Diurnal variation of atmospheric water vapor based on GPS observations over Taiwan

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Abstract: Diurnal variations in the atmospheric vapor at Banchiao of Taiwan are studied by analyzing 30 min-averaged data in the summer of 1998. The surface meteorological measurements were mainly obtained from the Central Weather Bureau (CWB) of Taiwan. It is found that precipitable water (PW) is increased in the afternoon. The maximum of precipitable water appears at around 0900 LST. The diurnal range of precipitable water is larger on the days with than without rainfall events. Rainfall events often occur in the afternoon and early morning. We also examine the difference in the characteristics of the PW signatures with and without rainfall according to the occurrence of the times for the rainfall peak and the onset of rainfall.
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Keywords: GPS, Precipitable water, Water vapor, Rainfall.

1. Introduction

Atmospheric water vapor plays a key role in the atmospheric radiation budget and global hydrological cycles. Traditionally its diurnal variation is primarily examined by the observations from the radiosonde s ounding, which is typically lunched twice daily and, hence, insufficient to capture the representative characteristics of the diurnal variation. Recently, the GPS observations that provide continuous measurements of water vapor were used to study the diurnal variations in the USA [Aiguo et al 2002]. In this contribution, we investigate the diurnal variation of water vapor based on GPS observations in Taiwan whose climatology dramatically differs from that in the Northern America. The differences are primarily due to the fact that Taiwan is located in the boundary of the sub-tropical and tropical regions with much more abundant of water vapor in the atmosphere in addition to its fast changing topography surrounding by the oceans.

Here we study the diurnal variations in the atmospheric vapor at Banchiao of Taiwan by analyzing 30 min-averaged data in the summer of 1998.

2. Data and Analysis Method

2.1) GPS-sensed PW data

Summer is the rainy season of the year in Taiwan. Rainfall is a very important source of water resources to Taiwan. If there is not enough rainfall in summer, Taiwan will be likely lack of water for the rest of the year. To understand the climatology of atmospheric water vapor, we study its diurnal variation in summer in this paper.

The GPS receiver records tracking data from 7-8 satellites every epoch, typically 30 seconds for CWB's GPS stations. Path delays were then derived from the GPS tracking data by using the Bernese v4.2 software [Beutler et al., 1996] and from International GPS Service precise orbits. These path delay data were used to derive the 30 min-averaged path delay using a cut-off angle 10° . The wet path delay induced by water vapor was obtained by subtracting the hydrostatic delay (using the Saastamoinen model [Saastamoinen, 1972] from the total delay. The wet path delay was mapped into zenith wet delay (ZWD) by using the wet mapping function of Niell [1996]. The ZWD was converted into atmospheric precipitable water using π parameter [Bevis et al., 1992, 1994]. Air temperature (Ts) was used to estimate the weighted atmospheric mean temperature (Tm, used to compute π) by using local Tm-Ts relationship derived from stations BANC and HUAN [Liou et al. 2001].

2.2) Diurnal Analysis Method

The 30 min-averaged data of GPS-sensed PW were first converted into diurnal anomalies by removing the daily mean for each day. The diurnal anomalies were then averaged over each day to obtain mean diurnal anomalies

3. Result and discussion.

Fig. 1 shows the mean diurnal anomaly of PW estimated from GPS using 3-month data acquired in Banchiao in Summer of 1998. The precipitable water is increased in the afternoon. Its maximum and minimum appear at around 0900 and 2330 LST, respectively. Fg.2

shows the mean diurnal temperature variation for the 3-month period of study. The temperature is increased from about 0700LST and reaches a maximum of 32.63° C at around 1200 LST. Fig. 3 shows the number of rainfall events during summer in 1998. Rainfall often occurs in the afternoon (1400-1600 LST) and late afternoon (1700-1900 LST). Atmospheric long-wave radiation is coming and is increased with time in the morning so that surface temperature is also increased and reaches a maximum at around 1200 LST. Therefore precipitable water is increased in the afternoon because water vapor on the ground was evaporated into atmosphere. Water vapor continues to accumulate in the atmosphere until it starts to rain if any. Hence rainfall often occurs in the afternoon.

Fig. 4 and 5 show the mean diurnal variations of GPS-derived precipitable water on days with and without rainfall, respectively, during the period from 1 June to 31 August 1998. The figures show the diurnal range of precipitable water is larger on the days with than without rainfall events.

Fig. 6 show the PW signatures for the days with heavy rainfall on June 4, June 23,July 5 and July 28, 1998, which continues to rain for 12, 7, 3 and 9 hours, respectively. The corresponding accumulated rainfalls are 105.8, 94.0, 38.5 and 58.6 mm, respectively. We find that rainfall occurs when the peak of the PW exceeds a threshold, about 50 mm or so. For example the maximum PWs are 65.91 mm at 1700 LST before the beginning of rain on June 4, 68.61 mm on July 5, and 69.08 mm on July 28. All of the exceeds 50 mm. Figure 7 shows PW signatures of three examples for the days without rainfall. It is seen that the peak of the PW is less than the threshold 50 mm Therefore we can utilize the amount of PW as an indicator to improve forecasting of heavy rainfall. If the maximum of PW exceeds the threshold, there will have a better chance to have heavy rainfall after a few hours

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4. Conclusions

This paper investigates the diurnal variations in atmospheric water vapor at Banchiao of Taiwan in the rainy season from June to August of 1998 based on GPS-derived precipitable water and surface meteorological observation data.

The precipitable water is increased in the afternoon. Its maximum appears at around 0900 LST. Rainfall often occurs in the afternoon and late afternoon. The diurnal range of precipitable water is larger on the days with than without rainfall events. The maximum PW occurs a few hours before the beginning of heavy rainfall if it exceeds the threshold.

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5. Acknowledgments

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Figure

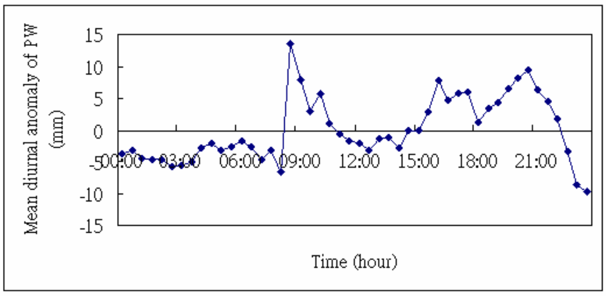

Fig1. Mean diurnal anomaly of PW estimated from GPS

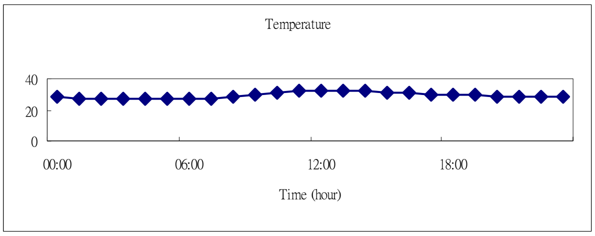

Fig2. Three-monthly mean temperature.

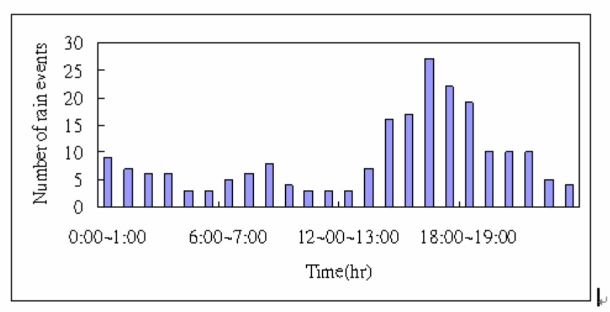

Fig.3 The number of rain events during summer in the 1998

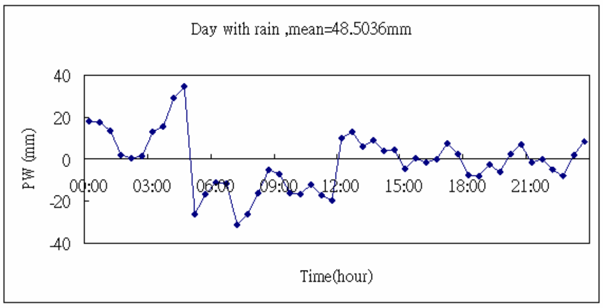

Fig.4 Mean diurnal variations of GPS-measured precipitable water on days with rain

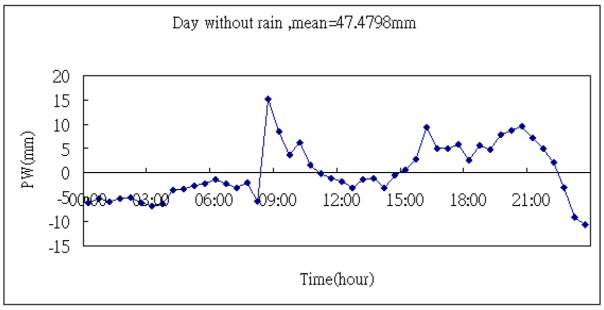

Fig.5 Mean diurnal variations of GPS-measured precipitable water on days without rain

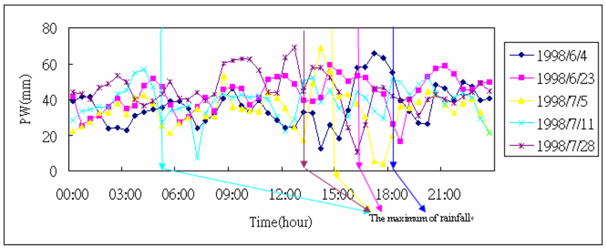

Fig. 6 PW signatures before the beginning of heavy rainfall on 6/4, 6/23, 7/5,7/11 and 7/28.

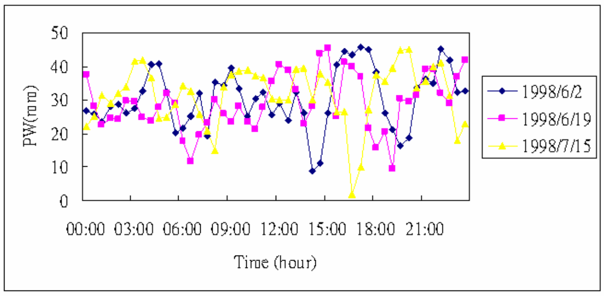

Fig.7 Examples of PW signatures on the days without rai nfall.