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WRF Model Sensitivity Analysis of orographic precipitation in the Snowy Mountains of Southeastern Australia

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Wintertime cold fronts generate much of the precipitation in the Snowy Mountains of south eastern Australia. A case study of a heavy precipitation event in late autumn (May 2016) is presented. A frontal system generated from a strong cut-off low passed over the mountain producing up to 145 mm of precipitation over a period of 72 hours. Observations from the Himawari-8 satellite reveal a optically thick, well-defined frontal cloud band that is heavily glaciated, which is followed by shallow orographic clouds composed primarily of supercooled liquid water in the post-frontal environment. Given the many challenges in short-term quantitative precipitation forecasting (e.g., complex physical mechanisms and surface geometry), the main objectives are (1) evaluating the performance of the simulation of precipitation and clouds using high density ground based observations, and (2) exploring the impact of changes in the topography (Topo-run: lessening the rise above 1 km by 75%), horizontal resolution (Res-run: interpolating the orography data from 3 km resolution on to 1 km resolution model grid) and the microphysics (MP-run) schemes on the magnitude and the spatial distribution of precipitation. A range of simulations are conducted to investigate the sensitivity of the above-mentioned factors against the "control" simulation.
The model shows a considerable level of skill in simulating the spatial distribution of precipitation and the associated cloud properties, such as cloud-top temperature and phase as observed by Himawari-8 and, to lesser extent, in predicting precipitation amount over high elevations. It is found from the Topo-run that the maximum precipitation decreases, up to 70% over the mountains, leading to a reduction of about 27% on average. Changing the microphysics schemes from the Thompson double-moment 6-class scheme to the single-moment 5-class scheme (WSM5) leads to a change of spatial distribution of precipitation with a reduction of precipitation over the mountain peaks and enhanced precipitation over the windward and lee slopes. The domain-averaged rain accumulation is less sensitive to the choice of microphysics (about 6% increase) compared with its clear impact on the precipitation pattern. The single-moment scheme tends to simulate a larger ice mixing ratio and is less favourable for clouds composed of supercooled liquid water. Orographic precipitation, however, shows much less sensitivity (only a slight reduction of about 4% in the area-average of the accumulated precipitation) to upscaling the horizontal resolution. There is also a marginal impact on the spatial distribution of precipitation of replacing the coarse horizontal resolution of the orography data with the finer grid spacing. This further suggests that the precipitation biases are more likely to be arising from uncertainties in the physical processes rather than the resolution of the grid spacing in the orography.