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Using low-cost GNSS receivers to densify existing GNSS water-vapor monitoring networks

Andreas Krietemeyer (1), Marie-claire ten Veldhuis (1), Eugenio Realini (2), and Nick van de Giesen (1)

(1) Water Resources, Faculty of Civil Engineering, TU Delft, Delft, Netherlands (a.krietemeyer@tudelft.nl), (2) GReD - Geomatics Research & Development srl, Italy

Water vapor plays an important role for the prediction of rainfall in numerical weather prediction (NWP) models. Particularly the forecasting of small-scale extreme events is essential for flood-prone areas. Recent research shows that the assimilation of Precipitable Water Vapor (PWV) can be beneficial for extreme weather forecasting. Different techniques exist to estimate the amount of PWV in the atmosphere. Traditional radiosonde releases offer precise measurements but are limited both spatially and temporally, and their ascension trajectory is significantly affected by the wind. Satellite-based measurements (e.g. InSAR) are characterized by a good spatial but poor temporal resolution. Another possibility to estimate PWV is to exploit the signal delays from Global Navigation Satellite System (GNSS) satellites. However, existing GNSS monitoring networks have inter-station distances in the order of tens of kilometers, which is not sufficiently dense to capture small-scale water vapor variations. These networks were originally designed for geodetic purposes and are characterized by expensive geodetic-grade dual-frequency receivers and antennas. A densification with such receivers is not economically feasible. Instead, low-cost single-frequency receivers may be utilized to decrease the inter-station distances. In the context of the European project BRIGAID (BRIdging the GAp for Innovations in Disaster resilience) , we deployed four single-frequency stations with inter-station distances of 4-5 kilometers in the city of Rotterdam, Netherlands, and four more around the town of Monterosso al Mare, Italy. We present verification results by co-aligning two single-frequency receivers equipped with different antenna types to the International GNSS Service (IGS) station DLF1 in Delft, Netherlands. To investigate whether the low-cost receiver or the antenna limits the precision of the water vapor estimations, we split the data from a dual-frequency antenna to a single-frequency receiver and a dual-frequency receiver. To account for the ionospheric delay and to process the data in Precise Point Positioning (PPP) mode, we apply the Satellite-specific Epoch-differenced Ionospheric Delay (SEID) model using existing dual-frequency stations from 50-80 kilometers and 200-300 kilometers distance. This experiment addresses the feasibility of low-cost single-frequency GNSS stations to densify existing GNSS networks for water vapor monitoring. Data obtained from the increased spatial density of PWV estimations may be highly beneficial for NWP modeling and extreme rainfall forecasting.