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Multi-scale analysis of the impact of increased spatial resolution of soil moisture and atmospheric water vapour on convective precipitation

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The distribution of water vapour in the planetary boundary layer (PBL) and its development over time is one of the most important factors affecting precipitation processes. Despite the dense radiosonde network deployed during the Convective and Orographically-induced Precipitation Study (COPS), the high spatial variability of the water vapour field was not well resolved with respect to the detection of the initiation of convection. The first part of this investigation focuses on the impact of an increased resolution of the thermodynamics and dynamics of the PBL on the detection of the initiation of convection. The high spatial resolution was obtained using the synergy effect of data from the networks of radiosondes, automatic weather stations, synoptic stations, and especially Global Positioning Systems (GPSs). A method is introduced to combine GPS and radiosonde data to obtain a higher resolution representation of atmospheric water vapour. The gained spatial resolution successfully improved the representations of the areas where deep convection likelihood was high. Location and timing of the initiation of convection were critically influenced by the structure of the humidity field in the boundary-layer.

The availability of moisture for precipitation is controlled by a number of processes including land surface processes, the latter are strongly influenced by spatially variable fields of soil moisture (SM) and land use. Therefore, an improved representation of both fields in regional model systems can be expected to produce better agreement between modelled and measured surface energy fluxes, boundary layer structure and precipitation. SM is currently one of the least assessed quantities with almost no data from operational monitoring networks available. However, during COPS an innovative measurement approach using a very high number of different SM sensors was introduced. The network consisted of newly developed low-cost SM sensors installed at 43 stations. Each station was equipped with sensors at three different depth (5, 20 and 50cm) simultaneously measuring SM and soil temperature.

Within the framework of this work, a strategy to study the effects of SM, evapotranspiration and water vapour in the PBL on convective precipitation is applied on different scales, from local to regional. The SM and atmospheric fields are compared to their related representation within the COSMO-CLM, high-resolution regional model applied in the climate mode. The optimized fields are used for initialization of the model runs to study the impact of surface and PBL processes on convective precipitation. The combination of dense observations with COSMO-CLM simulations permits a rigorous analysis of the water transfer process chain from SM and fluxes to convective initiation and precipitation. This work constitutes a central part of the overall COPS strategy by thorough analysis of the measurement and model data and aims to improve the QPF by better process representation in the regional model COSMO-CLM.