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Characterizing atmospheric turbulence with a dense GNSS network: temporal and spatial analysis of high-rate slant delays

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Forecasting sudden thunderstorms and torrential rain in urban areas is a crucial objective for disaster prevention and mitigation. Such severe storms are often abrupt and highly localized phenomena with a horizontal scale of few kilometers, which makes them difficult to be predicted by current numerical weather models. Short-term predictions on such small scales could potentially benefit from reliable measurements of the temporal and spatial fluctuations of water vapor in the atmosphere. Since most of the atmospheric water vapor is contained in the troposphere, it is possible to estimate the amount of precipitable water vapor (PWV) from the analysis of Global Navigation Satellite System (GNSS) tropospheric delays: the estimated signal delay due to the tropospheric refractivity along each receiver-satellite line-of-sight, or slant delay, is mapped to the zenith direction and divided in its hydrostatic and wet components in order to estimate the PWV over a GNSS station. The water vapor distribution and its variability can be monitored by employing a network of continuously operating stations. Atmospheric turbulence can be characterized by analyzing the temporal and spatial fluctuations of tropospheric delays.

This work focuses on the stochastic analysis of refractivity fluctuations in the wet troposphere by means of temporal and spatial structure functions applied to observed tropospheric delays. High-rate (1 Hz) observations obtained from a dense network of dual frequency GNSS receivers have been processed by precise point positioning, taking into account the effects of satellite clock instability on the estimated tropospheric delay. The resulting structure functions show power-law behaviors varying between 5/3 and 2/3, consistently with Kolmogorov turbulence theory. The impact of different slant delay geometries is evaluated by elevation-based satellite selection. The effect of different tropospheric conditions on the correlation length and magnitude of the measured fluctuations is studied, suggesting the possibility to characterize and monitor turbulence in the wet troposphere at local scale by means of a continuously operating dense GNSS network.

Keywords: GNSS, PPP, troposphere, water vapor, atmospheric turbulence