Geophysical Research Abstracts
Vol. 17, EGU2015-10000, 2015
EGU General Assembly 2015

Orographic precipitation at global and regional scales: Observational uncertainty and evaluation of 25-km global model simulations

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Precipitation over land exhibits a high degree of variability due to the complex interaction of the precipitation generating atmospheric processes with coastlines, the heterogeneous land surface, and orography. Global general circulation models (GCMs) have traditionally had very limited ability to capture this variability on the mesoscale (here ∼50–500 km) due to their low resolution. This has changed with recent investments in resolution and ensembles of multidecadal climate simulations of atmospheric GCMs (AGCMs) with ∼25 km grid spacing are becoming increasingly available. Here, we evaluate the mesoscale precipitation distribution in one such set of simulations obtained in the UPSCALE (UK on PrACE - weather-resolving Simulations of Climate for globAL Environmental risk) modelling campaign with the HadGEM-GA3 AGCM.

Increased model resolution also poses new challenges to the observational datasets used to evaluate models. Global gridded data products such as those provided by the Global Precipitation Climatology Project (GPCP) are invaluable for assessing large-scale features of the precipitation distribution but may not sufficiently resolve mesoscale structures. In the absence of independent estimates, the intercomparison of different observational datasets may be the only way to get some insight into the uncertainties associated with these observations. Here, we focus on mid-latitude continental regions where observations based on higher-density gauge networks are available in addition to the global data sets: Europe/the Alps, South and East Asia, and the continental US.

The ability of GCMs to represent mesoscale variability is of interest in its own right, as climate information on this scale is required by impact studies. An additional motivation for the research proposed here arises from continuing efforts to quantify the components of the global radiation budget and water cycle. Recent estimates based on radiation measurements suggest that the global mean precipitation/evaporation may be up to 10 Wm-2 (about 0.35 mm day-1) larger than the estimate obtained from GPCP. While the main part of this discrepancy is thought to be due to the underestimation of remotely-sensed ocean precipitation, there is also considerable uncertainty about ‘unobserved’ precipitation over land, in particular in the form of snow in regions of high latitude/altitude. We aim to contribute to this discussion, at least at a qualitative level, by considering case studies of how area-averaged mountain precipitation is represented in different observational datasets and by HadGEM3-GA3 at different resolutions.

Our results show that the AGCM simulates considerably more orographic precipitation at higher resolution. We find this at the global scale both for the winter and summer hemispheres, as well as in several case studies in mid-latitude regions. Gridded observations based on gauge measurements generally capture the mesoscale spatial variability of precipitation, but differ strongly from one another in the magnitude of area-averaged precipitation, so that they are of very limited use for evaluating this aspect of the modelled climate. We are currently conducting a sensitivity experiment (coarse-grained orography in high-resolution HadGEM3) to further investigate the resolution sensitivity seen in the model.