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Characteristics of the Arctic Oscillation and related teleconnection phenomena under climate change in the snapshot attractor picture

Dániel Topál (1), Mátyás Herein (2), and Tímea Haszpra (3)

(1) Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Meteorology, Hungary (topaldani@gmail.com), (2) MTA-ELTE Theoretical Physics Research Group, (3) Eötvös Loránd University, Institute for Theoretical Physics

The Arctic has experienced amplified warming during the past decades. The Arctic Oscillation (AO) has already been linked to Arctic-mid-latitude wintertime weather teleconnection patterns across the Northern Hemisphere in the literature. Here we evaluate the AO phenomenon in the ensemble framework using model outputs from the state-of-the-art CESM Large Ensemble Project under RCP8.5 climate change scenario for the 1920-2100 time-period.

In a changing climate, where one or more relevant parameters are changing in time, there can be no stationarity by definition, whereas stationarity is crucial for the applicability of temporal averages, which is a standard method in the wider climate community. To avoid the problem of evaluating time averages in a changing climate, we turn to a gradually strengthening approach of snapshot attractors. Qualitatively speaking, the snapshot view implies that climate change can be better understood if we imagine many parallel Earth systems – i.e. the 35 ensemble members instead of the one real Earth system – all of which are controlled by the same physics and are subject to the same external forcing.

Therefore, we use 35 ensemble members of the CESM-LE climate model each of that represents a climate realization differing in their initial conditions only for RCP8.5 scenario. Due to memory loss after a given finite convergence time all the members of the ensemble are 'attracted' to the snapshot attractor of the climate system, which can be represented as a definite area of the phase space indicating the climate's internal variability. Hence, after the convergence time has passed the variability of the system is independent of the initial conditions, consequently it characterizes the natural internal variability.

We perform Empirical Orthogonal Function (EOF) analyses of the wintertime sea level pressure (SLP) field over the domain poleward of 20°N for the 35 ensemble members. This allows us to examine the climate's internal variability regarding the SLP field and the related EOF modes including long-term projections of the AO-index. According to our experience, the internal variability of the climate system results in different EOF patterns of the SLP field regarding the different ensemble members even in the case of a quasi-stationary climate. This yields that caution should be taken when assessing long-term changes in the AO.

To illustrate this problem we investigate possible changes in the AO related teleconnection phenomena by 2100, including the October NH snow cover as a possible predictor of DJF mid-latitude surface temperature anomalies. We examine the statistical correlation over time regarding each of the ensemble members and also over the ensemble members at each time instant which results in a time-dependent correlation coefficient. Our results emphasize the importance of applying the snapshot attractor framework when studying changes of the climate system.