An Analysis of the Precipitable Water Vapor Observed over the PIMO GPS Station

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ABSTRACT

Remote sensing of the atmosphere using Global Positioning Systems has been made possible with the derivation of the precipitable water vapor (PWV) from the tropospheric wet delay experienced by the signal propagation. Although limited by the missing observational data from the receiver, it is observed that the PWV obtained from this data gives reasonable values when considered for the cases of wet and dry seasons and when analyzed with a measurable meteorological variable, such as the amount of rainfall. A continual update of the record for PWV is highly recommended for further studies on the behavior of the atmospheric water vapor and its contribution to the changing climate.

INTRODUCTION

Water vapor plays a significant role in the physical and chemical processes of the atmosphere. It is also considered as one of the major contributors to the greenhouse effect. Analyses of the water vapor would contribute greatly to studies, such as weather forecasting and climate change.

Global Positioning Systems (GPS) have been used in the remote sensing of the atmosphere. Due to their good spatial and temporal coverage, the GPS's complement radiosondes and ground- and space-based water vapor radiometers which are either limited in cold, dry regions or in the presence of clouds and rain (Bevis et al., 1992).

GPS signals experience delays as they propagate through the atmosphere. In the troposphere, the delays are classified as hydrostatic delay or as wet delay. The wet delay due to the atmospheric water vapor is more variable and harder to remove. However, it is from these delays that the precipitable water vapor can be estimated (Bevis et al., 1992).

Derivation of the precipitable water vapor from the zenith wet delay

The precipitable water vapor (PWV) is related to the zenith wet delay (ZWD) by a factor of Π,

$$PWV = \Pi \times ZWD \qquad (1)$$

where both the PWV and ZWD are in units of length (m). The dimensionless constant of proportionality, Π is given by:

$$\Pi = \frac{10^6}{\rho R_v \left[\left(\frac{k_3}{T_m} \right) + k_2' \right]} \qquad (2)$$

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where ρ is the density of water, R_v is the specific gas constant for water vapor, T_m is a weighted mean atmospheric temperature and k_3 and k'_3 are the refractivity constants (Bevis et al., 1994)

The mean atmospheric temperature is related to the surface temperature, T_s,

$$T_m = 70.2 + 0.72T_s \quad (3)$$

where T_s can be obtained from any meteorological station (Bevis et al., 1994).

Since the values of ρ, R_v are well-defined, the uncertainty of Π is derived from the uncertainties of T_m and the refractivity constants. If the term k_3/T_m is large enough, the contribution of k'_2 can be neglected and thus, the error in Π can be approximated to 2% (Bevis et al., 1994).

METHODOLOGY

The PIMO station is one of the National Aeronautics and Space Administration, Jet Propulsion Laboratory (NASA JPL) GPS ground-based receivers in the Philippines. It is located at a latitude of 14°35' N and a longitude of 121° E, within the grounds of the Manila Observatory at the Ateneo de Manila University, Quezon City.

The GPS receiver records the observation data every 300 seconds in GPS time. These are then sent to the regional data centers, to the global data centers, and then to the data analysis centers for processing. The observation files in the Receiver Independent Exchange (RINEX) format can be obtained from the Crustal Dynamics Data Information Service (CDDIS) at http://cddisa.gsfc.nasa.gov. These files would be submitted to JPL's AutoGIPSY for the processing for tropospheric delay. The ZWD and PWV are derived using the utility programs written in C language by Reyes, which was later modified for this study (Reyes & McNamara, 2000).

Temperature profiles are recorded every hour by the Advanced Meteorological Station, located within the grounds of the Manila Observatory.

It is very important to consider the time indicated in the records. Observation files from the GPS receivers are in GPS time, which differs from the Coordinated Universal Time (UTC) by a few leap seconds. Temperature profiles, on the other hand are recorded in the local time, which is 8 hours ahead of the UTC. For consistency in this study, the UTC is chosen as the standard time.

In the process of obtaining the observation files, it is noted that there were days with no available data, as well as days with incomplete data. Therefore, in these cases, the ZWD and PWV were set to zero, and consequently, not included in the results.

RESULTS AND DISCUSSION

The Philippine climate is described mainly by its wet and dry seasons. In this study, two months were selected for each season based on the relative completeness of the data for that month.

The dynamic change of the amount of PWV is observed in Figs. 1 and 2. The amount of PWV for the months of August and September 2000 (Fig. 1) varies from a minimum value of 0.134 m to a maximum value of 0.167 m. On the other hand, for the months of December 2000 and January 2001 (Fig. 2), it varies from a minimum of 0.122 m to a maximum of 0.164 m. It is observed that the PWV lowered in general during the dry season.

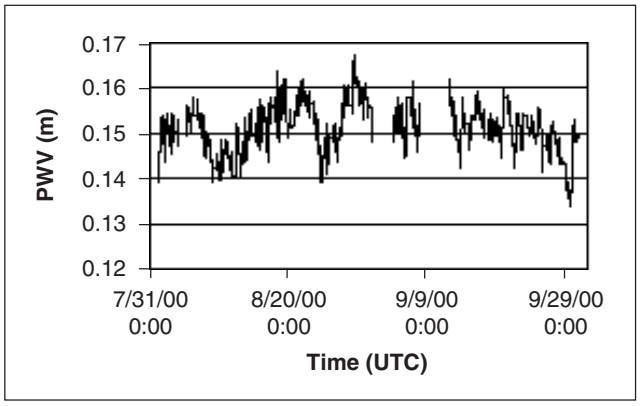

Fig. 1. Plot of the Precipitable Water Vapor (PWV) for August 2000 to September 2000 (wet season).

A comparison of the PWV with a measurable meteorological variable would give some insight into its behavior or variation.

The PWV is described as the height of the equivalent column of liquid water directly above the receiver. Thus, the variation of the amount of PWV can be analyzed with rainfall data.

To illustrate, the case of December 31, 2000 is selected since there is a noticeable dip in the PWV at this time (Fig. 2). The hourly averages of the PWV are derived (Fig. 3) since the rainfall data are recorded every hour (Fig. 4).

In this case, after a slight variation during the early hours, the PWV continually decreased at 1200 UTC. It is at this time when there was a sudden occurrence of rain, which eventually lessened towards the end of the day.

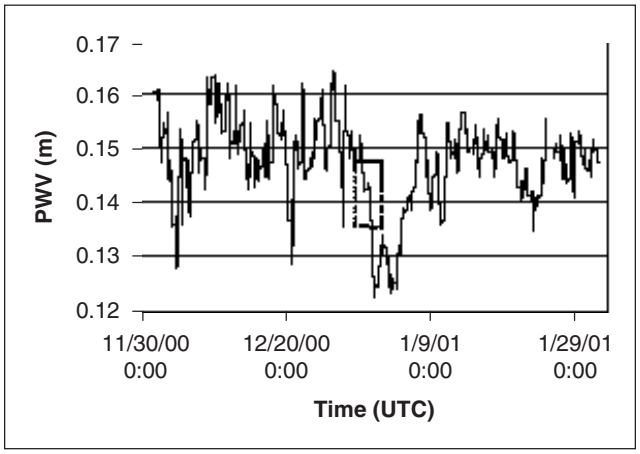

Fig. 2. Plot of the Precipitable Water Vapor (PWV) for December 2000 to January 2001 (dry season).

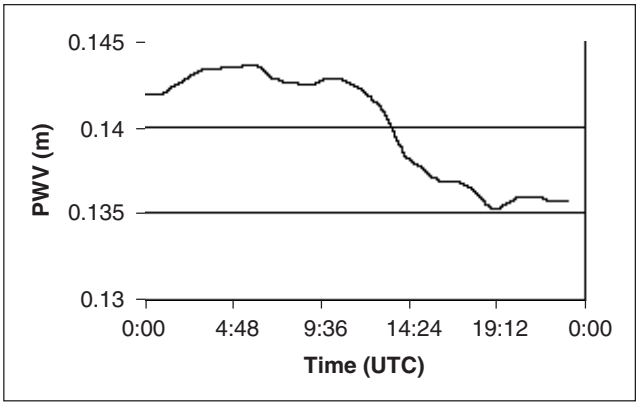

Fig. 3. Plot of the Hourly Average Precipitable Water Vapor for December 31, 2000.

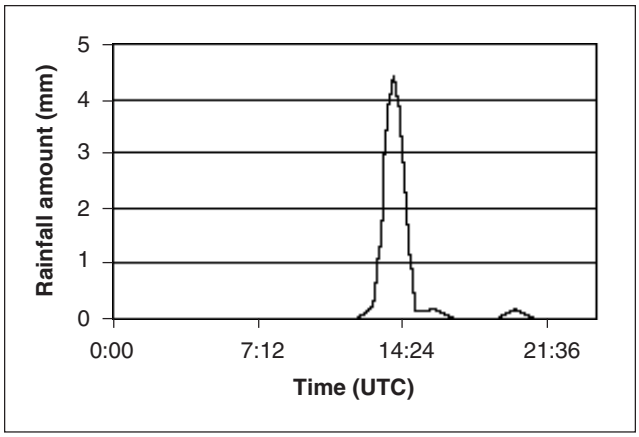

Fig. 4. Plot of the rainfall amount for December 31, 2000 where the peak occurs at 14:00 UTC.

Therefore, it is reasonable to infer that when it rains, there is an associated decrease in the PWV. It should be noted that one of the considerations for this was the relatively short distance between the GPS receiver and the meteorological station since the PWV is defined directly over the GPS receiver.

The archive for the observation data for the PIMO station started only in April 1999. Thus, it is recommended that there should be a continuous update of the record and the analyses on PWV for studies such as weather forecasting and climate variability.

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