A Constant Conversion Factor for Retrieval of PWV from GPS Signals in Tropical Region

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***Abstract*— In this paper, a constant conversion factor *PI* is proposed for retrieval of Precipitable Water Vapor (PWV) from Global Positioning System (GPS) signal delay in Tropical region. The factor *PI* is calculated using water-vapor weighted mean temperature (T_m). For Tropical region, T_m doesn't vary much and thus range of *PI* values is also small. Therefore, using the data obtained from 5 different sites of Tropical region, a constant *PI* value of 0.163 is proposed for calculation of PWV from GPS signals in Tropical region. The proposed conversion factor allows for the ease of PWV retrieval, which is useful in meteorological studies and also applicable in satellite communications.**

Keywords— Global Positioning System (GPS), Precipitable Water Vapor (PWV), Radiosonde, Zenith Wet Delay (ZWD), *PI*

I. Introduction

Precipitable Water Vapor, PWV is the total column of water vapor content in Earth's atmosphere which strongly links to the hydrological cycle and dynamical processes especially in Tropical regions where the overall PWV is high. Water vapor climatology is typically investigated using Radiosonde and satellite observations but such observations are limited in the high-resolution diurnal variations and high spatial-temporal resolution [1]. To overcome such shortcomings, Global Positioning System (GPS) signal is extensively being used to retrieve the PWV values.

Estimation of PWV values from GPS is based on the signal delay. The total zenith path delay is classified as zenith wet and dry delay. The Zenith Wet Delay (ZWD) is a function of atmospheric water vapor profile and is important for retrieving the PWV values. Once the ZWD value is estimated, PWV values can be derived by simply multiplying ZWD by a dimensionless conversion factor *PI*. This factor *PI* is calculated using water-vapor weighted mean temperature (T_m). However, T_m is calculated using the Radiosonde profiles, which are usually difficult to be obtained with high spatial and temporal resolutions and therefore the surface temperature (T_s) is used to get the estimates of T_m.

From the literature, Bevis Equation [2] is one of the well-known (T_m-T_s) equations. To get the correct estimates of T_m and T_s, both the Radiosonde station and weather station are required to be collocated, which is not always the case. Thus in our study we investigated the stations from Tropical region and propose an alternative method to calculate the factor *PI* which doesn't require temperature inputs and makes the calculation of *PI* easier.

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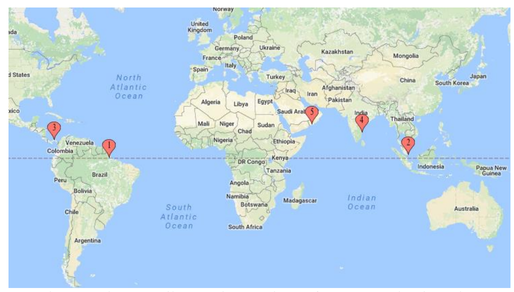

Fig. 1. Five Radiosonde Stations from Tropical region

II. Datasets and Data Processing

A. GPS Data

ZWD is estimated from a GPS receiver using GIPSY-OASIS II version 6.3 software at a given time and location. PWV (mm) can then be derived using eq. (1) and (2).

$$PWV = \frac{PI * ZWD}{\rho_l}, \quad (1)$$

where,

$$PI = \frac{10^6}{\left(\left(\frac{K_3}{T_m}\right) + K'_2\right) R_v}. \quad (2)$$

The variables and refractivity constants are described in [2]. Here we note that *PI* values are calculated using T_m which is obtained from Radiosonde data or from T_s. For this study, PWV values are processed for IGS station from Singapore (NTUS) for year 2014 [3].

B. Radiosonde and Weather Station Data

Radiosonde data for 5 different stations (as shown in Fig. 1 and listed in Table I) from Tropical region are downloaded from the database of Wyoming University [4]. In general, Radiosonde balloons from different stations are released twice a day. In this study, the Radiosonde profiles are used in eq (3) for calculation of T_m values, where, *e* is the water vapor pressure and *T* is the air temperature at given height, *Z*.

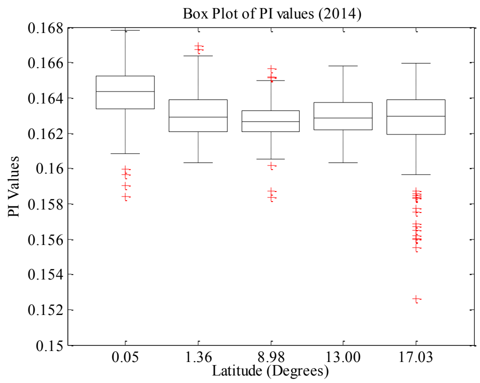

Fig.2. Box Plot of PI values for one year data (2014) from 5 different locations

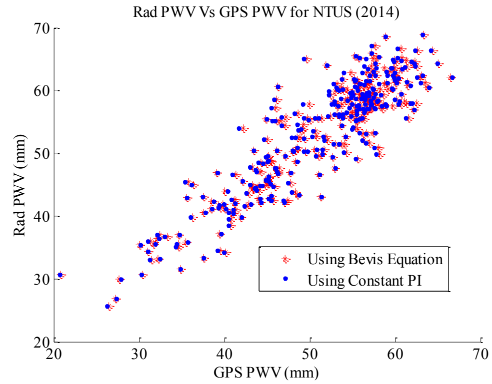

Fig.3. Scatter plot between GPS PWV and Rad PWV

$$T_m = \frac{\int \frac{e}{T} dz}{\int \frac{e}{T^2} dz} \qquad (3)$$

T_m values can also be calculated using surface temperature T_s. And the most common equation is the Bevis equation [2] as shown in eq (4).

$$T_m = 70.2 + 0.72 T_s \qquad (4)$$

In this paper, surface temperature data from weather station of Nanyang Technological University, Singapore is used.

III. Results and Analysis

A. Constant Coversion Factor, PI

TABLE I
PI VALUES FOR DIFFERENT LOCATIONS

Country/Station Id	Latitude, Longitude of Stations (Degree)	*PI* values		
		Max	Min	Median
Brazil / 82099	0.05,-51.07	0.166	0.118	0.163
Singapore / 48698	1.36, 103.98	0.165	0.158	0.163
Belize /78807	8.98, -79.58	0.166	0.160	0.163
India / 43279	13.00, 80.18	0.167	0.127	0.163
Oman / 41316	17.03, 54.08	0.176	0.158	0.164

Fig. 2 presents the boxplot of *PI* values for 5 Tropical stations calculated using eq (2)-(3) for one year (2014) data. *PI* values are calculated using the temperature and for Tropical regions we experience more or less same temperature throughout the year with very less seasonal changes. Thus from the boxplot, we can observe that there is not much variation in the *PI* values and the median *PI* value is similar for different stations in Tropics.

The range and median *PI* values for all the stations are summarized in Table I. The maximum range calculated is just 0.048 (for Brazil). Since the range of variation of *PI* values is very small and *PI* values for different Tropical stations are very close to each other, it is therefore reasonable to propose a constant *PI* value for determining the GPS-derived PWV values with good accuracy for different Tropical regions. Thus analyzing the data form 5 Tropical stations, we propose a constant *PI* value of 0.163 for Tropical regions.

B. Performance Comparision and Discussion

In this section we validate the proposed constant *PI* value. For this purpose, we calculate PWV values for NTUS (GPS PWV). The GPS PWV values are calculated using eq (1)-(2). Here the GPS PWV values are calculated in two ways; (a) using the constant *PI* value (b) using the Bevis equation, eq (4). The GPS PWV values are then compared against the PWV values calculated from Radiosonde, Rad PWV [5].

Fig. 3 shows the scatter plot between Rad PWV and the GPS PWV calculated using Bevis equation in red stars and plot between Rad PWV and the GPS PWV calculated using constant *PI* values in blue dots. The correlation coefficient between Rad PWV and GPS PWV (calculated using either *PI* values) is found to be 0.89. The difference between the two is within +/- 5 mm for 80% of time. The higher differences may be results of stations being separated by a distance of approximately 22 km.

However, it is clearly shown that there is not much difference between GPS PWV calculated using either Bevis equation or constant *PI* value. The difference between the two can be at maximum 1mm. And percentage of occurrence of which is very less. Thus based on the results presented, we conclude that the proposed constant *PI* value works with good accuracy for Tropical region.

IV. Conclusion

In this paper, we proposed a constant conversion factor *PI* for retrieval of GPS PWV in Tropical regions. Results show that the GPS PWV values calculated using the constant *PI* value are equally reliable as using the other methods like Bevis Equation. Moreover, the proposed method is relatively simpler and computationally efficient as the site-specific meteorological data are not required.

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