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Towards using a ground-based network of microwave radiometers and water vapor lidars for improving short-term weather forecasts

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Short-term forecasts of current high-resolution numerical weather prediction models still have large deficits in forecasting the exact temporal and spatial location of severe, locally influenced weather such as summer-time convective storms or cool season lifted stratus or ground fog. Often the thermodynamic instability - especially in the boundary layer - plays an essential role in the evolution of weather events. While the thermodynamic state of the atmosphere is well measured close to the surface (i.e. 2 m) by in-situ sensors and in the upper troposphere by satellite sounders, the planetary boundary layer remains a largely under-sampled region of the atmosphere where only sporadic information from radiosondes or aircraft observations is available.

The major objective of the DWD (German Weather Service) funded EMF (Extra-Murale-Forschung) project ARON is to design an optimized network of ground based microwave radiometers (MWR) and compact Differential Absorption Lidars (DIAL) for a continuous, near-real-time monitoring of temperature and humidity in the atmospheric boundary layer in order to improve short-term forecasts of thermodynamic (in)stability.

Nowadays, ground-based MWR are network-suitable, robust instruments providing temperature and humidity profiles with high temporal resolution under almost all weather conditions, with exception of heavy precipitation. Microwave profilers are highly suited for continuously monitoring the temporal development of atmospheric stability before the initiation of deep convection, especially in the atmospheric boundary layer. The vertical resolution of microwave temperature profiles is best in the lowest kilometer above the surface, decreasing rapidly with increasing height. In addition, humidity profile retrievals typically cannot be resolved with more than two degrees of freedom for signal, resulting in a rather poor vertical resolution throughout the troposphere. Additional information about water vapor could be provided below clouds by a potential network of water vapor DIAL instruments.

In this contribution, we show how the combination of MWR and DIAL can improve the retrieval and forecast of atmospheric stability. Specifically, the combination of ground-based networks with satellite overpasses and conventional observing systems will be evaluated. Since networks of MWR and DIAL sensors are currently not available for operational weather forecasting, the potential of their assimilation into a convective-scale numerical weather prediction (NWP) model can be investigated within an Observing System Simulation Experiment (OSSE). In this study we use the Consortium for Small-scale MOdelling (COSMO) model for Germany (COSMO-DE) with the horizontal resolution of 2.8 km, which is run operationally at the German Weather Service (DWD). Simulation and direct assimilation of ground based MWR observations require a fast radiative transfer model and its adjoint. For this purpose we assess the ground-based version of the RTTOV radiative transfer model, recently developed at the University of L'Aquila. The long-term goal is to quantify the impact of different network configurations (i.e. instrument spatial density, type and accuracy of the instruments) on the accuracy of atmospheric analyses and short-term forecasts in order to give recommendations for a future observation network design.