Temperature and humidity profile retrievals from synergistic satellite (MTG-IRS) and ground-based (Microwave Radiometer, SYNOP) observations

Spatially and temporally resolved fields of temperature and humidity within the planetary boundary layer (PBL) are the crucial variables for short-term forecasting with convection resolving numerical weather prediction models (NWP). Despite their potential positive impact on NWP analysis and forecast, both variables are still not adequately (vertically, horizontally and temporally) measured by current observing systems.

The hyperspectral infrared sounder (IRS) will operate from geostationary orbit on-board the Meteosat Third Generation (MTG) and provide unprecedented temporally and spatially resolved view into the atmosphere. However, even hyperspectral infrared satellite observations still leave gaps in the observation of the PBL structure, mainly due to the limited vertical resolution of the satellite as well as the strong influence of the surface properties or clouds (Teixeira et al., 2021). Moreover, atmospheric profiles retrieved from hyperspectral observations show increasing uncertainty in the lowest few kilometers of the atmosphere (Wagner et al., 2024).

In order to fill the existing observational gap, ground-based remote sensors for measuring temperature, humidity and wind profiles have been developed that are nowadays suitable for network operation. Especially, passive microwave radiometers (MWR) have been characterized accurately concerning their 24/7 reliability, accuracy, and information content. A network of ground-based MWRs has the potential to provide real time, all-sky profile observations. On the European level, first instrument networks are in the process of being established, e.g. within the European Research Infrastructure Consortium ACTRIS.

With our study, carried out within the Hans-Ertel Center for weather research of DWD (HErZ), we attempt to answer the question, to what extent the synergy of ground-based MWR and standard 2m temperature/humidity measurements (SYNOP) with hyperspectral infrared satellite observations (IRS) can improve temperature and humidity profiling over the ICON-D2 domain.

We develop retrievals of temperature and humidity profiles based on reanalysis as the truth and applying Neural Network (NN) approach allowing an optimal blending of IRS radiances with surface-based remote sensing observations and standard 2m meteorology over the ICON-D2 domain. We simulate satellite observations using RTTOV model and use the MWRpy package for ground-based MWRs. In the first attempt, the retrievals are developed for two stations: the Jülich Observatory for Cloud Evolution (JOYCE) and the DWD Observatory Lindenberg (RAO). Other suited ACTRIS sites will be considered as well.

After the launch of MTG-S we plan to apply the developed retrievals to real MWR, SYNOP and IRS observations and to assess the impact of assimilation of obtained atmospheric profiles on the short-term forecasts of crucial variables such as low-level winds, cloudiness, atmospheric stability, and severe weather.

In this contribution, we present the first results of the study including simulation of satellite and ground-based observations from reanalysis, neural network architecture and performance of the MWR, IRS and synergistic MWR+IRS and SYNOP+IRS retrievals applied to simulated observations.