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GPS climatology : the analysis of long term trends of pricipitable water vapor

Kiyoto Yoshida[1*], Kosuke Heki[1]

[1]Dept. Natural His. Sci., Hokkaido Univ.

The atmospheric delays (Zenith Total Delay, ZTD) estimated by Global Positioning System (GPS) consist of hydrostatic (Zenith Hydrostatic Delay, ZHD) and wet delays (Zenith Wet Delay, ZWD). Because the former can be calculated from surface pressure, we can isolate the wet delay. ZWDs are proportional to precipitable water vapor (PWV), and provide useful information for meteorology. The original aim of GPS meteorology was the improvement of forecast of mesoscale meteorological phenomena such as heavy precipitation. This has been already fulfilled, when Japan Meteorological Institute started to incorporate water vapor information from GEONET, the Japanese dense continuous GPS array, into their routine weather forecast program. The present study aims at climatological application, i.e. we focus on the long-term trend of PWV. Global warming enhances saturated water vapor pressure, and will increase atmospheric water vapor (Trenberth et al., 2007). Water vapor itself has a stronger greenhouse effect than carbon dioxide, and it is important to understand its dynamics. It is also important in studying the seasonal and inter-annual water budget in atmosphere, ocean and on land.
We used ZTD data of F2 and F3 solutions of GEONET provided by Geographical Survey Institute, and converted them into ZWD/PWV by subtracting ZHD calculated using temperature and pressure data at nearby meteorological observatories (data available from the Japan Meteorological Business Support Center). We used the 140 pairs of GPS point and meteorological observatories, and tried to find climate signals from PWV time series 1996 to 2008.
We found increasing trends of PWV at most of the points by least squares method (average rate was 0.21 mm/year). This is consistent with the average trend of ground temperature of ~0.015 deg/year considering the Clausius-Clapeyron relation between the ground temperature and water vapor. PWV increases were not really linear but showed a wavy structure possibly related to long-term climate changes such as PDO (Pacific Decadal Oscillation). We also performed EOF (Empirical Orthogonal Function) analysis to investigate influences of inter-annual climate changes such as ENSO (El Nino Southern Oscillation) and AO (Arctic Oscillation). The leading mode was the seasonal change, where we could see signals related to ENSO (e.g. mild winter in El Nino and severe winter in La Nina).
We also compared ZTD values in the F2 and F3 solutions. Only in F3, at many GPS points, we found (possibly) artificial negative jumps in ZTD of about 30 mm at epochs around 2002. Now we are currently investigating what is responsible for these jumps. In the climatological discussions, we used ZTD in the F2 solution, in which we do not find such jump.

Keywords: GPS climatology, el nino southern oscillation, pacific decadal oscillation, arctic oscillation