GPS-Meteorology Network in Wuhan Region

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Abstract  There are three aspects in the study of GPS meteorology network in the Wuhan region. The first is the comparison of the GPS precipitable water vapor between final ephemeris and ultra-rapid ephemeris for which the relative coefficient is 99.97 and the root mean squares is 0.048 mm. It can be concluded that ultra-rapid ephemeris can be used to get the GPS precipitable water vapor for the real-time prediction. The second is the comparison of precipitable water vapor of GPS stations and the distribution of water vapor in the Wuhan region is acquired. The change of GPS precipitable water vapor and rainfall in a rainfall process are compared and analyzed. The change of GPS precipitable water vapor can reflect and predict the process of rainfall.

Keywords  continuous operational reference system; precipitable water vapor; final ephemeris; ultra-rapid ephemeris

CLC number  P228.4

Introduction

GPS continuous operational reference system (GPS CORS) is widely set up in cities for urban survey and navigation. Observation of the spatial-temporal changes of water vapor is important for weather forecasting, especially for monitoring and predicting small and medium scale weather calamity whose horizontal scale is less than 100 km and whose active time only lasts for several hours. It can improve the accuracy of the starting field of the numerical forecast mode that assimilates continuous PWV monitoring that serves as the foundation of GPS numerical weather forecast mode. It is necessary to carry out the GPS meteorology research with GPS CORS in order to predict the small and medium scale weather calamity.

Compared with usual methods, such as radiosonde, water vapor radiometer and satellite observation, GPS method has some advantages in measuring precipitable water vapor, such as higher temporal and spatial resolution and it is also much cheaper. The measurements from GPS method have accuracy which is very close to those observed by water vapor radiometers and radiosondes, thus GPS method can be used to forecast precipitable water vapor. In the aspects of the reliability between GPS zenith wet delay and precipitable water vapor, many scholars have compared the data taken from water vapor radiometer, radiosonde and GPS precipitable water vapor, and achieved the results that GPS has approximately the same precision as water vapor radiometer and radiosonde.

In this study, we focus on the distribution of precipitable water vapor in Wuhan. There are eight GPS stations in the network of Wuhan, notated by WHHK, WHDH, WHHN, WHXZ, WHCD, WHHP, WHJF and WHXN, respectively. The lengths of baselines between these GPS stations are shown in Table 1.
Table 1  Baselines and their lengths of GPS meteorology network of Wuhan region

| Baseline       | Length / m | Baseline       | Length / m | Baseline       | Length / m |
|----------------|------------|----------------|------------|----------------|------------|
| WHCD-WHDH      | 38 237.596 | WHDH-WHHN      | 38 832.869 | WHHN-WHJF      | 46429.838  |
| WHCD-WHHN      | 29 608.077 | WHDH-WHHP      | 43 692.373 | WHHN-WHXZ      | 91371.486  |
| WHCD-WHHP      | 47 175.933 | WHDH-WHJF      | 7 719.707  | WHHP-WHXZ      | 42499.802  |
| WHCD-WHJF      | 44 847.113 | WHDH-WHXZ      | 53 279.164 | WHHP-WHXZ      | 42008.690  |
| WHCD-WHXZ      | 79 652.571 | WHHN-WHHP      | 69 698.362 | WHJF-WHXZ      | 46458.528  |

1  GPS precipitable water vapor from final ephemeris and that from ultra-rapid ephemeris

It is necessary to obtain the real-time GPS precipitable water vapor in order to apply GPS precipitable water vapor on meteorology field to monitor and predict short-time weather calamity. Many scholars have gotten the results that GPS can be used in meteorology field for which most of the GPS precipitable water vapor were obtained by final ephemeris. Final ephemeris can be obtained after 13 days, and the ephemeris which can be obtained in advance is ultra-rapid ephemeris. Their satellite orbits are 5cm and 10cm. Ultra-rapid ephemeris must be used to calculate GPS precipitable water vapor in order to realize the real-time prediction of precipitable water vapor.

Using the data from 301st to 321st days in 2005 of GPS meteorology network in Wuhan region, we got the daily zenith tropospheric delay of the stations using RELAX mode with high precision positioning software GAMIT and IGS final ephemeris (ultra-rapid ephemeris). The lengths of the baselines should be more than 500 km long when using GAMIT to process GPS data. In this way, zenith wet delay of every station is an absolute estimate; otherwise, zenith wet delay is a relative absolute estimate. This study calculates the data of GPS meteorology network in Wuhan region appending 2 other IGS stations which are Beijing Fangshan and Shanghai sheshan stations in order to obtain the absolute estimate of the zenith tropospheric delay.

This paper chooses GPS station WHCD and WHDH to compare the differences of GPS precipitable water vapor between final ephemeris and ultra-rapid ephemeris. There are 4 precipitable water vapor estimates of WHCD everyday and there are 24 of WHDH because of the observation data of the air pressure. The differences in the results between final ephemeris and ultra-rapid ephemeris of WHCD and WHDH are shown in Fig.1.

2  Distribution of water vapor in Wuhan region

It can be found that the results of final ephemeris and ultra-rapid ephemeris are contiguous not only on the numerical value but also on the trend. The relative coefficient between final ephemeris and ultra-rapid ephemeris is 99.97% for which the root mean square is 0.048 mm. It can be concluded that ultra-rapid ephemeris can be used to get the GPS precipitable water vapor for the real-time prediction.
study with WHCD, WHDH, WHHP, WHJF, WHXZ. The GPS data is from the 244th to 306th days of 2005 (September to October). The atmospheric pressure data of WHDH and WHJF is taken once every hour and for the other three stations it is taken once every 6 hours.

The comparison of the stations’ precipitable water vapor in GPS meteorology network of Wuhan region is shown in Fig.2. It can be found that the precipitable water vapor of WHDH and WHJF are higher than the other three stations. Table 2 shows the statistics on the mean value of the precipitable water vapor from the 244th to 306th days in 2005, and it is better to compare the differences of the precipitable water vapor among the five stations of GPS meteorology network in Wuhan region.

Table 2  Comparison of stations’ precipitable water vapor in GPS meteorology network of Wuhan region/mm

| Station/day | 244~258 | 259~273 | 274~288 | 289~306 |
|------------|---------|---------|---------|---------|
| WHCD       | 41.99   | 47.45   | 30.83   | 22.22   |
| WHDH       | 43.08   | 50.68   | 34.67   | 24.43   |
| WHHP       | 38.38   | 46.83   | 29.43   | 20.37   |
| WHJF       | 42.40   | 50.32   | 33.52   | 23.86   |
| WHXZ       | 40.41   | 47.42   | 30.85   | 20.92   |

Combining Table 2 and Fig.2, it can be concluded that the arrays of precipitable water vapor of Wuhan region from high to low are WHDH, WHJF, WHCD, WHXZ and WHHP. We can research the distribution of water vapor using GPS network data.

3  Description of the process of rainfall using GPS precipitable water vapor

The best advantage of using GPS in meteorology is that it can predict the weather calamity within a short period of time, so that this paper describes the process of using GPS meteorology network in analyzing rainfall. There is a strong rainfall on the 246th day of 2005 according to the rainfall information of Wuhan region. This paper reflects the process of analyzing rainfall using the data of GPS precipitable water vapor from the 245th to 247th days of 2005. The comparison of GPS precipitable water vapor and rainfall in Wuhan is shown in Fig.3. The values of precipitable water vapor in WHHP and WHXZ are taken once every 6 hours, while it is taken once every hour in WHDH and WHJF.

It can be found that the strong rainfall took place after the GPS precipitable water vapor reaches the peak value and changed steadily. In order to reflect the relationship of the GPS precipitable water vapor and rainfall, this paper does a comparison of GPS precipitable water vapor and the rainfall in WHJF using hour as the unit as shown in Table 3.

From Fig.3 and Table 3 we can find that the precipitable water vapor goes up from 1 o’clock on the 245th day to 6 o’clock on the 246th day, and there is light rainfall when the precipitable water vapor is close to the peak value. The precipitable water vapor reaches the peak value at 6 o’clock on the 246th day and changes steadily until 19 o’clock, but the maximum is 12.4 mm at 7 o’clock on the 246th day. The GPS precipitable water vapor goes down from 20 o’clock on the 246th day and the rainfall ended at that moment.

Rainfall changes periodically with increase in and the comparative stability and the rapid decrease in water vapor. There are three periods of the process of rainfall: the first period is the chrysalis
of rainfall and the water vapor in the atmosphere goes up gradually at this moment; it arrives at the peak value and the rainfall take place during the second period; the water vapor goes down and the process of rainfall ends in the third period. The GPS precipitable water vapor can reflect the accumulation, the steady changes and the release of the water vapor and it is according to the change in water vapor during the process of rainfall. The rainfall reaches the maximum 1 hour after the water vapor reaches the maximum and then changes steadily. This shows that the process of rainfall can be predicted with the GPS precipitable water vapor and other weather forecast.

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### Table 3  Comparison of GPS precipitable water vapor in WHJF and the rainfall in Wuhan / mm

| Hour | GPS-PWV | Rain | GPS-PWV | Rain | GPS-PWV | Rain |
|------|---------|------|---------|------|---------|------|
| 245  |         |      | 246     |      | 247     |      |
| 1    | 39.979  | 7    | 0       | 65.887 | 1.6    | 59.558 | 8    |
| 2    | 41.003  | 3    | 0       | 65.473 | 2.6    | 60.310 | 6    |
| 3    | 42.049  | 1    | 0       | 66.214 | 3.2    | 61.441 | 6    |
| 4    | 43.405  | 1    | 0       | 66.355 | 1.8    | 61.199 | 2    |
| 5    | 47.082  | 5    | 0       | 66.356 | 3.5    | 60.899 | 2    |
| 6    | 47.511  | 5    | 0       | 67.010 | 1.6    | 61.094 | 2    |
| 7    | 48.060  | 5    | 0       | 66.88  | 12.4   | 61.341 | 4    |
| 8    | 48.249  | 5    | 0       | 66.355 | 6      | 60.480 | 4    |
| 9    | 48.446  | 3    | 0       | 65.946 | 4      | 59.671 | 1    |
| 10   | 49.183  | 7    | 0       | 65.980 | 3.9    | 59.682 | 5    |
| 11   | 49.678  | 7    | 0       | 65.387 | 8      | 59.037 | 5    |
| 12   | 50.445  | 5    | 0       | 64.972 | 5.1    | 58.480 | 1    |
| 13   | 52.465  | 7    | 0       | 65.526 | 6.8    | 58.391 | 8    |
| 14   | 52.812  | 5    | 0       | 65.616 | 4.7    | 57.744 | 4    |
| 15   | 53.140  | 1    | 0       | 65.658 | 2.8    | 56.947 | 0    |
| 16   | 54.328  | 6    | 0       | 65.83  | 4      | 56.216 | 2    |
| 17   | 54.866  | 2    | 0       | 65.864 | 2      | 56.013 | 4    |
| 18   | 55.327  | 3    | 0       | 65.924 | 2      | 56.161 | 0    |
| 19   | 56.647  | 0    | 0       | 66.04  | 1.8    | 56.249 | 3    |
| 20   | 57.302  | 0.5  | 0       | 64.386 | 0.8    | 55.973 | 3    |
| 21   | 57.069  | 0.4  | 0       | 64.703 | 1.1    | 55.534 | 7    |
| 22   | 57.183  | 0.4  | 0       | 64.387 | 0      | 54.560 | 3    |
| 23   | 56.767  | 0.5  | 0       | 64.297 | 0      | 53.469 | 5    |
| 24   | 56.926  | 4.9  | 0       | 63.758 | 8      | 54.204 | 5    |

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