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Predicting Climate Change through Response Operators in a Coupled General Circulation Model

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Global Climate Models are key tools for predicting the future response of the climate system to a variety of natural and anthropogenic forcings. Typically, an ensemble of simulations is performed considering a scenario of forcing, in order to analyse the response of the climate system to the specific forcing signal. Given that the the climate response spans a very large range of timescales, such a strategy often requires a dramatic amount of computational resources. In this paper we show how to use statistical mechanics to construct operators able to flexibly predict climate change for a variety of climatic variables of interest, going beyond the limitation of having to consider specific time patterns of forcing. We perform our study on a fully coupled GCM - MPI-ESM v.1.2 - and for the first time we prove the effectiveness of response theory in predicting future climate response to CO_2 increase on a vast range of temporal scales. We specifically treat atmospheric (surface temperature) and oceanic variables (strength of the Atlantic Meridional Overturning Circulation and of the Antarctic Circumpolar Current), as well as the global ocean heat uptake.