Improving Precipitation and Humidity NWP-forecasts with GNSS-ZTD Data Assimilation

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Introduction

Humidity is an important parameter for short-range precipitation forecasts of Limited Area Numerical Weather Prediction (NWP) models, especially at high resolutions. At the same time it is a difficult parameter to initialize because of its high variability in time and space. Radar reflectivity data and Zenith Tropospheric Delay (ZTD) data from ground-based Global Navigation Satellite System (GNSS) tracking stations contain humidity information and thus offer a great possibility to improve the humidity initialisation in NWP-models. The assimilation of radar and ZTD data has shown to have a positive impact on the prediction of precipitation patterns and cloud forecasts. This poster presents the current data assimilation setup at the Royal Meteorological Institute (RMI) of Belgium and the plans to add ZTD-GNSS data.

Data Assimilation: Calculating Initial Conditions

Data assimilation creates the initial conditions for a NWP-forecast by incorporating new observations in an previous model-forecast.

Elements of Data Assimilation
- Observations and observation error statistics
- A previous forecast as background
- Model error statistics
- Observation operators: convert model variables to quantities measured by observation instruments (e.g. humidity to ZTD). Used to compare observation values with model values.

Output of Data Assimilation:
- A best estimate of the current state of the atmosphere
- Based on differences between model values and observations
- Taking into account the uncertainty in the observations and the model.

The Current Data Assimilation Setup

Current Experimental Setup
- Upper-air: 3-Dimensional Variational Assimilation (3DVAR)
  - Obs.: conventional data + radar data
- Surface: Extended Kalman Filter (EKF)
  - Obs.: 2m temperature and relative humidity (T2m, RH2m)

Results
- Data assimilation improves Root Mean Square Error (RMSE) and BIAS scores for RH2m and T2m (experiment without radar data)

Test with single radar (Wideumont)
- Left: precipitation observations
- Right: effect of radar data on analysis (radar+synop analysis - synop analysis for specific humidity at lowest model level)

The ALARO-model
- Model version cy38t1 + ALARO-0 + 3MT
- Lateral boundary conditions from Arpege global model
- Model geometry: 4km horizontal resolution, 46 vertical levels
- Surface scheme SURFEX

GNSS-ZTD Future Plans

The aim is to add GNSS-ZTD data to the assimilation process.
- Goal: Improve rainfall and cloud forecast
- Why GNSS-ZTD data?
  - Information on atmospheric water vapour content and surface pressure
  - Dense network over Belgium
  - Good spatial and temporal resolution
- Required data-format: BUFR (binary)
- Pre-processing: bias correction, whitelisting, height-difference correction, spatial and temporal thinning
- Observation operator: calculate model equivalent ZTD
  Using the integration of the model calculated refractivity
  \[ ZTD = \sum_i ZTD_i \text{ per model layer} \]
  \[ ZTD = ZHD + ZWD \text{ summation over all layers} \]
  \[ ZHD = \text{Zenith Tropospheric Delay} \]
  \[ ZWD = \text{Zenith Wet Delay, proportional to local pressure} \]
  \[ ZHD = \text{Zenith Hydrostatic Delay, proportional to local pressure} \]

4km-DOMAIN