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Analysis of GNSS sensed slant wet delay during the severe weather events in central Europe

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Over the last few decades, anthropogenic greenhouse gas emissions have increased the frequency of climatological anomalies such as temperature, precipitation, and evapotranspiration. It is noticed that the frequency and severity of the intense precipitation signify a greater susceptibility to flash flooding. Flash flooding continues to be a major threat to European cities, with devastating mortality and considerable damage to urban infrastructure. As a result, accurate forecasting of future extreme precipitation events is critical for natural hazard mitigation. A network of ground-based GNSS receivers enables the measurement of integrated water vapour along slant pathways providing three-dimensional water vapour distributions. This study aims to demonstrate how GNSS sensing of the troposphere can be used to monitor the rapid and extreme weather events that occurred in central Europe in June 2013 and resulted in flash floods and property damage. We recovered one-way slant wet delay (SWD) by adding GNSS post-fit phase residuals, representing the troposphere's higher-order inhomogeneity. Nonetheless, noise in the GNSS phase observable caused by site-specific multipath can significantly affect the SWD from individual satellites. To overcome the problem, we employ a suitable averaging strategy for stacking post-fit phase residuals obtained from the PPP processing strategy to generate site-specific multipath corrections maps (MPS). The spatial stacking is carried out in congruent cells with an optimal resolution in elevation and azimuth at the local horizon but with decreasing azimuth resolution as the elevation angle increases. This permits an approximately equal number of observations allocated to each cell. The spatio-temporal fluctuations in the SWD as measured by GNSS closely mirrored the moisture field associated with severe weather events in central Europe, i.e., a brief rise prior to the main rain events, followed by a rapid decline once the storms passed. Furthermore, we validated the one-way SWD between ground-based water-vapour radiometry (WVR) and GNSS-derived SWD for different elevation angles.