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Representation of orography and its effect on the atmospheric flow in global weather forecasts

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The importance of orography for the large-scale atmospheric circulation has been well investigated in the past through both theoretical and modelling studies. However, some questions related to the impacts of orography on the atmospheric flow remain. In this study, a set of global medium-range forecasts are performed with different horizontal and orographic resolutions ranging from 160km to 9km to understand the impacts of the representation of orography on the Northern Hemisphere winter circulation. The forecasts are performed with the Integrated Forecast System (IFS) of the European Centre for Medium-Range Weather Forecasts (ECMWF). Particular questions addressed here are 1) what is the effective orographic resolution in the IFS? and 2) how much do atmospheric and orographic resolution increases, respectively, contribute to overall improvements in the Northern Hemisphere (NH) winter forecast skill obtained when increasing the horizontal resolution of the IFS? Analysis of resolved torques from experiments performed with different atmospheric resolutions but with the same orographic resolution reveals that the effective orographic resolution in the IFS is of approximately 4 to 5 times the (horizontal) grid box size. However, it also appears that the effective orographic resolution depends on the geographical regions. For experiments using no parametrizations of subgrid orography effects, it is found that the orographic resolution increases are responsible for most of the overall increase in skill obtained when increasing the horizontal resolution of the IFS. Otherwise said, atmospheric resolution increases alone (without increasing the orographic resolution) contribute little to the increase in skill in the NH winter throughout the troposphere. In the stratosphere, better atmospheric resolution leads to an improved skill due to a better representation of gravity waves propagation and breaking. If the subgrid orographic parametrizations are turned on, the benefits of increasing the orographic resolution decrease because the parametrizations account for unresolved effects. However, they do not entirely disappear suggesting that the parametrizations are not perfect. This is even more true at low resolutions, typical of global climate models (160km). Analysis of barotropic winds and surface pressure changes in forecasts performed at 9km with different orographic resolutions demonstrates that all scales of orography are equally important for the obtained changes in the winter circulation and the forecast skill increase.