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Numerical simulations of banded orographic convection over the eastern Italian Alps: influence of atmospheric conditions and local topography

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Elongated and quasi-stationary convective rainbands triggered by small-scale orography and capable of producing heavy precipitation are often observed over the Italian Alps. Such features occurred in the final and most intense phase of the Vaia storm over the eastern Italian Alps, on the evening of 29 October 2018. South-east/north-west oriented bands, driven by the strong Sirocco wind, caused floods and landslides in several locations. In the present work, the thermodynamic conditions favorable for their formation and the triggering by small-scale topographic features are investigated through semi-idealized numerical simulations with the Weather Research and Forecasting (WRF) model.

Simulations are initialized using radio-sounding data measured at Udine-Rivolto, upstream of the eastern Italian Alps, at 18:00 UTC, 29 October. The small-scale energy needed to develop convection is provided by prescribing background thermal fluctuations embedded in the low-level flow or applying random perturbations to the topographic field.

The first tests using a simplified smooth ridge highlight that rainbands develop even without the triggering effect of small-scale topographic features. The simulated convection tends to organize in non-stationary bands which result from flow-parallel roll-type circulations with tilted updrafts reaching 6-7 km altitude. A sensitivity analysis with simulations at 1, 0.5 and 0.2 km grid spacing highlights that results are independent of the model resolution.

The influence of stability, wind intensity and wind shear on the development of rainbands is also investigated, using different idealized sounding profiles in the absence of small-scale topographic triggers. Similar to previous studies, results highlight that band-shaped convection is favored in vertically sheared intense flows without rotation of wind direction with altitude and weakly unstable cap clouds. The presence of convective inhibition in the boundary layer is fundamental for constraining the release of convection over the idealized ridge. On the other hand, intense instability or saturated layers within the mid-upper part of the statically unstable cap cloud disrupt the convective organization.

The presence of small-scale topographic perturbations, capable of releasing energy in the upstream edge of the unstable cap cloud in the form of lee waves, causes stationary rainbands which enhance the spatial variability in cumulative precipitation. The intensity of convection is efficiently amplified by individual obstacles when the induced wave pattern is in phase with the forced ascent generated by the main ridge. Moreover, the coupling between induced gravity waves and low-level convergence zones due to flow channeling and deflection has been revealed effective for rainband formation.

Finally, simulations with the real eastern Alpine orography demonstrate that, under Sirocco conditions, highly stationary bands are triggered by the topographic perturbations of the south-eastern Alpine foothills, individuating the favorable location of orographic rainbands for future similar convective events.