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The 'Swabian MOSES 2023' re-analysis: how do high-resolution campaign observations change the analysis state of a convective-scale NWP system?

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High-impact weather caused by summertime convection poses a considerable threat to people and property. Southwest Germany is particularly frequently affected by hailstorms and associated damage, with an anomalously high number of hail days per year. Yet, forecasting convective events remains one of the greatest challenges in numerical weather prediction (NWP), even for regional high-resolution convective-scale NWP systems. Here, we test to what extent the assimilation of comprehensive high-resolution observations of the lower troposphere from a field campaign improves initial conditions and the quality of subsequent forecasts of convective events.

From June to August 2023, the 'Swabian MOSES 2023' campaign took place in the southwest German mountain ranges. During the campaign, a wide range of instruments to observe the dynamical and thermodynamical characteristics of the lower troposphere, distributed across an area of roughly 100 km x 100 km, was deployed. In this contribution, we will present a campaign re-analysis dataset that utilizes 3 months of ground-based remote sensing and in-situ campaign observations in addition to observations from the operational observation network. The observations are assimilated hourly in the regional forecasting system of the DWD, which employs the non-hydrostatic model ICON at 2.2 km grid spacing (ICON-D2) and the Kilometer Scale Ensemble Data Assimilation system (KENDA) with 40 ensemble members. In addition to the operationally available observations we assimilate 1) vertical profiles of the horizontal wind retrieved from an unprecedented network of 12 Doppler wind lidars (DWL), 2) reflectivity from an X-Band radar, 3) radiosoundings released at 2 sites during intensive observation periods, 4) ground-based zenith path-delay observations from a (not yet operationally assimilated) German-wide network of Global Navigation Satellite Systems receivers, and 5) 2-meter temperature and relative humidity observations from six campaign surface stations.

We will present the setup of the assimilation experiments and quantify which and where new information is added to the analysis. We specifically focus on the assimilation of DWL-retrieved wind profiles and their influence on the mesoscale circulation in southwest Germany. For example, we find that the mean absolute observation-to-background difference is slightly larger for the wind profiles retrieved from DWLs than for wind profiles retrieved from operational radar wind profilers. Yet, the observation-to-analysis difference is similar for all wind profiler data. In

addition, we compare the 4D campaign re-analysis dataset with a quasi-operational control re-analysis that excludes the campaign observations. The comparison indicates systematic wind direction differences in southwest Germany resulting from the assimilation of campaign observations. These differences are propagated in re-forecasts, which we will illustrate exemplarily for (i) one week of deterministic re-forecasts of dry and convective days, and (ii) for a 20-member ensemble re-forecast of a small-scale high-impact convective event.