Application of GPS Technology to Meteorology in Antarctica

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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 — GAMIT/GLOBK is utilized; multiple schemes are adopted and we got the total tropospheric zenith delay. Two kinds of models, Saastamoinen 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 PWV, and field meteorologic data are combined to analyzing. Good results are achieved for all sessions and stations.

1. Introduction

GPS technology can be a useful complementation to traditional meteorology especially in Antarctica, where the weather chop and change. Taking into consideration that GPS permanent stations can provide all-year-around observation and the SCAR Epoch GPS Campaigns ensure to provide periodic data, we can make best use of these data to develop research on GPS Meteorology.

In this paper we mainly 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 calculate PWV.

2. Determination of PWV by GPS data processing and mathematical models

2.1 Zenith delay calculation from GPS signals

Total zenith tropospheric delay, which can be calculated through the baseline solution and net adjustment of the GPS observation net, is expressed as:

$$ZALL=ZDRY+ZWET \qquad (1)$$

where ZALL is zenith neutral delay; ZDRY is zenith dry component; and ZWET is zenith wet component.

In order to obtain the ZALL, we use the GPS data processing software GAMIT and GLOBK designed by the MIT, and processed the 1998/1999/2000 data of the Great Wall Station and the 1999 data of the Zhongshan Station.

Saastamoinen and Hopfield models were adopted to calculate the ZDRY component. The differences between the two models are influenced obviously by temperature and humidity, while slightly by air pressure. Routine weather data, which were provided by Polar Research Office, Chinese Meteorology Academy of Science, were used in the actual calculation. When ZALL and ZDRY are calculated, we can get ZWET easily from formula 1.

2.2 Calculation of PWV

We usually use IWV（Integrated Water Vapor）and PWV（Precipitable Water Vapor）to express the water vapor information in the atmosphere. And

$$PWV = IWV / \rho_w \qquad (2)$$

where ρ_w is the density of the water in liquid state.

Then PWV can be deduced from ZWET through the model traditional AN Model（Askne and Nordius 1987）,

$$PWV = K * ZWET/\rho_w \qquad (3)$$

$$K^{-1} = 10^{-6} R_v [k_3/T_m + k_2'] \qquad (4)$$

where K is conversion coefficient, ρ_w is the density of the water in liquid state; R_v is the water vapor constant; T_m is the weighted average of the temperature（*Davis et al.*1985）.

$$T_m = \frac{\int_h (P_v / T) dh}{\int_h (P_v / T^2) dh} \qquad (5)$$

$$k_2' = k_2 - mk_1 \qquad (6)$$

$$m = M_v / M_d \qquad (7)$$

$$N = k_1 * P_d / T + k_2 * P_v / T + k_3 * P_v / T^2 \qquad (8)$$

where M_v is molecular weight of water vapor; M_d is molecular weight of dry air; N is air refractivity exponent; k_1、k_2、k_3 are physical constants; P_d is partial pressure of dry air; P_v is partial pressure of water vapor.

3. Determination of PWV directly by mathematical models

3.1 Traditional meteorology model

$$PWV = \left(\int_h^H Pvdh \right) / \rho_w \qquad (9)$$

or

$$PWV = \left(\int_h^H (P_v / T) dh \right) / (\rho_w * R_v) \qquad (10)$$

where h is the elevation of the GPS observation station; H is the elevation of the top of the troposphere. This model needs sounding observation, however, which is lack at the Great Wall Station.

3.2 C.W. Alan Model（1972）

The water vapor at the height h is expressed as:

$$= 0.21\, e_h 10^{-h/22} \text{ (PWV in centimeter)} \qquad (11)$$

$$\approx 0.21\, e_h \text{ (PWV in centimeter per unit air mass)} \qquad (12)$$

where e_h is the water vapor pressure at the height h.

4 Calculation and result analysis

4.1 GPS solution network

Some Antarctic stations, which participated in the SCAR Epoch GPS Campaigns such as

DAL1, ESP1 and PAL1 in the Western Antarctica, DAV1 and MAW1in the Eastern Antarctica, and some IGS stations such as SANT, OHIG, MCM4, VESL and PALM were selected to construct the GPS 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.

4.2 Determination of the conversion coefficient K of 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 data we adopted are mainly concentrated in the January and February, we get the conversion coefficient K of the two stations respectively through 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.

4.3 PWV result analysis

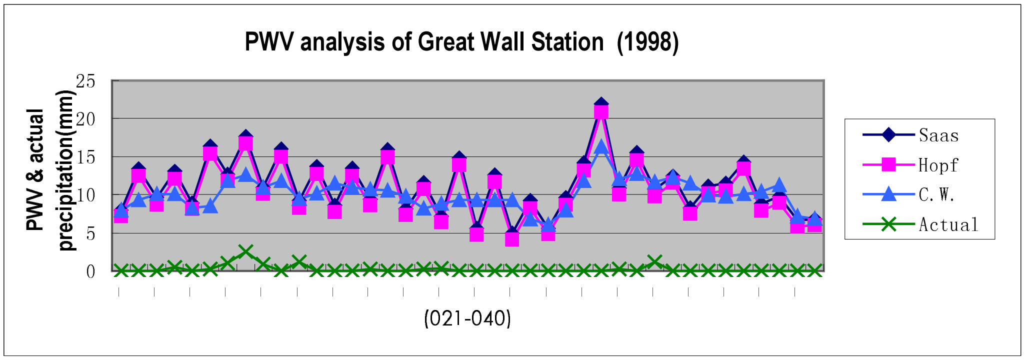

Fig.1 PWV of 1998 at the Great Wall Station

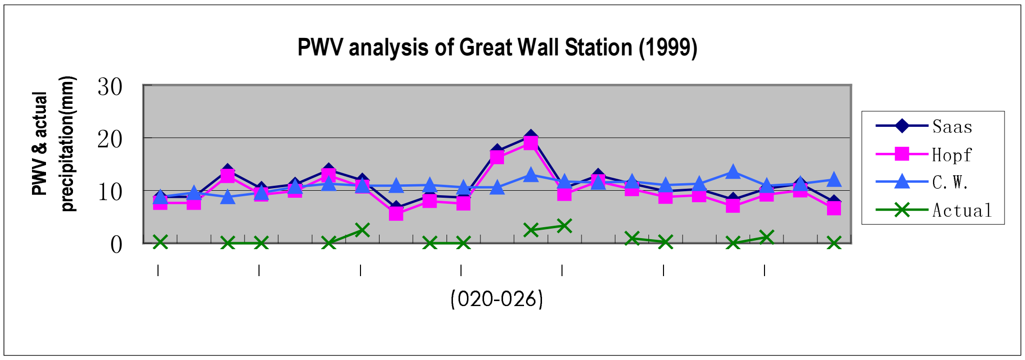

Fig.2 PWV of 1999 at the Great Wall Station

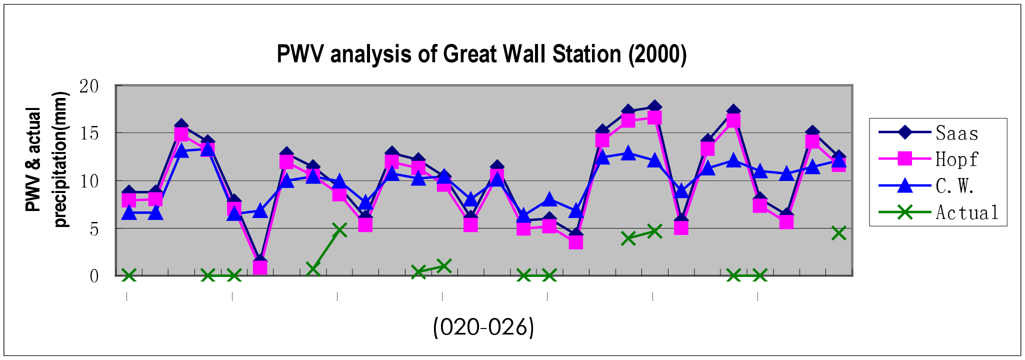

Fig.3 PWV of 2000 at the Great Wall Station

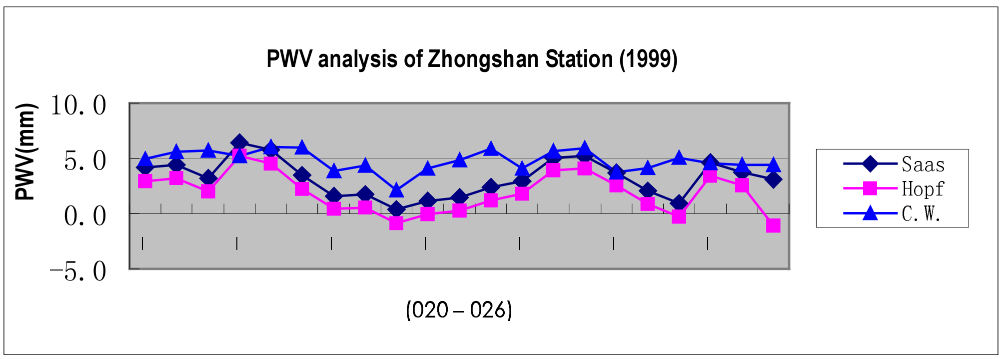

Fig.4 PWV of 1999 at the Zhongshan Station

We can 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 there is no rainfall record. For this reason and the error of model and calculation, negative appeared in the Hopfield Model.

4.4 Conclusions

According to the results, the trends of PWV are consistent with each other. The increase of PWV is the necessary condition, not sufficient condition, of actual rainfall. The relation between the PWV and actual rainfall needs further study.

GPS/MET can be convincing complement to the current meteorology .We can make best use of GPS technology and weather data to study the Antarctic climate, and apply GPS technology to other research fields.

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