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Precipitation Related to Fronts and Cyclones in a Kilometer-Scale European Climate Simulation

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A major fraction of precipitation in Europe is produced by extratropical cyclones and their associated warm and cold fronts, often up to hundreds of kilometers away from the cyclone center. It is therefore indispensable to include fronts in comprehensive analyses of weather impacts of cyclones. Frontal precipitation is typically a combination of stratiform and embedded convective precipitation, and convection plays an important role in particular for generating flash floods. Therefore, when assessing the role of frontal precipitation based on model simulations, a realistic representation of convection is crucial to study short-term precipitation impacts such as hourly extremes.

In this study, we investigate precipitation related to fronts and cyclones in a ten-year kilometer-scale regional climate simulation over Europe. The simulation has been conducted with a GPU-enabled version of the COSMO model at 2.2 km horizontal resolution (1542 x 1542 x 60 grid points). Deep convection is resolved explicitly, which vastly improves the representation of convective precipitation compared to models with parameterized deep convection, for instance regarding the diurnal cycle of summer precipitation or convective organization at cold fronts. The model domain includes most of Europe and the Mediterranean, which is large enough to contain most fronts affecting Europe in their full extent. Studying nine years of the simulation (2000 – 2008) at hourly resolution, we aim to gain a comprehensive overview of the relation of precipitation to fronts and cyclones over Europe, both structurally and quantitatively, including seasonal, regional, and diurnal effects of both regular and extreme precipitation.

We identify fronts based on equivalent potential temperature at 850 hPa and cyclones based on sea level pressure, and track both using a new feature tracking algorithm suitable for high-resolution data. Local fronts of thermal origin are eliminated from the analyses. Two complementary approaches are used to relate precipitation to fronts: a minimum distance criterion, which is simple and robust; and front track projections, a technique that is more involved but enables us to distinguish between pre- and postfrontal contributions, and to determine the distance to a front taking into account its movement. The second approach also allows us to diagnose the composite mean distribution of precipitation across all warm and cold fronts. First results show that most precipitation is produced in a twelve-hour window centered at the time of frontal passage, but substantial contributions still occur up to 36 hours behind cold fronts.

A more detailed classification of precipitation is obtained by disaggregating the precipitation field into front- and cyclone-related contributions, enabling comparisons between components such as pre- and postfrontal; cyclonic, concurring (near warm and cold front, capturing occlusion or T-bone areas), and isolated front segments; or front-related and non-frontal. Applying this classification to hourly extreme precipitation (defined by a local percentile over the whole time period) indicates, for instance, that hourly extreme events are mostly non-frontal and occur mainly during summer in the afternoon, but many also occur during the night in summer/fall, with substantial cold-frontal contributions.