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Effects of the horizontal resolution of climate models on the simulation of extreme hourly precipitation in the Tibetan Plateau and surrounding areas

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Extreme precipitation events, represented by the extreme hourly precipitation (EHP), often occur in the Tibetan Plateau and surrounding areas (TPS) as a result of the complex topography and unique geographical location of this region and can lead to large losses of human life. Previous studies have shown that the performance of extreme precipitation simulations can be improved by increasing the resolution of the model, although the mechanisms are not yet not clear. In this study, we firstly compared the most recent high-quality satellite precipitation product with station data from Nepal, which is located on the southern edge of the Tibetan Plateau. The results showed that the GPM dataset can reproduce extreme precipitation well and we therefore used these data as a benchmark for climate models of the TPS. We then evaluated the fidelity of global climate models in the representation of the boreal summer EHP in the TPS using datasets from the CMIP6 High-Resolution Model Intercomparison Project (HighResMIP). We used four global climate models with standard (about 100 km) and enhanced (up to 25 km) resolution configurations to simulate the EHP. The models with a standard resolution largely underestimated the intensity of EHP, especially over the southern edge of the Tibetan Plateau. The EHP can reach up to 50 mm h^{-1}in the TPS, whereas the maximum simulated EHP was <35 mm h^{-1} for all the standard resolution models. The mean intensity of EHP is about 5.06 mm h^{-1} in the GPM satellite products, whereas it was <3 mm h^{-1} in standard resolution models. The skill of the simulation of EHP is significantly improved at increased horizontal resolutions. The high-resolution models with a horizontal resolution of 25 km can reproduce the geographical distribution of the intensity of EHP in the TPS. The intensity–frequency distribution of EHP also resembles that from GPM products, showing the same features up to 50 mm h^{-1}, although it slightly overestimates heavy precipitation events. Finally, we propose possible physical linkages between the simulation of EHP and the impacts of the resolution of the model and physical processes. Phenomena over the Indian Ocean at different timescales and the diurnal variation of precipitation in the TPS are used to propose possible physical linkages as they may play an important part in the simulation of EHP in the TPS. Further analysis shows that an increase in the horizontal resolution helps to accurately reproduce the features of water vapor transport on days with extreme precipitation, the northward-propagating intraseasonal oscillation over the Indian and western Pacific Ocean monsoon regions in the boreal summer, the intensity and number of tropical cyclones over the southern Asian monsoon regions, and the peak time and amplitude of the diurnal cycle of precipitation. This increase in accuracy contributes to the improvements in the simulation of EHP in the TPS. This study suggests improvements to increase the horizontal resolution of the GCMs and lay a solid foundation for the accurate reproduction and prediction of EHP in the TPS.