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# Estimation and Validation of Precipitable Water Vapor From the Permanent GPS Array of the Geographical Survey Institute (GEONET)

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This paper investigates the accuracy and the error sources of the atmospheric precipitable water vapor (PWV) estimated from the permanent GPS array of the Geographical Survey Institute (GEONET), Japan. The microwave signals transmitted from GPS satellites are delayed when they pass through the atmosphere, which induces geodetic errors in precise positioning. To remove the errors, the tropospheric delay is estimated from the GPS data (carrier phase) itself together with geodetic parameters of interest such as station position by least square inversion. By subtracting the zenith hydrostatic delay calculated from surface pressure measurements, the zenith wet delay is obtained, which can be converted into PWV by multiplying a proportional constant calculated from surface temperature. To investigate the accuracy and the features of PWV obtained in Japan, PWV estimated from the routine solutions of GEONET was compared with that observed at the 10 radiosonde stations of the Japan Meteorological Agency nearest to the GEONET stations over the Japanese Islands. The comparisons for the data of 6 months in 1996 showed that the agreement of the GPS-derived PWV was 3.7 mm in terms of r.m.s. difference. This value is comparable with those obtained using conventional meteorological instruments. However, the value is worse than those obtained in the central North America (Rocken et al., 1995), due to a systematic negative bias in the GPS-derived PWV relative to the radiosonde measurements.

As mentioned in above, the troposphere delay is corrected by estimating zenith delay simultaneously with the site coordinates in GPS analysis. This method relies on the troposphere delay and coordinates are separable from the phase observation data. However, these parameters, together with phase ambiguity parameters, are highly correlated if the elevation mask of 15 degrees is used, and are not easily resolved. As a consequence, the correlated parameters are more likely to be affected by the noise in the observation data and by the modeling errors. Deterioration of phase observation due to multipath and radome are especially large error sources in the case of GEONET. Systematic biases at most 20 cm for the station height and the discrepancy of the troposphere delay estimate among the neighboring sites up to 4 cm were seen in the old solution of GEONET. The ocean tide loading displacement of the GEONET stations was not corrected in the old GEONET analysis. The un-modeled site displacement results in the fake tidal signals in the troposphere delay estimate, and its amplitude reaches 12 mm (about 2 mm in precipitatable water vapor) for M2 signals. The strategy of the routine analysis of GEONET was modified for implementing updated models, fixing the above problems, optimizing the network analysis, etc. The all past data after 1996 was reanalyzed. The bias in the solution was mitigated by taking the new phase correction map which is obtained by a phase calibration experiment for the GEONET monument types. The tidal signals in the troposphere estimates are mostly eliminated by applying the ocean tide loading model of Matsumoto et al. (2000). The accumulation of the improved troposphere estimates from the new solutions provides opportunities to apply them to various research fields as a fundamental dataset.