Observational impact of ground-based profiling networks

The demand for accurate weather forecasts is increasing because of, for example, high-impact events becoming more frequent and more extreme. However, convection-resolving numerical weather prediction systems still lack precise initial conditions, particularly in the atmospheric boundary layer (ABL). Thus, capturing the evolution of the ABL remains a crucial challenge for short-term meteorological forecasting but also for further sustainable applications, such as renewable energies. To help fill the existing observational gap, ground-based remote sensing sensors for measuring temperature and humidity, such as microwave radiometers (MWR) and water vapor lidars (DIAL), have been developed and are now suitable for network operation. The first instrument networks are currently being established within programmes such as the European E-PROFILE programme and the European Research Infrastructure Consortium ACTRIS.

As these temporally highly resolved observations typically represent column observations with a defined vertical extent and resolution, but no horizontal coverage, the main research question to be answered is the following: to what extent can a particular observational constellation of ground-based networks (e.g., number of instruments per target area) improve short-term forecasts of crucial variables, such as humidity, temperature, cloudiness, atmospheric stability, and, consequently, severe weather.

In this contribution, we present the progress in assessing the impact of ground-based profiling networks, with a focus on DIALs and MWRs.

Firstly, we present a computationally efficient Ensemble Sensitivity Analysis (ESA) set-up applied to quantify the impact of different configurations of a DIAL network on ICON-D2 forecasts. Using a 180-member ICON-D2 ensemble and an ensemble-based sensitivity, here, the ESA method quantifies the change in variance of a forecast metric ensemble due to the assimilation of additional DIAL observations. First results indicate that, for the default network configuration and two summer afternoon cases, the additional observations reduce the variance of the model ensemble on average by 5.5 to 7 percent depending on the specific water vapor forecast metric used. The forecast metrics respond as expected to changes in the network parameters, that is, their ensemble variance decreases further for smaller instrumental errors and larger vertical ranges of the DIALs.

Secondly, we demonstrate preliminary results from the VITAL II (Vertical profiling of the troposphere: Innovation, opTimization and AppLication) measurement campaign which will take place from 1 June to 31 August 2026 in the Cologne Bay region between the west German cities of Cologne, Bonn, and Aachen. Seven profiling sites over a wide variety of land surface types will be installed and employed. At these sites, ground-based remote sensing systems such as DIALs, Doppler lidars and MWRs will be operated to provide reliable, nearly continuous observations of ABL temperature, humidity, winds, and turbulence. Uncrewed aircraft systems (UAS) will additionally be operated at selected sites during an intensive observation period. A large number of radiosondes will complement the profiling observations.

During VITAL II, the first data from the Infrared Sounder on board of Meteosat Third Generation (MTG-IRS) will become available, providing temperature and humidity fields over Europe with a temporal resolution of 30 minutes. We aim to improve the accuracy and resolution of MTG-IRS profiling in the ABL and under cloudy conditions by combining it with the ground-based in-situ and MWR observations. First results of the temperature and humidity profile retrievals from combined IRS and MWR observations will be shown.