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Uncertainty Assessment for HATPRO Microwave Radiometer Measurements and Calibrations

The atmospheric boundary layer (ABL) is the most important under-sampled part of the atmosphere. ABL monitoring is crucial for short-range forecasting of severe weather within highly resolving numerical weather predictions (NWP). Top-priority atmospheric variables for NWP applications like temperature (T) and humidity (H) profiles are currently not adequately measured. Ground-based microwave radiometers (MWRs) like HATPRO (Humidity And Temperature PROfiler) are particularly well suited to obtain such T-profiles in the ABL as well as coarse resolution H-profiles. It has been shown by previous studies that the assimilation of MWR observations is beneficial for NWP models, however MWR data are not yet routinely assimilated into operational NWP. The HATPRO measures in zenith and other angles throughout the troposphere over an area with ~10 km radius and has a temporal resolution on the order of seconds. Measured brightness temperatures (TB) are used to retrieve the T- and H-profiles. Path integrated values IWV (Integrated Water Vapor) and LWP (Liquid Water Path) are quite reliable with excellent uncertainties up to 0.5 kg/m^2 and 20 g/m^2, respectively.

Driven by the E-PROFILE program, a business case proposal was recently accepted by EUMETNET to continuously provide MWR data to the European meteorological services. Also, the European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases (ACTRIS) and the European COST action PROBE (PROfiling the atmospheric Boundary layer at European scale) currently focus on establishing continent-wide quality and observation standards for MWR networks for research as well as for NWP applications. The German Weather Service (DWD) also investigates the potential of HATPRO networks for improving short-term weather forecasts over Germany.

For all this it is important to obtain an overview of what HATPROs are capable of in regard to their measurement uncertainty. This was done by conducting coordinated experiments at JOYCE (Jülich Observatory for Cloud Evolution) and the FESSTVaL (Field Experiment on Submesoscale Spatio-Temporal Variability at Lindenberg) campaign in 2021 within a prototype MWR network. The goal is to develop a standard procedure for error characterization that can be applied to any HATPRO network instrument (guidance for operators).

Important error components are absolute calibration errors (biases), drifts (instrument stability, leaps between calibrations), radiometric noise and also location specific radio frequency interferences (RFI). For the absolute calibration with liquid nitrogen, the repeatability, the integration time and the time between calibrations are essential. Differences between consecutive calibrations are analysed, the right duration of a calibration and the right amount of time between calibrations are proposed, referring to the magnitude of the observed drifts. For the determination of noise levels for each channel, covariance matrices (correlated noise) of measured brightness temperatures on the cold- and hotload references are presented. RFI are detectable via clear-sky azimuth- and/or elevation scans.