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Disentangling the forcing mechanisms of heavy precipitation events along the Alpine south side using potential vortcity inversion

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Extreme precipitation events occurring on the Alpine south side have a tremendous societal impact. The precise forecasts of such precipitation events are of utter importance for damage reduction measures. To this end it is crucial to understand the mechanisms forcing and triggering precipitation of both the large-scale and the meso-scale atmospheric flow field. Previous studies have shown that an upper-level streamer over Western Europe typically accompanies extreme precipitation events along the Alpine southside. Streamers are meridionally elongated intrusions of stratospheric, high potential vorticity (PV) air into the troposphere. Static stability is reduced beneath a PV streamer, thus facilitating convection, and the wind field is cyclonic around the PV streamer, thus forcing moisture transport towards the Alps on its downstream flank. Here, the substructure of a streamer and its impact on a heavy-precipitation event is studied.

A case study based on the ERA-40 reanalysis dataset of the ECMWF is undertaken. Piecewise PV inversion is used to change small subparts of the streamer and investigate their impact on the flow and thermodynamic fields. The changes are performed in such a way that they resemble observed forecast errors in the PV distribution. Hence, the inversion experiments illustrate the consequences of misforecasts.

To quantify the impact of the PV streamer's substructure on the Alpine precipitation, different approaches are pursued: (a) The slightly altered fields are taken as initial conditions for a integration with the CHRM numerical weather prediction model, allowing to assess the changes in model precipitation; (b) Changes in the vertical stability are quantified, both by considering changes in the convective available potential energy (CAPE) and by considering a cumulative index which is based upon several traditional static stability indices. The convectionally unstable areas are located in the tip of the streamer, but small changes in the stability are also observed in the Alpine region; (c) The transport of humid air masses is analyzed by measuring the impinging integrated humidity fluxes. The magnitude of the moisture transport towards the Alps is dependent both on the latitudinal extent of the streamer and its amplitude. The former determines how effectively the streamer can tap into the subtropical moisture reservoir and the latter influences the amount of water that can be transported; (d) Finally, the orographic lifting on the Alpine southside is considered. This lifting strongly depends on the vertical stratification and on the impinging flow speed (as given by the dimensionless mountain height or Froude number),and hence reacts sensitive to any change of the PV streamer's substructure.

In summary, the accumulated precipitation of the experiments conducted show noticeable differences in both the location and the amplitude. These differences are due to the interaction of the altered flow field, stability and moisture transport with the complex Alpine topography.