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Basic research of now-casting system for severe storms by using a dense GPS network

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The frequency and intensity of torrential rains are increasing. Though localized horizontal inhomogeneities of water vapor distribution were observed prior to such kind of rainfalls in historical cases, these phenomena occur suddenly and have a horizontal scale of a few kilometers. So, local heavy rainfalls are difficult to predict by current weather forecasting systems or models.

The integrated amount of water vapor along the zenith direction (or PWV: precipitable water vapor) can be estimated by GPS meteorology, that is a method to compute PWV from troposphere-induced delays in GPS signals. PWV estimation by using the nation-wide Japanese GPS network: GEONET cannot achieve enough horizontal resolution to predict local heavy rainfalls since the network is deployed with inter-station distances of about 20 kilometers.We propose the system for real-time monitoring of high accuracy PWV horizontal distribution with a few kilometers scale which is considered to be beneficial to predict localized heavy rainfall by using a dense GPS network.

We deployed a dual-frequency(DF) GPS network for PWV estimation around Uji campus of Kyoto University, japan, with inter-station distances of about 1-2km. We executed an observation campaign on July and August 2011 and July 2012 for testing the accuracy of GPS-derived PWV. The difference of GPS-derived PWV with radiosondes and radiometer was at most 2mm in RMSE when averaging GPS zenith delays from multiple satellites.

We have developed the basic components of a system for estimating ZTD(Zenith total delay) by the GPS software RTNet, monitoring, interpolating, and visualizing PWV derived from the GPS receiver network, with the aim of producing a heavy rain early warning system based on semi-real time analysis of GPS observations.

For turning this system into practical use, the deployment of single-frequency (SF) GPS receivers is recommended for economic reasons. However, in single frequency receiver processing ionospheric delay information is required to achieve high accuracy troposphere-induced delay solution because small scale perturbation of ionospheric delay between two GPS stations cannot be removed even with differential processing.

We thus investigated the performance of Local Ionosphere Models (LIMs), generated from DF GPS network around the SF receivers. In RTNet, LIMs are generated by estimating the 1st or 2nd order gradient of ionosphere-induced delay between GPS stations. We tested the accuracy of ZTD estimation from ionosphere-corrected SF analysis by analyzing D_ZTD(delta ZTD, ZTD difference between DF_ZTD and SF_ZTD corrected by LIMs). In the test, LIMs are generated from DF GPS network with inter-station distances of about 3km.

The result from data among the period 22nd-29th Feb, 2012 showed that SF-ZTD, estimated by using a LIM for each satellite (satellite-specific model), produces D_ZTD at most 17mm in RMSE. This value becomes at most 3mm in PWV, which means not accurate enough to be applied for severe storm monitoring. The difference of this RMSE between 1st order gradient model and 2nd order gradient model was ver small: about 0.05mm.

Analysis of the day-to-day variability of the D_ZTD during a period of 200 days from the 22nd Feb, 2012 shows that the trend is close to that of PDOP. This result suggests that D_ZTD is highly affected by satellite geometry.

Keywords: Extreme weather, GPS meteorology, Precipitable Water Vapor, Dense GPS network, Ionosphere-induced delay