GPS Meteorology in Antarctica

E Dongchen Cheng Xiao Zhou Chunxia
Antarctic Center for Surveying and Mapping
of China, Wuhan University, Wuhan 430079，China

Abstract - This paper mainly discusses how to deduce the atmospheric Precipitable Water Vapor (PWV) from tropospheric zenith wet delay using ground-based GPS receivers. The data from SCAR Epoch 1998/1999/2000 Antarctic GPS Campaigns are used to construct the GPS analytical networks. A high-accuracy GPS processing software package — GAMIT/GLOBK is utilized; multiple schemes are adopted and we got the tropospheric zenith all delay. Two kinds of models, Saastamonien and Hopfield, are used to calculate the zenith dry delay. Before calculating the atmospheric Precipitable Water Vapor (PWV), we firstly use the long-term meteorological data of the two stations to calculate the K value, which is accommodated with the time January and February of the two stations. After that wet zenith delay are calculated into IPWV, and field meteorologic data are combined to analyzing. Good results are achieved for all sessions and stations.
Key words: GPS, Tropospheric zenith delay, Precipitable Water Vapor, Antarctica.

I Introduction

Water vapour is an important parameter in the study of meteorological phenomena, since the formation of clouds, fogs, and precipitations depends on its condensation.

In this work we utilize some observation of the SCAR Epoch GPS Campaigns and the IGS stations to study and validate the feasibility and veracity of using GPS data to get the Precipitable Water Vapour (*PWV*). Software used to processing GPS data is GAMIT/GLOBK developed by MIT.

The retrieval of *IPWV* from GPS is performed by computing the zenith all path delay (*ZALL*) affecting the radio signals propagation in the neutral atmosphere at each station. The *ZALL* can be decomposed into the zenith wet delay (*ZWD*) and the zenith hydrostatic delay (*ZHD*): starting from *ZALL,* the *ZWD* can be infered by subtracting *ZHD*, computed using a model exploiting surface measurements of pressure, and than can be directly transformed into *PVW*.

The *ZALL* is usually divided into two components, the zenith hydrostatic delay and the zenith wet delay:

$$ZALL = ZHD+ZWD \quad (1)$$

The hydrostatic component *ZHD* can be modeled with high accuracy if surface pressure is measured with an error better of 0.5 mb. The wet component *ZWD* is poorly predicted by models, being water vapour spatially and temporally highly variable. Therefore, it is computed by subtracting *ZHD* from *ZALL*.

The *PWV* is than computed using the relationship:

$$IPWV = K*ZWD /\rho_w \quad (2)$$

where the constant of proportionality *K* is a function of various physical constants and of the mean temperature of the water vapour in the atmosphere. Alternatively its monthly averaged values can be computed by linear regression applied to historical data.

II Data Set

Observation Sites selected: China Great Wall station (Station ID: *GWS1*) and Zhongshan station (*ZSS1*); SCAR GPS stations including *DAL1,ESP1,PAL1* in west Antarctica and *DAV1,MAW1* in East Antarctica; several IGS station: *SANT*、*OHIG*、*MCM4*、*VESL*、*PALM.*

GPS solution network: And according to the data distribution of each year, we constructed the GPS solution network respectively. The Great Wall Station was included in year 1998,1999 and 2000; the Zhongshan Station only in year 1999.

We adopted *ITRF97* as the earth referencing framework and *J2000* as the spatial inertial referencing system.

III Processing Results and analysis

1. Results of Baseline processing

The results implies that the relative accuracy of baseline length reaches 10^{-8}～10^{-9}, the repeat ratio of baseline horizontal vector and baseline length is smaller than 5mm, vertical vector is smaller than 1cm. The results calculated using χ^2 statistics from every solution network is illustrated in Table.1.

The results is good enough to deduce Zenith delay.

Year	S-N vector precision	E-W vector precision	vertical vector precision	Baseline precision
1998	2.8mm+ 0.6 x 10^{-8}	4.0mm+1.3 x 10^{-8}	9.6mm+0.8 x 10^{-8}	4.2mm+0.4 x 10^{-8}
1999	1.7mm+ 0.4 x 10^{-9}	2.9mm+0.06 x 10^{-9}	2.2mm+0.6 x 10^{-9}	2.8mm+0.07 x 10^{-9}
2000	2.0mm+ 0.4 x 10^{-8}	0.2mm+0.8 x 10^{-8}	9.9mm+0.4 x 10^{-8}	4.9mm+0.1 x 10^{-8}

Table.1 Precision and repeat ratio of baseline processing

2. Determination of K for the Great Wall Station and Zhongshan Station:

The value of K is not fixed but changes along with the time and climate. And taking into account the GPS observation period we adopted are mainly concentrated in the January and February, we get the conversion coefficient *K* of the two stations respectively through linear regression analysis of the period Jan 20th –Feb 10th of year 1998-2000.

The K is 0.15223793 at the Great Wall Station and 0.15086563 at the Zhongshan station.

3. PWV result analysis

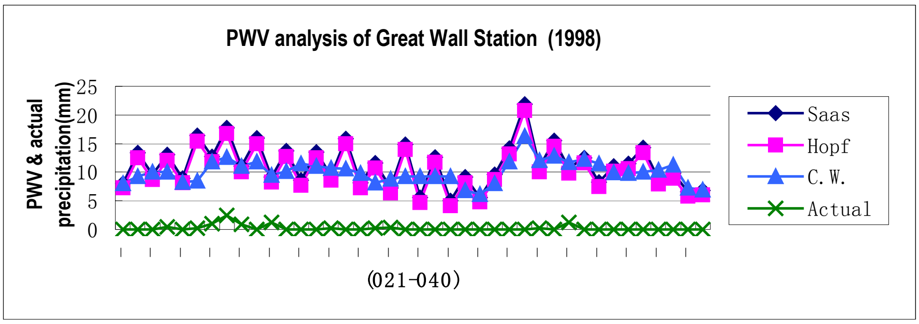

Fig.1 PWV of 1998 at the Great Wall Station

From the in-site observation of rainfall, we could see that rainfall is very small in January and February 1998. However just from the little rainfall we could see the PWV trend concluded in the GPS measurement. For example in day 024,026 and 036, PWV increases rapidly before the rainfall.

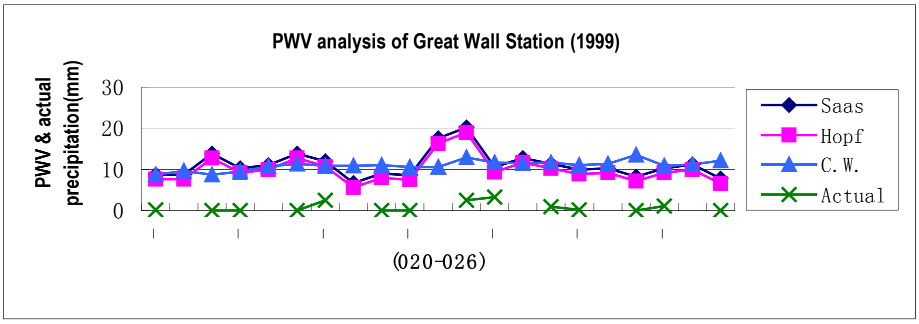

Fig.2 PWV of 1999 at the Great Wall Station

In Fig.3, we could see that before the rain at day 022,023 and 024, PWV increases rapidly. There are only two deviations among the results from deferent models.

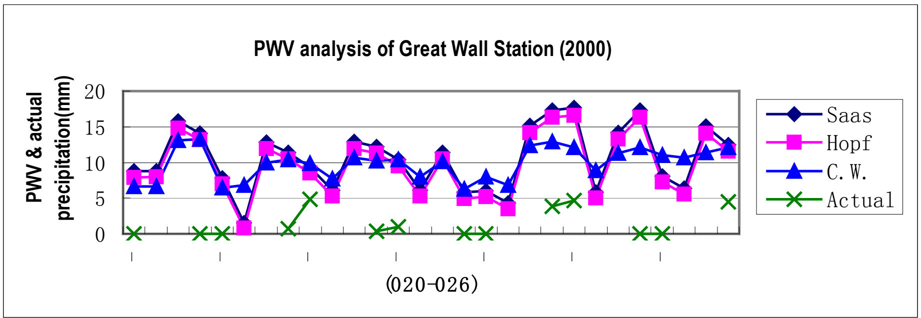

Fig.3 PWV of 2000 at the Great Wall Station

From the figure above, we could see that the consistency is fairly good.

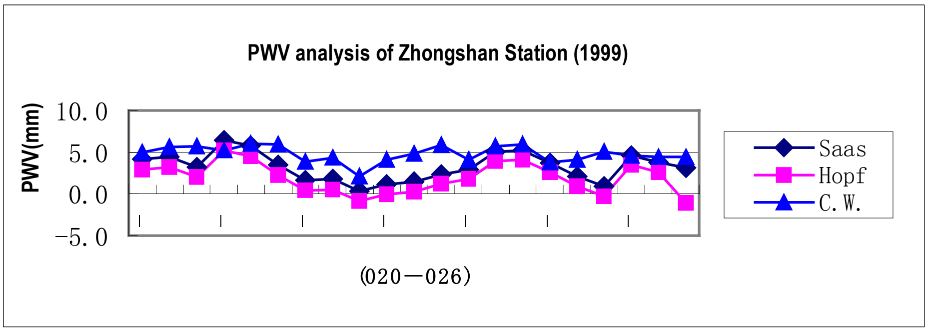

Fig.4 PWV of 1999 at the Zhongshan Station

The final result of Zhongshan station is illustrated in Fig.4. From this picture, we could see that the PWV of the Zhongshan Station is very small, which is consistent with the fact that there is very small rainfall at the Zhongshan Station, and therefore there is no rainfall record ever since. For this reason and the error of model and calculation, negative appeared in the Hopfield Model.

IV Conclusion

According to the results, the change of PWV values is consistent with the trend of rainfall. The increase of PWV is the necessary condition but not sufficient condition of actual rainfall. The relationship between the PWV and actual rainfall needs further study.

GPS Meteorology will be a convincing complement to current conventional meteorology methods. We can make best use of GPS data from SCAR GPS mission to carry out more GPS meteorology study for the Antarctic climate change.

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