Diurnal variation of precipitable water vapor observed with GPS in Thailand

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Abstract

Observation using GPS receiver was performed to obtain PWV (Precipitable Water Vapor) with high time resolution at six stations in Thailand by GAME-T (GEWEX Asian Monsoon Experiment -Tropics). Diurnal variation of PWV was examined using GPS data obtained during 1998-1999. The results show that the diurnal variation is weak both in the dry season (from January to April, November, and December) and the wet season (from May to October) over Thailand. At Bangkok, the amplitude of diurnal variation is less than 1mm. Precipitable water vapor decreases in the morning showing minimum, but its peak is unclear. And PWV at Bangkok have especially clear diurnal variations in April 1998 and March 1999. The amplitude of PWV is about 5mm, its maxima appear around early morning and minimum appear in evening. In these periods, westerly wind at 850hPa is significantly weaker than those in other months. On the other hand, prominent seasonal variation can be observed in PWV over Thailand. There is clear difference in change of PWV between dry and wet season. At Bangkok, variation of about 10-15 days cycle is prominent in PWV with large amplitude of about 40mm in the dry season. In case of the wet season, however, variation of PWV is smaller than that in the dry season, and mean PWV keeps high value of between 50mm to 60mm. In general, the diurnal variation of PWV in the dry season is clearer than that in the wet season. Variation of water vapor is small in the wet season because of nearly saturated water vapor in the atmosphere as the result of continuous supply by monsoon. In case of Thailand, however, the diurnal variation of PWV is not clear even in the dry season, and the clear diurnal variations of PWV appear before monsoon onset at Bangkok.

Keyword: precipitable water vapor, dirunal variation

1. Introduction

Around Indochina Peninsula, large quantities of water vapor are supplied by monsoons. The water vapor produces convective activity and precipitation, which play important role in tropical atmospheric dynamics.

There have been many studies discussing about diurnal variation of convective activity in this area. Nitta and Sekine (1994) analyzed the diurnal variation of convective activity in the tropical western Pacific using by the geostationary meteorological satellite of Japan (GMS) data. They found that large diurnal variation of convection exits in this area, and over the continents and large island, the peak of convection is in late afternoon to evening. Ohsawa et al. (2001) investigated distribution of diurnal variation of convective activity in detail using by GMS data, and found that some maxima tend to appear in the windward areas of mountain, in basins and valleys, and in costal area. They suggested that these maxima are closely associated with terrain or terrain-include local circulation.

Convergence of water vapor intensifies convective activity in general. It is important to get information of water vapor in the atmosphere for investigation of diurnal variation. However, it is insufficient with time resolution of observational data such as soundings data to discuss local circulation.

Global Positioning System (GPS) observation is usually used monitoring of the land deformations. Recently, atmospheric water vapor information can be obtained from GPS. Many researchers have investigated study about water vapor using GPS, however, there are few studies in tropical Asia.

In this study, the diurnal variation of water vapor in Thailand is investigated by means of precipitable water vapor (PWV) estimated from GPS with high time resolution.

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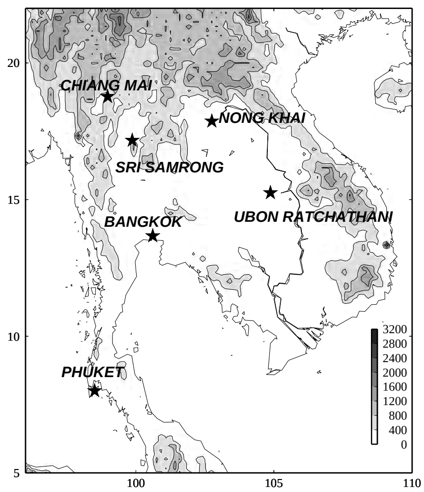

Fig. 1: The location of GAME-T GPS observation station: contours of elevation with 400 m interval.

2. Observation and data analysis

Observation using GPS receiver has been performed at six stations (Bangkok, Chiang Mai, Nong Khai, Phuket, Sri Samrong and Ubon Ratchatani) in Thailand since 1998 in the part of GAME-T. The locations of GPS stations are shown in Fig.1. GPS antennas are fixed on the roof of each building of meteorological department.

The GPS data were received at 30-second intervals and recorded to the hard disk automatically. The atmospheric delay of GPS is estimated at one-hour intervals from GPS data using by analytic software, BERNESE4.2. The zenith hydrostatic delay was estimated from surface pressure, latitude and ellipsoidal height at each observation station (Elgered et al., 1991). The zenith wet delay was converted into precipitable water vapor by using Π parameter (Askne and Nordius, 1987). The weighted mean temperature Tm was estimated from surface temperature Ts observed at Thai Meteorological Department (TMD) (Bavis et al., 1992). We estimated PWV from GPS data at especially four stations (Bangkok, Chiang Mai, Nong Khai and Ubon Ratchatani) in 1999.

Surface pressure, temperature, relative humidity and rain gauge data were provided from TMD. These data are sampled three hourly (01, 04, 07, 10, 13, 16, 19, 22LST). The objective analysis data such as wind and temperature of NCEP/NCAR Reanalysis were used.

3. Results and discussion

3.1 Diurnal variation

The analysis term is divided into two periods: the dry season period (from January to April and from November to October) and the wet season period (from May to October).

Figure 2 shows the time series of daily GPS-PWV and saturated water vapor observed at Bangkok in 1999. There is clear difference in change of PWV between the dry and the wet seasons. In the dry season, variation of about 10-15 days cycle is prominent in PWV with large amplitude of about 40mm. In case of the wet season, however, variation of PWV is smaller than that in dry season, while mean PWV keeps high value of between 50mm to 60mm. Saturated water vapor in Fig.2, estimated by using NCEP data, is almost a constant value during 1999. During the wet season, PWV estimated from GPS becomes nearly saturated water vapor. It is suggested that water vapor in the atmosphere is saturated as the result of continuous supply by monsoon and precipitation.

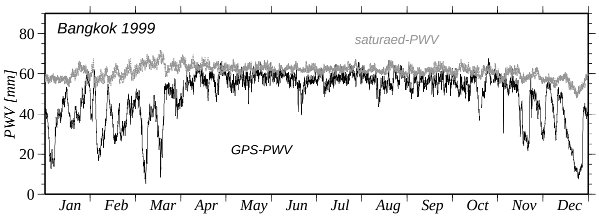

Fig. 2: The time series of daily PWV of GPS (lower line) and saturated water vapor (Upper line) observed at Bangkok in 1999.

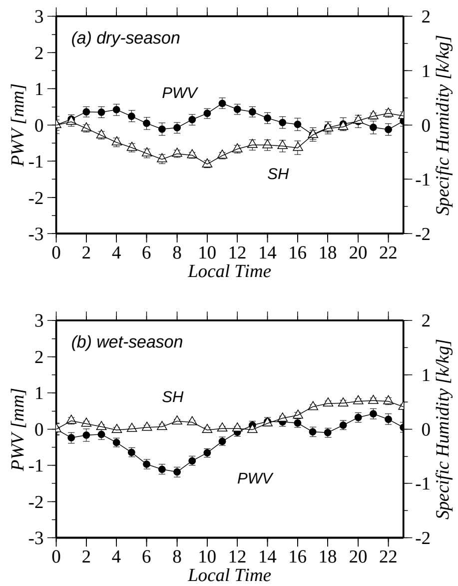

Fig. 3: The mean diurnal variation of PWV and SH in the dry and wet season at Bangkok in 1999. All values are shown in term of deviation from 00LST. The error bars mean estimated standard deviation of average.

Figure 3 shows the averaged diurnal cycle of PWV in each period. All values are shown in term of deviation from 00LST. The error bars mean the standard deviations of the average, which are equal to the standard deviation divided by the square root of sampling number. Diurnal cycle of PWV at Bangkok is weak both in dry and wet season. The amplitude is less than 1mm. Precipitable water vapor decreases in the morning having a clear minimum, but its maximum peak is unclear. Other two stations in Thailand except for Chiang Mai have similar diurnal variation.

Takagi et al. (2000) showed the diurnal variation of PWV calculated from GPS at Lhasa in Tibet. The diurnal variation at Lhasa has a clear minimum around 18LST and 15LST in the premonsoon and the monsoon period, respectively. Also in Japan, GPS-PWV has prominent diurnal variation. Sasaki and Kimura (2001) suggested that variation of PWV differ in location such as mountains, inland and costal area. Moreover, Wu et al. (2003) investigated that at Sumatra island, located western part of Indonesia, distinct diurnal variation of precipitable water vapor exits even on days with heavy rain, while a minimum around 18LST.

3.2 Seasonal variation

For more detailed exploration of diurnal variation, we investigated amplitude of monthly averaged diurnal cycle of PWV and the relation between the diurnal variation and low level wind speed. Figure 4 shows the amplitude of the monthly averaged diurnal cycle of PWV with monthly mean wind speed (850hPa) at Bangkok in 1999. In March, the monthly averaged amplitude of the diurnal cycle of PWV is peculiar large compared with in other month. In other month, however, the amplitude is always small. It is suggested that clear diurnal variation of PWV exists only in March in 1999 at Bangkok. On the other hand, monthly mean wind speed at 850hPa is weaker in March than those in other month.

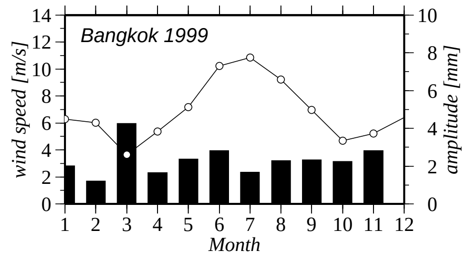

Fig. 4: Monthly mean wind speed at 850hPa (solid line) and amplitude of monthly averaged diurnal variation of PWV (bar graph) at Bangkok in 1999.

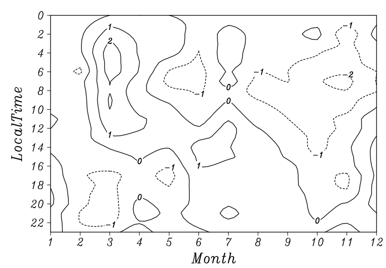

Fig. 5: Monthly averaged diurnal variation of PWV in 1999. All values are shown in term of deviation from 00LST.

Figure 5 shows monthly averaged diurnal variation of PWV in 1999. All values are shown in term of deviation from 00LST.

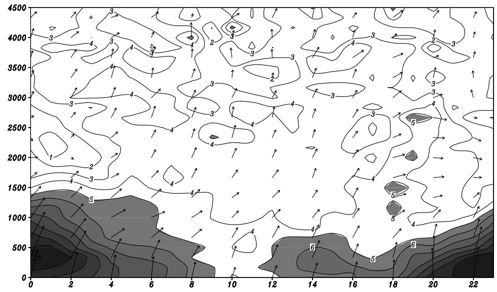

Fig. 6: Averaged diurnal variation of horizontal wind vorticity during March 1999. The contour shows wind speed, vector shows wind direction and speed. Upward and rightward arrows indicate southerly and westerly wind. More than 5m/s area was shaede.

Precipitable water vapor decrease about 4mm in daytime, has a minimum around 20LT in March. Diurnal variations of PWV in other month are weaker than that in March, and their peaks are unclear. Averaged diurnal variation of horizontal wind velocity during March 1999, which observed by wind profiler at Bankok, is showed in Figure 6. In night time, strong sea breeze is prominent while its wind speed is about 10m/s. The diurnal variation of horizontal wind is clear only in March. It implies that water vapor increase by this sea breeze during this month.

Difference of weekly averaged surface temperature (Ts) at Bangkok and weekly averaged sea surface temperature (SST) at Gulf of Thailand (10N, 100E) in 1999 was estimated. There is difference of about 2 degree between Ts and SST, while amplitude of diurnal variation of surface temperature is about 4 degree. It is suggested that this difference between Ts and SST is enough to weaken or intensify the sea breeze.

These results indicate that the diurnal cycle of PWV become clears as the results of the effects of sea breeze, when the ambient low -level wind speed is weak and the thermally induced local circulations are active. The amplitude of diurnal variation of PWV at Bangkok seems to be associated with thermal local circulations during mild low-level wind speed is weak at the onset period of monsoon. By analysis of observation data, Murata et al. (2002) suggested that the precipitation at Kototabang, West Sumatra Province in Indonesia, tend to occur when the low-level westerly is weak.

4. Conclusion

In this study, precipitable water vapor was estimated from GPS data in 1999 around Thailand with high time resolution. Clear difference in temporal variation during dry and wet season was found. In the dry season, about 10-15 days cycle is prominent with large amplitude of about 40mm. In the wet season, however, variation of PWV is much smaller than that in dry season, although mean value of PWV keeps high value of between 50mm to 60mm.

Amplitude of monthly averaged diurnal cycle of PWV was estimated. The amplitude in March is especially large compared with that in other month at Bangkok. In March, the low level wind is weak, and diurnal variation of surface wind is clear. It is suggested that the amplitude of diurnal variation of PWV at Bangkok is associated with thermally induced local circulations generated under mild ambient wind around the onset of monsoon.

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Acknowledgments

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