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Application of Ground Based GPS Technology in Rainstorm Detection

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Contents

1、Introduction

1992， Bevis proposed first the method of using ground-based GPS meteorology technology to detect precipitable water vapor (PWV).

At the beginning of the 21st century, the United States and European countries have successively carried out large-scale projects of GPS meteorology application, such as MAGIC、WAVEFRONT、GASP、NOAAGSD, by using GPS network established by surveying and mapping, earthquake and meteorology departments.

The comparative research on the methods of extracting zenith water vapor content from GPS station data in China's coastal areas is also being actively carried out (Lu yongduo et al., 2016)

2、Basic principles

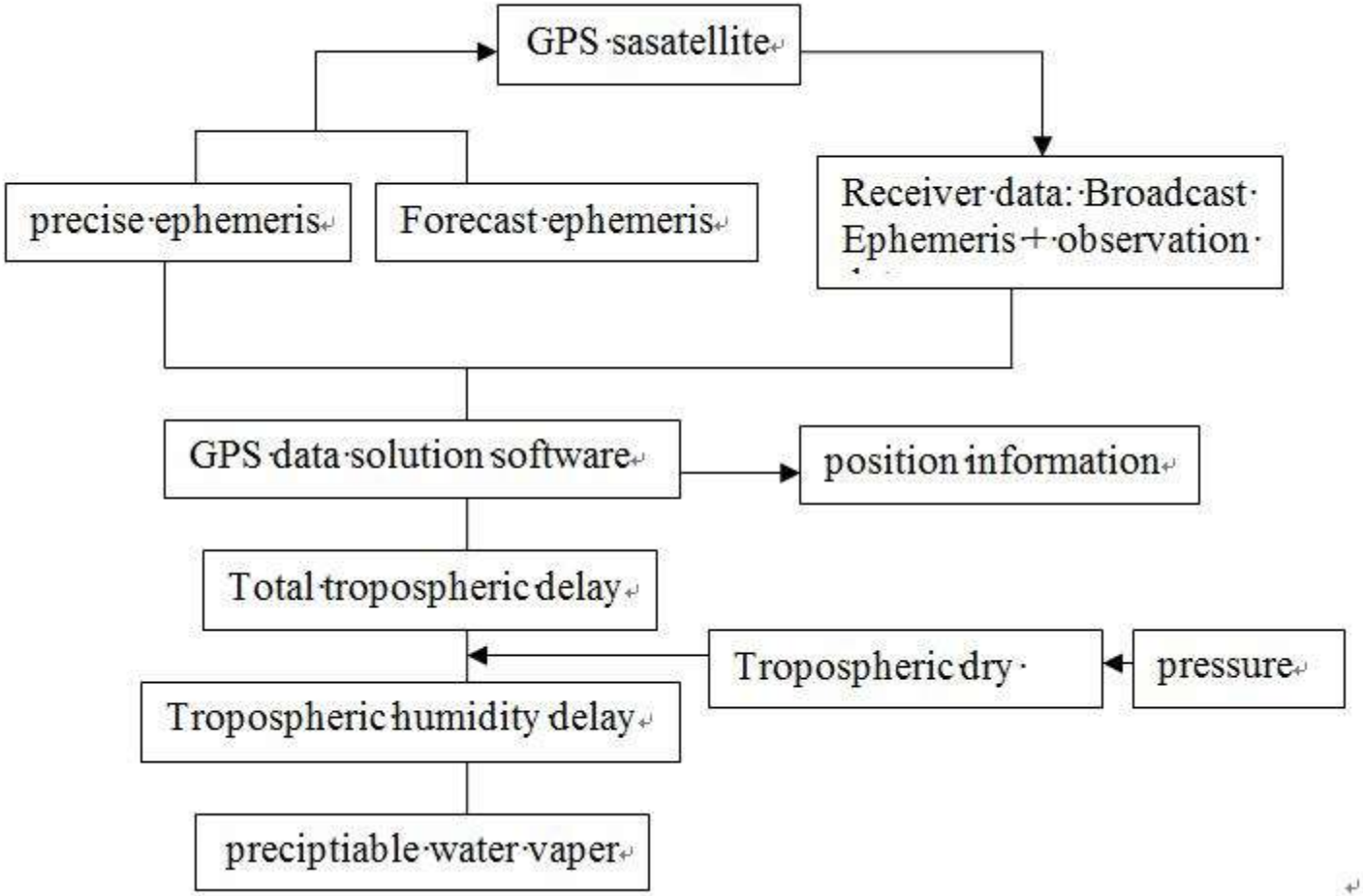

Fig.1 ground base GPS inversion preciptiable water vaper process

2、Basic principles

$$D(EL) = DZ * DM(EL) + WZ * WM(EL) \quad (1)$$

Where D（EL） is the total delay, EL is the altitude angle, DZ is the dry delay, WZ is the wet delay, DM is the projection function of the dry delay and WM is the projection function of the wet delay. The projection function is a mathematical model related to the altitude angle of each delay. The dry delay can be calculated by saastamoinen model, and the wet delay can be obtained by subtracting the dry delay from the total delay, the relationship between zenith wet delay and PWV is as follows:

$$PWV = \Pi \bullet WZ \quad (2)$$

Where Π is a dimensionless conversion factor related to air temperature and pressure, which is the basic principle of ground-based GPS meteorology.

3、Water vapor inversion application

On July 21, 2012, a heavy rainstorm occurred in Beijing. In this paper, GPS technology was used to invert the water vapor for 11 days before and after the rainstorm, so as to verify the feasibility of using GPS technology to forecast the rainstorm weather and verify the inversion accuracy.

3.1、Site selection

The absolute PWV is obtained from long-distance measuring the selected stations. The stations involved include four IGS stations, named Beijing (BJFS), Wuhan (WUHN), Shanghai (SHAO) and Kunming (Kunm). Beijing station can download and obtain meteorological data, and the data can be obtained from CDDIS. The rainstorm occurred in Beijing on July 21, 2012, with an annual accumulated day of 203. In order to reflect characteristics of precipitable water on that day accurately, 11 days of data from July 17 to July 27, corresponding to an annual accumulated day of 199 to 209, were selected for calculation.

3.2、precision analysis

At present, the detection of atmospheric water vapor by the world meteorological department mainly depends on the detection of sounding balloon, so in order to verify the correctness of GPS/PWV, this paper compares GPS/PWV with Radio/PWV.

Table 1 GPS/PWV and Radio/PWV relation

Station name	Average GPS/PWV (mm)	Mean deviation（mm）	Relative mean deviation
BJFS	47.78	3.67	7.7%

3.2、precision analysis

As shown from Figure 2, except for the day of 203, GPS/PWV and Radio/PWV data are basically consistent, which can accurately reflect the PWV content in the air. The day of 203 corresponds to July 21, which is the time of Rainstorm in Beijing. The Radio/PWV time resolution is 12 hours, which can not quickly and accurately reflect the extreme weather change of PWV, while GPS/PWV can better reflect the change of water vapor in the air.

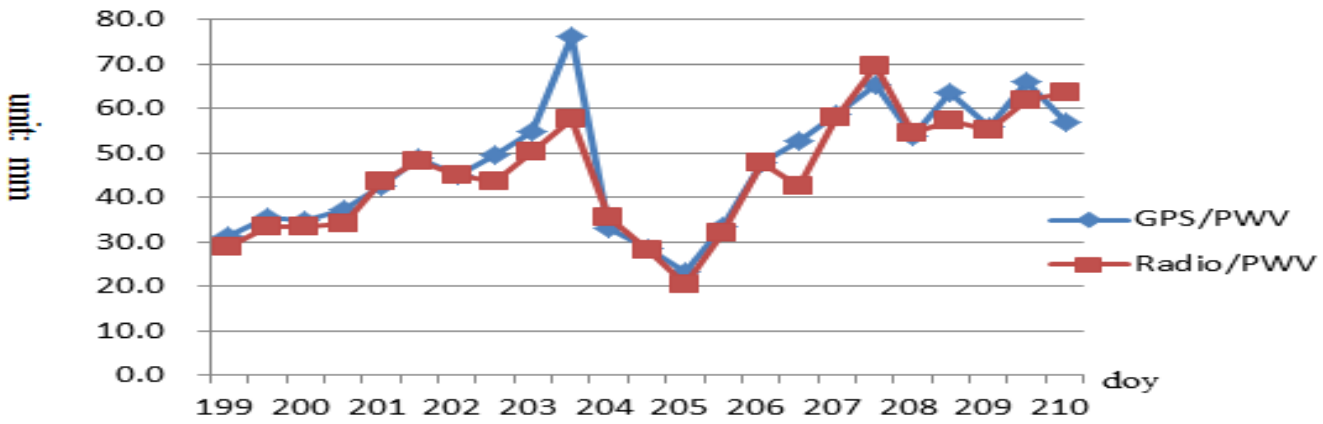

Fig.2 BJFS station doy of year 199 to 209 PWV

3.2、precision analysis

The day of 203 corresponds to July 21, which is the time of Rainstorm in Beijing. Beijing time is 8 hours faster than GPS time. As can be seen from Figure 3, GPS/PWV increases rapidly from 00:00 in 203 days, and reaches the peak at 10:00 on day of 203. The corresponding Beijing time is 08:00-18:00 on day of 203. In general, the trend of GPS/PWV reflects the trend of precipitation, the actual rainfall time is about 5 hours later than GPS/PWV, and the GPS/PWV reaches more than 60 mm when heavy rain occurs.

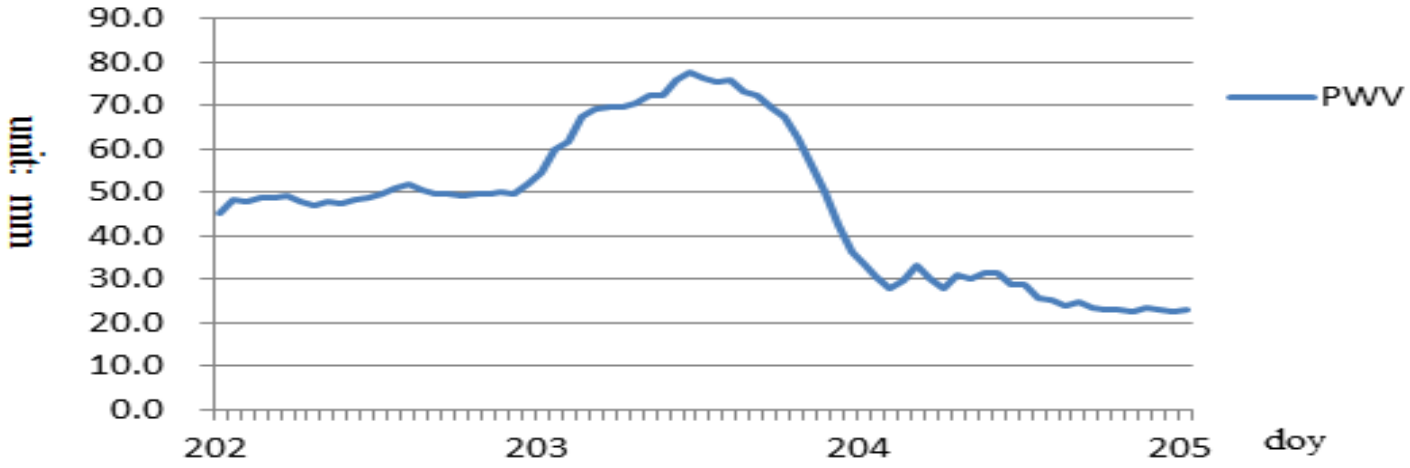

Fig.3 BJFS station day of year 202 to 204 GPS/PWV

3.2、precision analysis

The relationship between the trend of GPS/PWV and precipitation can refer to the actual weather conditions of that day, and the weather conditions of Beijing from July 17 to July 27, 2012 are shown in Table 2.

Table.2 BJFS station GPS/PWV relation with Beijing weather

doy	GPS/PWV（mm）	weather
199～201	30～40	Sunny to cloudy
202	40～50	Cloudy to thunderstorm
203	40～75	Heavy rain to cloudy
204	22～35	sunny
205	25～45	Cloudy to overcast
206	45～55	Cloudy to thundershower
207	45～65	heavy rain
208～209	50～65	Moderate rain to heavy rain

3.2、precision analysis

The wet delay is highly correlated with the amount of precipitation. The conversion factor ∏ for each period of 199 to 209 days in 2012 can be obtained by formula (2), as shown in Figure 4.

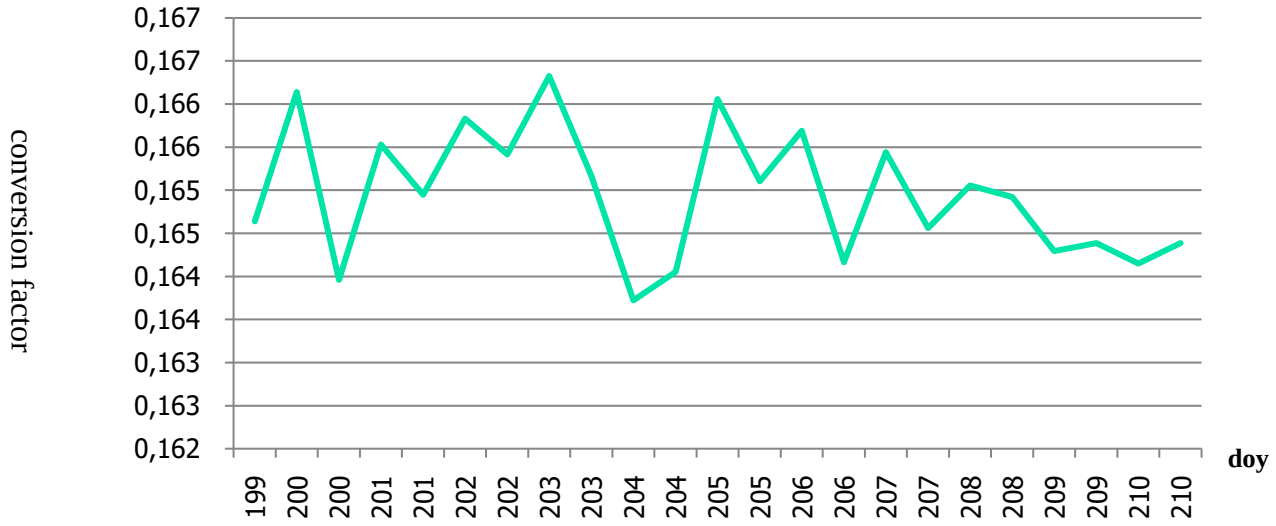

Fig.4 wet delay conversion factor

4、Conclusions

（1） GPS / PWV can forecast precipitation well, and it is consistent with the actual situation

（2） Compared with Radio/PWV, GPS/PWV has a higher Time resolution, When rainstorms occur in Beijing, GPS/PWV increases rapidly in a short time, with a time delay of about 5 hours.

（3） Through the wet delay and the amount of precipitation, the wet delay conversion factor in Beijing is calculated as to about 0.165.