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A single type of winter European atmospheric blocking underestimated by GCMs, and improvements found for eddy-permitting ocean parametrization

Simon Michel, Anna von der Heydt, Michiel Baatsen, René van Westen, and Henk Dijkstra
Insitute for Marine and Atmospheric reasearch Utrecht, Utrecht University, Utrecht, the Netherlands

Midlatitude atmospheric blockings largely influence the usual synoptic flows propagating eastward in the atmosphere. They are characterized by long-lived, large-scale high-pressure systems, which have a significant impact on the trajectories of jet streams, and thus on the distribution of stormtracks and weather systems they drive. As a result of their formation, long-standing extreme weather can occur in different forms and during different seasons: heat waves, cold waves, drought, floods... Therefore, the study of their future activity and related climate extremes is highly important in the context of a changing climate. Meanwhile, the literature shows that coupled General Circulation Models (GCMs) of climate highly underestimate blocking frequencies in a wide variety of regions, thereby largely limiting the use of GCMs for climate extremes forecasts. This is notable for blockings occurring in regions and during seasons where they are prominent and have the largest societal impacts, such as boreal Winter European Atmospheric Blockings (WEABs). A wide variety of causes have been detected by former studies such as the horizontal resolution of the atmospheric model grid or GCM biases in tropical convection and North Atlantic current position. However, WEAB frequencies remain underestimated by all GCMs of the last three generations of the Coupled Model Intercomparison Project (CMIP3, CMIP5, and CMIP6).

Here, we first use an ensemble of historical simulations from 28 CMIP6 GCMs based on very different numerical schemes and grid resolutions and check their ability to simulate WEABs compared with the ERA5 reanalysis dataset. Using k-means clusterings methods based on blocking patterns, we show that a single type of observed WEABs, namely blockings occurring over the British Isles/North Sea regions, is largely underestimated by all GCMs, whose ensemble mean is nearly 65% lower than the frequency observed in ERA5. On the other hand, ERA5 frequencies of blockings occurring in Greenland, western Europe, and Scandinavia, all fall within the GCM range. This result indicates that GCM biases in simulating WEABs found by former studies are essentially affecting a specific location and, therefore, narrow their panel of potential causes. In addition, considering a subset of 8 out of the 28 GCMs with mesoscale eddy-permitting ocean resolution (*i.e.* higher than 0.25°x0.25°) from the HighResMIP ensemble, we find that the eddy-permitting parametric scheme allows to significantly increase the frequency of simulated WEABs. For the HighResMIP simulations, the frequency of British Isles/North Sea blockings is doubled for GCMs with eddy-permitting ocean resolutions but is still underestimated by an order of 50% compared

with ERA5 reanalysis data. This improvement is here hypothesized to be related to a less biased position of the North Atlantic current, which was identified by former studies as a reason for WEABs underestimation by GCMs.