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# DIURNAL VARIATIONS OF PRECIPITATION USING OPAQUE MICROWAVE FREQUENCY BANDS

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## 1. ABSTRACT

This paper presents diurnal variations of precipitation as observed using the Advanced Microwave Sounding Unit instruments, AMSU-A and AMSU-B, aboard the NOAA-15, NOAA-16, and NOAA-17 satellites. The method used for estimating precipitation was described by Chen and Staelin (2003) and Chen (2004). This method relies primarily on opaque microwave channels in the 54-GHz oxygen and 183-GHz water vapor resonance bands. NOAA-15, NOAA-16, and NOAA-17 are polar-orbiting satellites, so AMSU obtains global observations about six times a day. The local equatorial crossing times of these satellites are about 7 AM/PM, 2 AM/PM, and 10 AM/PM, respectively. The nearly-even positioning of these satellites facilitates a study of the diurnal variation of precipitation. A space-time resolution of 10°x10° by 3 months seems to be appropriate for studying the diurnal variations of precipitation. Diurnal variations of precipitation frequency were computed for AMSU data from July 2002 to June 2003. For this purpose, precipitation events were defined as observations where the retrieved precipitation rate was greater than a specified threshold. For this paper, the thresholds used included 0.1, 1, and 2 mm/h. It was observed that in the western Pacific part of the ITCZ the local preferred time of precipitation frequency varied from about midnight to about 0500 as the threshold was increased from 0.1 to 2 mm/h, and similar trends were observed in other parts of the ITCZ. This suggests that future studies on the diurnal variations of precipitation might focus on specific types of precipitation or ranges of precipitation rate.

## 2. INTRODUCTION

Precipitation climatology is important to hydrology and the study of the global energy cycle. Global precipitation has many significant modes of variation, one being the diurnal cycle which has not been thoroughly studied. A comprehensive study of the diurnal variations of precipitation over the continental U.S. was done by Dai et al. (1999). Satellite-based studies include those by Chang et al. (1995) using data from the Special Sounder Microwave Imager (SSM/I), and by Negri et al. (2002) using data from the Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI).

This paper presents a study of the diurnal variations of precipitation based on data from the Advanced Microwave Sounding Unit (AMSU) aboard the National Oceanographic and Atmospheric Administration (NOAA) NOAA-15, NOAA-16, and NOAA-17 satellites. This paper presents a continuation of the study presented in Chen et al. (2004).

## 3. DESCRIPTION OF AMSU

AMSU is a passive microwave instrument with channels in the opaque 54-GHz oxygen and 183-GHz water vapor resonance bands, and window channels near 23.8, 31.4, 89, and 150 GHz. AMSU's are aboard the NOAA-15, NOAA-16, and NOAA-17 polar-orbiting satellites, which were launched in 1998, 2000, and 2002, respectively. These three satellites have local equatorial crossing times that are separated by ~3-5 hours. AMSU/HSB aboard the Aqua satellite (launched in 2002) provided a nearly identical set of channels. These four satellites observed each point on the globe ~8 times daily for a period of about seven months and at least two are expected to operate into the future.

## 4. ESTIMATING PRECIPITATION-RATE USING AMSU-A/B

Chen and Staelin have developed a method for estimating precipitation rate for AMSU that relies primarily on the opaque channels in the 54-GHz and 183-GHz frequency bands (Chen and Staelin, 2003; Staelin and Chen, 2000) in contrast to previous methods that rely exclusively on window channels. Opaque channels are useful because they are insensitive to surface variations and they are sensitive to humidity, grauple size, and cloud-top altitude, which are important determinants of precipitation. This algorithm was trained using NEXRAD data over the eastern U.S. and adjusted using data from the Advanced Microwave Sounding Radiometer for the Earth Observing System (AMSR-E) aboard the NASA Aqua satellite (Chen, 2004). One weakness of the algorithm is that it does not detect warm rain. The algorithm was developed primarily for convective glaciated precipitation.

In addition to rain, AMSU also has been shown to be useful for sensing snow (Chen, 2004; Chen and Staelin,

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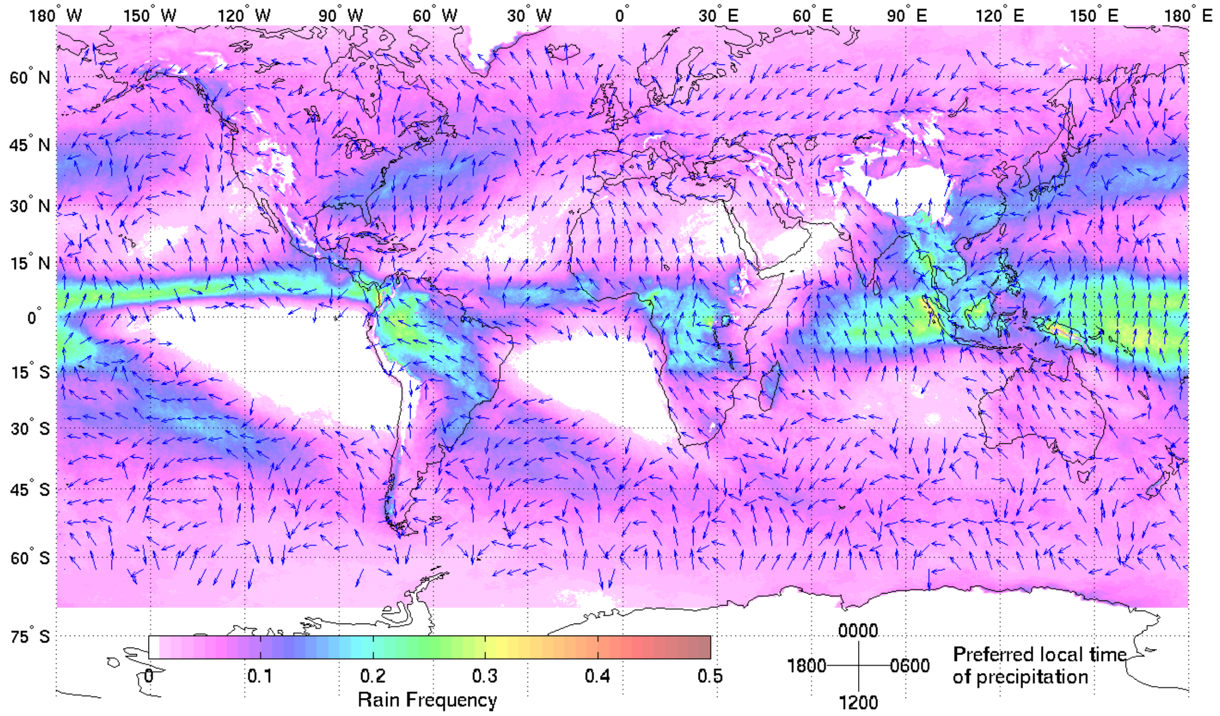

Fig. 1. Frequency and preferred local time of precipitation events with rates greater than or equal to 0.1 mm/h from July 2002 to June 2003

2003; Chen et al., May 2003; Chen et al., July 2003; Skofronick-Jackson et al., 2004).

## 5. COMPUTATION OF DIURNAL CYCLE

This section describes the model of the diurnal cycle and the computation of its parameters. Let $R$ be the mean rain rate or rain frequency over a specified period (e.g. a month, a season, a year) as a function of the time of day $t$ in hours. $R(t)$ is assumed to have the following form:

$$R(t) = A\cos[\omega(t-\tau)] + c \qquad (1)$$

where $A$ is the non-negative diurnal amplitude, $c$ the mean of $R(t)$, $\omega$ is the angular frequency of the diurnal cycle, and $\tau$ is the preferred time of precipitation. Since $t$ is in hours, $\omega = 2\pi/24$. $R(t)$ can be rewritten as follows:

$$R(t) = a\cos(\omega t) + b\sin(\omega t) + c \qquad (2)$$

where $a = A\cos(\omega\tau)$ and $b = A\sin(\omega\tau)$. Then, with the six daily observations provided by the NOAA-15, NOAA-16, and NOAA-17 satellites, one can use the least-squares approximation to determine the three unknowns, $a$, $b$, and $c$. $a$ and $b$ can then be used to compute $A$ and $\tau$. This method was used also by Chang et al. (1995). Each observation was assigned a time equal to the nominal local equatorial crossing of the northbound or southbound path of the observing satellite as described below:

- NOAA-16 southbound: 2 AM
- NOAA-15 southbound: 7 AM
- NOAA-17 southbound: 10 AM
- NOAA-16 northbound: 2 PM
- NOAA-15 northbound: 7 PM
- NOAA-17 northbound: 10 PM

## 6. SAMPLES OF DIURNAL VARIATION STUDIES

In Chen et al. (2004), it was observed that the preferred time of precipitation frequency could differ significantly from the preferred time of precipitation rate. In this paper, the dependence of the preferred time of precipitation frequency on the definition of precipitation event is studied.

Fig. 1 shows the diurnal variation of 10°×10° averages of precipitation frequency averaged over the period 7/2002 to 6/2003. An observation is considered precipitating if the retrieved precipitation rate is greater than or equal to 0.1 mm/h. Figs. 2 and 3 show the same thing except for thresholds of 1 and 2 mm/h, respectively, instead of 0.1 mm/h. In the area between 10° N to 10° S and between 150° E and 180° E, the preferred time of precipitation frequency changes noticeably as the threshold defining precipitation events rises from 0.1 to 2 mm/h. When the threshold is 0.1 mm/h the preferred time is around midnight. When the threshold is increased to 1 mm/h, the preferred time varies around 0200. When the threshold is increased further to 2 mm/h, the preferred time varies from about

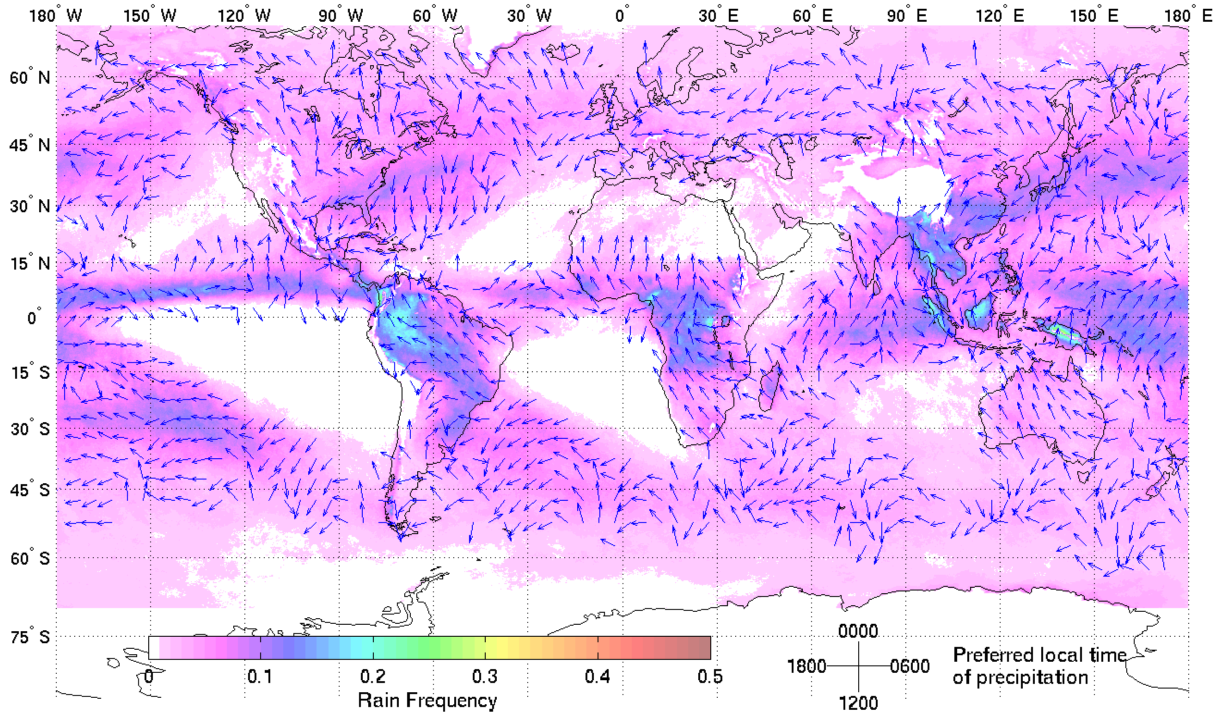

Fig. 2. Frequency and preferred local time of precipitation events with rates greater than or equal to 1 mm/h from July 2002 to June 2003

0400 to about 0600. Since the preferred time of frequency of heavier precipitation is near 0500, it is not surprising that the preferred time of precipitation rate is near 0500 as reported by Imaoka and Spencer (2000) using TMI and SSM/I. This suggests the possibility that different types of precipitation could have different preferred times. In this region, heavy precipitation tends to occur around 0500 while it seems that most light precipitation (i.e. between 0.1 and 2 mm/h) tends to occur between 1800 and 0000. Threshold-dependent shifts in the preferred time of precipitation were observed also in other regions throughout the ITCZ.

This raises the possibilty of a study involving the diurnal variation of specific types of precipitation events (e.g. extremely heavy, extremely light).

## 7. FUTURE WORK

This method of assign local observation times is not perfect since over a single northbound or southbound path between 70° N and 70° S, the local solar time varies over a range of more than 3 hours. Studies in which each observation is assigned the correct local solar time are in progress and may be presented in future conference proceedings papers or journal papers.

## 8. ACKNOWLEDGEMENTS

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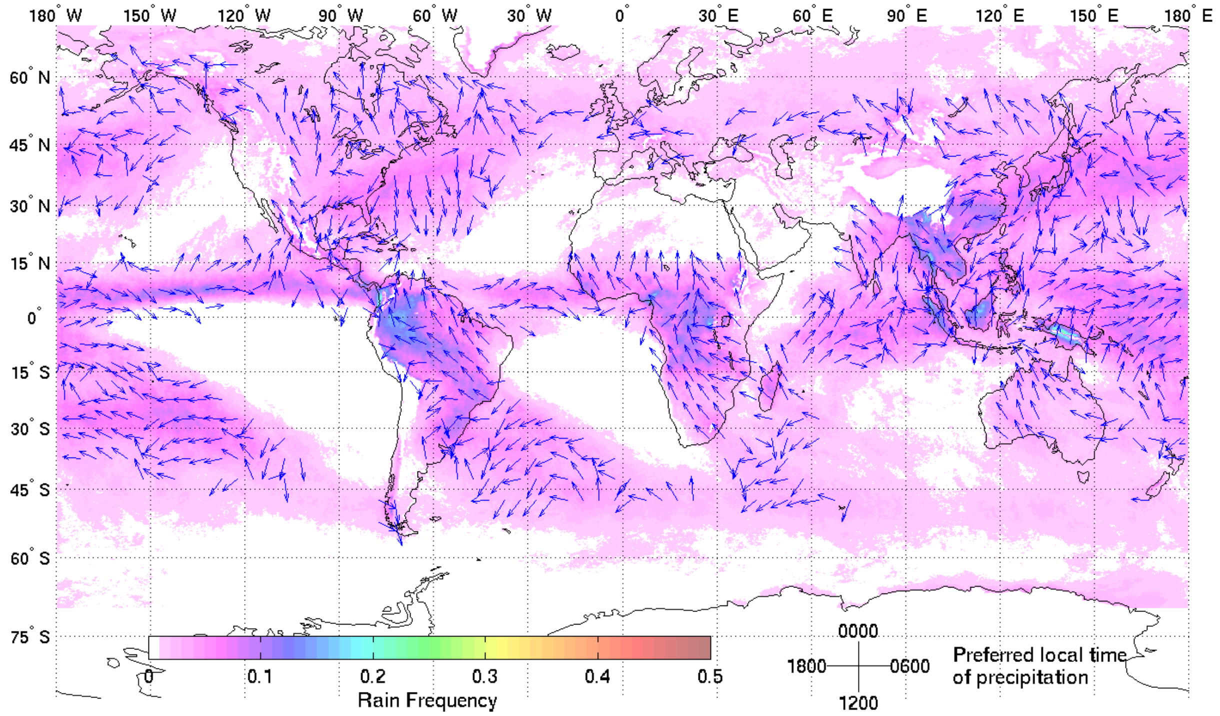

Fig. 3. Frequency and preferred local time of precipitation events with rates greater than or equal to 2 mm/h from July 2002 to June 2003

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