Geophysical Research Abstracts
Vol. 17, EGU2015-9664, 2015
EGU General Assembly 2015

Representation of blocking in an ensemble of high-resolution global atmospheric models

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The representation of modes of variability in atmospheric models depends crucially on the model's ability to simulate persistent circulation anomalies, for example during blocking episodes. Furthermore, models tend to underestimate blocking occurrence and it has been suggested that their relatively coarse resolution limits their ability to represent mid-latitude blocking.

Assessing the role of model resolution for blocking is computationally expensive, as multi-decadal simulations at the desired resolution are necessary for a robust estimation of blocking statistics. Here, we use an ensemble of four atmosphere-only global models for which simulations that fulfil this requirement are available at resolutions of roughly 25 km horizontal grid spacing in the mid-latitudes. This corresponds to about a fourfold increase in resolution over the highest-resolution CMIP5 (Coupled Model Intercomparison Project, Phase 5) models. The four models are (i) the ECMWF model (IFS) as used in the project Athena, (ii) the MRI-AGCM 3.2, (iii) CAM5, and (iv) our own HadGEM3-GA3 simulations obtained in the UPSCALE project (UK on PrACE - weather-resolving Simulations of Climate for globAL Environmental risk). We also use coarser (100-200 km grid spacing) versions of these four models with an as similar as possible model formulation to assess the sensitivity to resolution in a controlled modelling setup.

We use a two-dimensional blocking index to assess the representation of blocking in these simulations and in three reanalyses (ERA-Interim, ERA-40, MERRA). We evaluate the spatial distribution of climatological blocking frequency, the interannual variability of blocking occurrence as well as the persistence of blocking events. Furthermore, the degree to which blocking biases are associated with mean-state biases is quantified in the different models.

We find that the three reanalyses agree well on the blocking climatology. The sensitivity of the simulated blocking to model resolution depends on the season and also differs for different parts of the northern hemisphere: For Euro/Atlantic blocking, the increase in resolution eliminates nearly all of bias in spring, and robustly so for all four models. For the other seasons, however, the resolution sensitivity is much weaker. There is a slight enhancement in winter, whereas summer blocking continues to be strongly underestimated also by the high-resolution models. The improvement with resolution seen in spring can be attributed to an improvement in the model mean state, yet the underrepresentation of winter and summer blocking seen in both the low and high-resolution models is only partly associated with the mean-state bias. For Pacific blocking, we find no systematic sensitivity to model resolution.