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Advanced multi-GNSS troposphere modeling for improved monitoring and forecasting of severe weather

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The Royal Observatory of Belgium (ROB) contributes to the EUMETNET EIG GNSS Water Vapour Program (E-GVAP) aiming at the operational exploitation of GNSS signals for improving Numerical Weather Prediction (NWP). Within E-GVAP, ROB provides hourly-updated Zenith Tropospheric Delays (ZTDs) from a network of about 350 GPS stations covering Europe. Over the past years, many GPS station operators have upgraded their equipment to observe simultaneously multiple GNSS (GPS, GLONASS, Galileo). However, these additional observations are presently not exploited for operational meteorology, which still relies on the analysis of GPS-only observations to provide only ZTD (no or few information on spatial heterogeneities is provided). Improving this situation is one of the goals of the new COST Action ES1206: “Advanced GNSS Tropospheric Products for Monitoring Extreme Weather Events and Climate” (GNSS4SWEC) to which ROB participates.

In that context, ROB is investigating a new processing strategy using the latest Bernese software version 5.2 to provide new and enhanced tropospheric products, including the estimation of ZTD and horizontal gradients, based on the analysis of multi-GNSS observations. These products will improve the analysis of the behavior of atmospheric water vapor (including its local heterogeneities) and stimulate the use of GNSS for the monitoring and forecasting of severe weather.

As a first step, we studied the benefits of including GLONASS observations w.r.t. a GPS-only processing system, focusing particularly on the reliability and stability of the ZTD estimation. We also studied the sensitivity of the new multi-GNSS ZTD estimates with respect to the relative constraints imposed during the parameter estimation. In our setup, relative constraints of 0.007m provide a good balance between reducing the noise and allowing for the natural variability of the ZTD. We also show that the new multi-GNSS ZTD estimates generally agree with the GPS-only estimates at the level of 1-2 mm and that the multi-GNSS parameter estimates have slightly improved reliability and stability.

In a second step, we studied the capability of simultaneously estimating multi-GNSS tropospheric horizontal gradients and ZTD parameters, focusing again on the benefits brought by adding GLONASS observations. Therefore, we setup horizontal gradient estimation with a time resolution of 1 hour. We studied the sensitivity of the new multi-GNSS gradient estimates to the relative constraints and the impact of simultaneously estimating gradients on the estimated ZTD values. The results show that loose horizontal gradient constraints (e.g. 5m) degrade the quality of the ZTD estimation and that gradients must be estimated using quite tight relative constraints.

The previous results are combined in our final setup which estimates multi-GNSS ZTD and horizontal gradients with a time resolution of 1 hour.