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Elevation-dependent warming and its driving mechanisms in global climate model simulations at different spatial resolutions

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The enhancement of warming rates with elevation, a phenomenon which is referred to as Elevation-Dependent Warming (EDW), is one of the regional, still not completely understood, manifestations of global warming. Sentinels of climate and environmental changes, mountain regions have overall experienced more rapid and intense warming trends compared to the globally-averaged temperature increase in the recent decades, leading to serious impacts both on high-altitude mountain ecosystems and downstream.

In this work we analyse an ensemble of simulations from one state-of-the-art Global Climate Model (EC-Earth) run at five different spatial resolutions, from ∼125 to ∼16 km. The aim of the study is to investigate the impact of the model resolution on the representation of EDW, and to highlight possible differences in EDW characteristics and causes in three mountain regions of the Northern Hemisphere mid-latitudes - the Colorado Rocky Mountains, the Greater Alpine Region and the Tibetan Plateau–Himalayas.

Our results show that the changes in albedo and in downward longwave radiation are the more frequent EDW drivers in all regions and seasons and that this is reflected in both daytime and nighttime warming. In the Tibetan Plateau-Himalayas and in the Greater Alpine Region, an additional driver is the change in specific humidity. We also find that, while generally the model ability in simulating the existence of EDW in the different regions does not (clearly) depend on the spatial resolution which is employed, specific EDW characteristics such as its intensity and the relative role of different driving mechanisms may be different in simulations performed at different spatial resolutions. Overall, our results seem to indicate that the model resolution plays a crucial role in small areas such as the Alps, where a too coarse resolution would lead to an underrepresentation of the highest altitudes. In fact, elevational dependence of warming, as well as of other mechanisms or variables, could not be easily identified if the range of altitudes is too limited.

We also find that the role of internal climate variability in modulating the EDW signal can be significant, as suggested by the spread found in the multi-member ensemble of the EC-Earth experiments used.