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Stochastic analysis of spatio-temporal variations of high-resolution GNSS wet delays for meteorological applications

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Although designed for positioning purposes, the Global Navigation Satellite System (GNSS) can be also exploited for atmospheric sounding and in particular for troposphere water vapor content monitoring. The water vapor content in fact reflects in a GNSS signal delay, which can be evaluated in terms of Zenith Wet Delay (ZWD). This is an average parameter accounting for delays affecting the signals arriving to a GNSS receiver from all satellites in view.

The modeling of water vapor variations in space and time is still a challenging research topic: since it is difficult to characterize it in a deterministic way, stochastic approaches are often preferred; moreover, the turbulent behavior demands a high-resolution sampling both in time and space.

ZWDs derived from regional permanent GNSS networks result in high-rate time series, but the space resolution is still too loose for reconstructing the turbulent component of the water vapor content. Possible solutions can be envisaged from the coupling of GNSS with radar or SAR products or by the possibility to densify existing networks by exploiting low-cost GNSS receivers designed in view of meteorological applications.

With the aim of assessing the potential use of GNSS observations for this purpose, a network of 17 dual-frequency receivers, installed near the Uji campus of Kyoto University, Japan, was used. The network covers an area of about 10×6 km^2 and inter-station distances range between 1 and 2 km. All receivers are identical and observe GPS, GLONASS and QZSS at 1 Hz. Weather stations are installed within the network, measuring ground pressure and temperature for accurate ZWD and precipitable water vapor (PWV) retrieval.

In this work we exploit ZWDs derived by Precise Point Positioning (PPP) on observations of this network, which were extensively validated in previous studies by comparison with independent measurements by radiosondes and microwave radiometers.

The delay at a given epoch is modeled as a homogeneous random field. The estimated values, properly reduced to account for the height-dependent component, are used epoch-by-epoch to determine isotropic and anisotropic variograms, describing the spatial correlation of the ZWDs themselves.

In order to investigate the relationship between these second order statistics, rain-gauge observations and radar-derived precipitation values, an ad-hoc software tool was developed, able to compare all these data types.

From this comparison it results that meteorological atmospheric instabilities, associated to precipitation, reflect in specific behaviours of the ZWD variograms.

Directional variograms enhance a clear azimuth-dependent signature, consistent with the main direction of movement of precipitation clouds detected by radar.

Encouraged by these results, we start exploring the joint temporal and spatial variability of the ZWD field. On-going research activities on this subject, and specifically on the estimation of average wind velocities based on the frozen flow hypothesis will also be presented.

Keywords: GNSS, troposphere, zenith wet delay, covariance