous doubling in CO2 concentration (2xCO2) (for 2000 years), the other one an increase in CO2 emissions by 1\% every year, until the 2xCO2 level is reached (1pctCO2) (for 1000 years). An additional individual run has been performed under initial abrupt quadrupling in CO2 concentrations, for 2000 years. This is needed, in order to properly scale the Green function. As an additional check, one of the 2xCO2 members has been prolonged by 2000 additional years, in order to investigate the model convergence to the energetic equilibrium and the existence of the model drift.

We have adapted the approach described in Ragone et al. (2016) and Lucarini et al. (2017), where a large ensemble of simulations with an intermediate-complexity atmospheric model had been evaluated. Using a coupled model, such as MPI-ESM-CR, the aim is investigating the scale separation between the atmospheric and oceanic response.

First, we have computed the Green function for some specific observables from the 2xCO2 experiment. This task is very easily accomplished, because the time modulation of the forcing has the form of a Heaviside function. For the atmosphere, we have taken into account the total precipitation flux and the near-surface temperature. For the ocean, we have considered the global ocean heat uptake (OHU) and the strength of the Atlantic Meridional Overturning Circulation (AMOC), in terms of oceanic mass transport crossing 26N of latitude (in Sv). Secondly, we have predicted the behavior of the chosen observable in the 1pctCO2 scenario.

Figure 1 shows in orange/cyan and red/blue the evolution of the observables in the individual runs and multi-model mean for 2xCO2/1pctCO2, respectively. Figure 2 shows the 1pctCO2 evolution (orange) and the predicted evolution by means of the linear response theory. Figure 3 shows the same, for the near-surface temperatures in specific regions of the Northern Hemisphere: the Tropics (a), the extra-tropics (b), the North Atlantic cold blob (c)

A detailed description of the results and a discussion of the implications is the focus of a paper currently in preparation for Geophysical Research Letters.



Figure 1: Time series evolution of (a) T2m (in K), (b) P (in kg*m-2*s-2), (c) OHU (in W), (d) AMOC at 26N (in Sv). The tick lines denote the ensemble mean for 2xCO2 (in red) and for 1pctCO2 (in blue). The thin lines denote each realization of the 2xCO2 (orange) and 1pctCO2 (light blue) ensembles.



Figure 2: Comparison between simulated 1pctCO2 and reconstructed via response theory prediction: (a) T2m (in K), (b) P (in kg*m-2*s-2), (c) OHU (in W), (d) AMOC at 26N (in Sv).



Figure 3: Comparison between simulated 1pctCO2 and reconstructed via response theory prediction: (a) T2m in the 0-45N latitudinal belt (in K), (b) T2m in the 45N-90N latitudinal belt (in K), (c) T2m in the North Atlantic cold blob window (in K).

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