# Monsoon precipitation characteristics over Asia and Western Tropical Pacific Ocean

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## Abstract

Wind profilers offer the unique ability to directly measure vertical motion profiles through precipitating and non-precipitating cloud systems. This ability has been exploited through a series of analyses of evolution of convective boundary layer and mesoscale precipitating systems passing overhead of the wind profilers located at Gadanki (India), Aimeliik (Palau) and Dongshan (China). Tropical wind profilers and JW disdrometers (Gadanki and Aimeliik) analysis/results show clear seasonal dependence raindrop size distribution characteristics in summer monsoon and winter monsoon. During the Westerly monsoon often the precipitating systems are associated with mesoscale convection activities and also short duration with high intensity of rainfall.

*Keyword: Monsoon, Radar reflectivity, convective boundary layer, precipitation and Raindrop size distribution*

## 1. Introduction

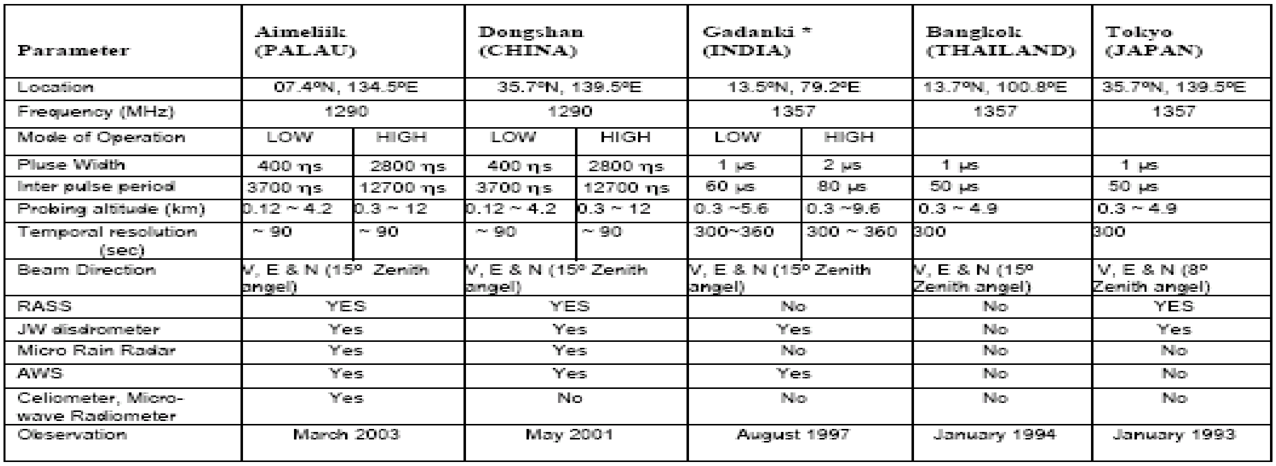
**Fig.1:** The map showing location of the wind profilers that are used for the present study.

Wind profilers (WP) operating around 1 GHz provides with good temporal and vertical resolution data to diagnose the convective boundary layer (CBL) and vertical structure of the precipitating cloud systems (Reddy et al. 2002). We proposed to use (Figure 1 & Table 1) utilize five wind profiler to understand the influence of boundary layer on Asia monsoon precipitation. However, for the present paper, we utilized Gadanki, Dongshan and Palau data.

## 2. Boundary Layer Characterization

Figure 2(a-c) shows the time-height cross-section of range corrected reflectivity (SNR) dB observed with Gadanki, Donghsan and Aimeliik wind profiler during different monsoon seasons. Strong reflectivity observed during morning hours corresponds to the morning transition or

Table 1. Characterisitcs of the Lower Atmopsheric Wind profilers used for the present study



| Parameter | Aimeliik (PALAU) | | Dongshan (CHINA) | | Gadanki * (INDIA) | | Bangkok (THAILAND) | Tokyo (JAPAN) |
|---|---|---|---|---|---|---|---|---|
| Location | 07.4°N, 134.5°E | | 35.7°N, 139.5°E | | 13.5°N, 79.2°E | | 13.7°N, 100.8°E | 35.7°N, 139.5°E |
| Frequency (MHz) | 1290 | | 1290 | | 1357 | | 1357 | 1357 |
| Mode of Operation | LOW | HIGH | LOW | HIGH | LOW | HIGH | | |
| Pluse Width | 400 ηs | 2800 ηs | 400 ηs | 2800 ηs | 1 μs | 2 μs | 1 μs | 1 μs |
| Inter pulse period | 3700 ηs | 12700 ηs | 3700 ηs | 12700 ηs | 60 μs | 80 μs | 50 μs | 50 μs |
| Probing altitude (km) | 0.12 ~ 4.2 | 0.3 ~ 12 | 0.12 ~ 4.2 | 0.3 ~ 12 | 0.3 ~5.6 | 0.3 ~9.6 | 0.3 ~ 4.9 | 0.3 ~ 4.9 |
| Temporal resolution (sec) | ~ 90 | ~ 90 | ~ 90 | ~ 90 | 300~360 | 300 ~ 360 | 300 | 300 |
| Beam Direction | V, E & N (15° Zenith angel) | | V, E & N (15° Zenith angel) | | V, E & N (15° Zenith angel) | | V, E & N (15° Zenith angel) | V, E & N (8° Zenith angel) |
| RASS | YES | | YES | | No | | No | YES |
| JW disdrometer | Yes | | Yes | | Yes | | No | Yes |
| Micro Rain Radar | Yes | | Yes | | No | | No | No |
| AWS | Yes | | Yes | | Yes | | No | No |
| Celiometer, Micro-wave Radiometer | Yes | | No | | No | | No | No |
| Observation | March 2003 | | May 2001 | | August 1997 | | January 1994 | January 1993 |

the morning rise of the inversion. The significant echo region appears in the lowest observational heights and ascends gradually, reaching a maximum height in the afternoon hours.

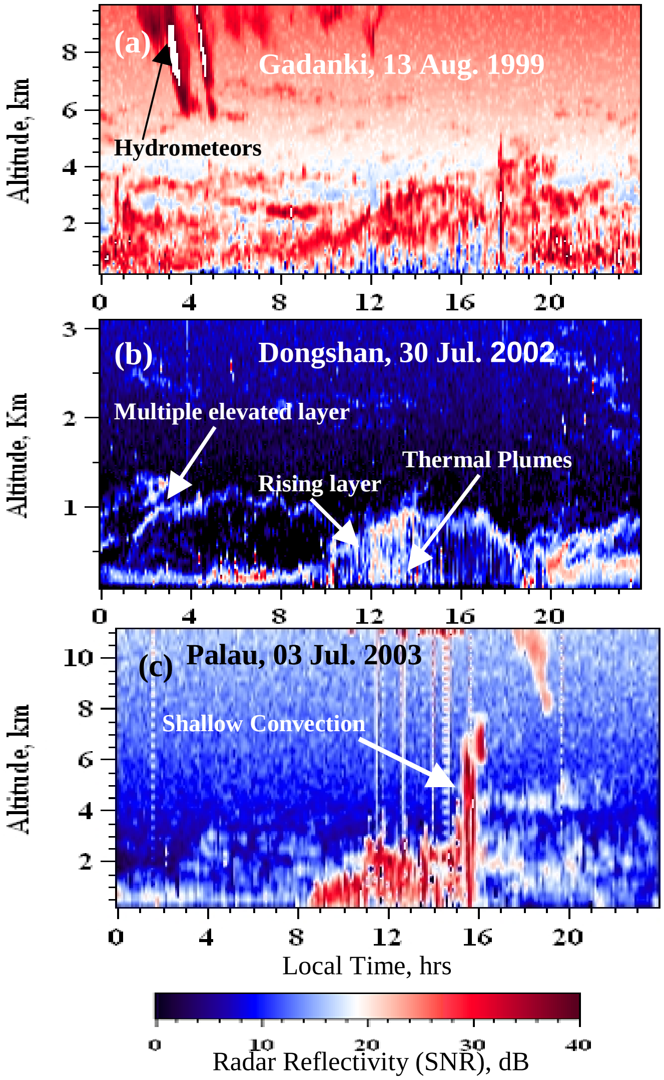


**Fig.2**: Time-height cross-section of Reflectivity (SNR), dB observed during summer monsoon convective boundary layer evolution at different locations.

Figure 3 shows the midday boundary layer height for all the days with well-formed CBL over Dongshan and Gadanki. The height shown for each day is the average over four hours in early afternoon (12:00 – 15:00 Local Time) of the boundary layer heights determined for each hour by subjective examination of the results of a peak-finding algorithm run on the reflectivity. The results suggest that the average CBL height at Dongshan varies between 1 and 1.5 km and whereas at Gadanki the boundary layer height various between 1.05 and 2.05 km. The marine boundary layer is most of the time less than 1 km. The CBL evolution depends on variety of factors and is not simply related to any local surface meteorological variables. The low boundary heights at Aimeliik during June and July are probably related to low Bowen ratios (ratio of sensible to latent heat flux at the surface) and very high humidity.

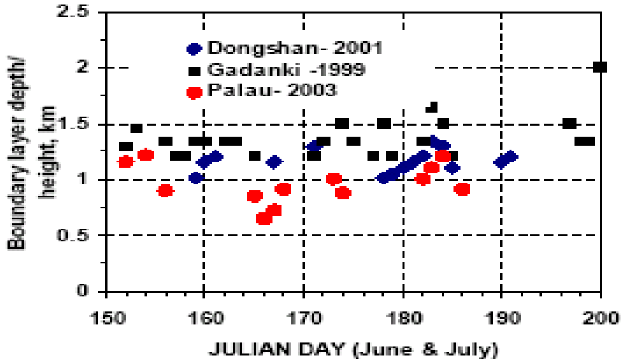


**Fig.3**: Average Boundary layer height observed during summer Monsoon period over Dongshan, Gadanki and Aimeliik.

### 3. Diagnostic studies of tropical precipitation

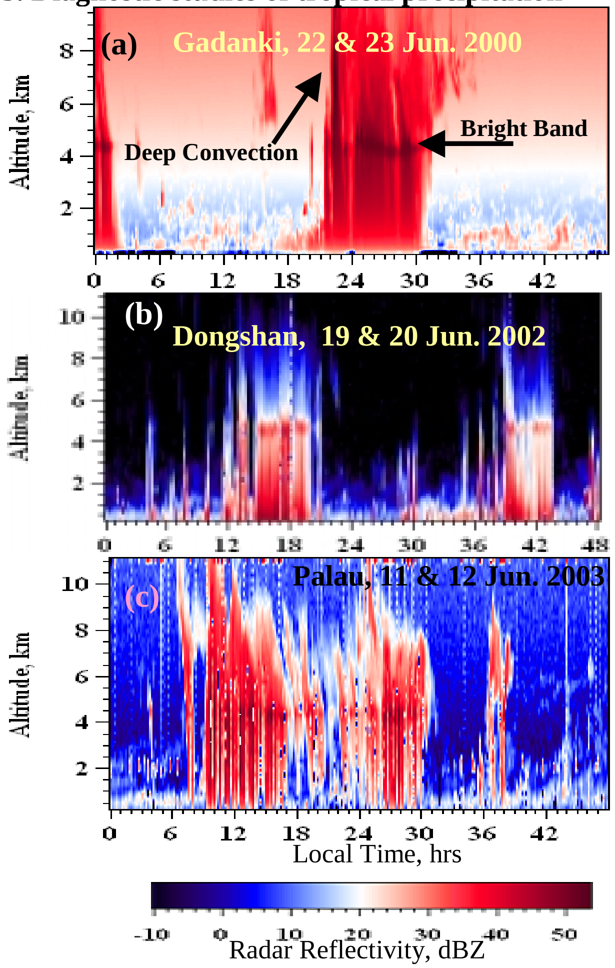


**Fig.4**: Time-height cross-section of Reflectivity, dBZ observed by the vertical beam of different wind profilers.

Figure 3 illustrates Gadanki, Dongshan and Aimeliik wind profilers potential for diagnosing the vertical structure of precipitating cloud systems. The reflectivity in the panel (a), panel (b) and panel (c) show a distinct episode of convective activity, and a bright band of high reflectivity associated with a melting layer is visible. The ability of Gadanki, Dongshan and Aimeliik wind profilers to clearly resolve the melting layer when it is present also provides a means of differentiating between stratiform and convective precipitation.

Precipitation events/storms at Gadanki are short lived around one hour with high intensity of the rain. Aimeliik most of the precipitation events are long lasting and mostly associated with heavy rainfall or tropical cyclones or both. Preliminary results from Gadanki confirm that at least half of tropical rainfall is stratiform in nature being associated with mesoscale convective systems. However, this research needs further detailed investigations, which are in progress.

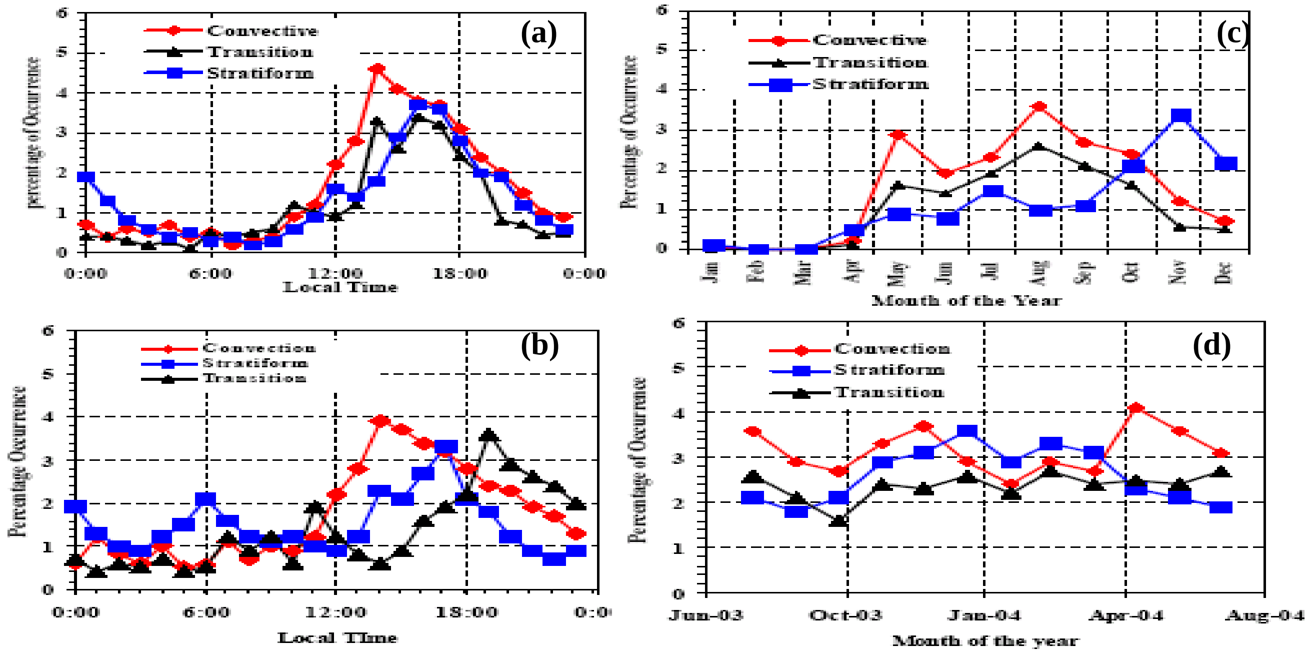


**Fig. 5**: Diurnal variation of Precipitating Clouds over (a) Gadanki and (b) Aimeliik during Monsoon. Seasonal variation of Precipitating Clouds over (c) Gadanki and (d) Aimeliik during Monsoon period.

To improve algorithms for the remote sensing of rainfall, which are crucial for meso- and large-scale circulations studies and climate applications through better determinations of precipitation type and latent heating profiles (Gage et al. 1994). Toward this end wind profiler-derived quantities, namely, equivalent reflectivity, Doppler velocity and spectral width from Doppler spectra were used to classify precipitation type in three categories: Convective, Transition (mixed convection-stratiform) and Stratiform (William et al 1995).

Figure 5 shows diurnal variations of precipitating cloud occurrence at Dongshan and Gadanki as observed by the wind profilers. Diurnal variation of convection seems to occur late afternoon and evening at Gadanki and Aimeliik. . The peak of stratiform precipitating cloud has smaller value and comes later than the convective clouds. The time delay between the peak of the stratiform and convective precipitating cloud corresponds to the life cycle of the mesoscale convective system. Several

## 4. Seasonal variation of Raindrop size distribution

The DSD variation at Gadanki and Aimeliik, generally, depends on seasonal change of monsoon precipitating cloud systems that are characterized by a variety of physical mechanisms that produce strong seasonal winds, a westerly and easterly monsoon. It is the combined effect of these mechanisms that produces (seasonal variation of raindrop size distribution) the monsoon's characteristic reversals of high winds and precipitating cloud systems. These results are very interesting and different from the sub-tropics. The present results suggest that the rain-type dependent of DSD properties in tropics may need more study. Despite the uncertainty in using radars to estimate rainfall, several studies have been conducted to determine the relationship between rain rate and radar reflectivity. By plotting the radar reflectivity against the rain rate, it has been found that the relationship between radar reflectivity and rain rates follows a "power–law", i.e.

$$Z = 10^{a} R^{b} \qquad \ldots \qquad (1)$$

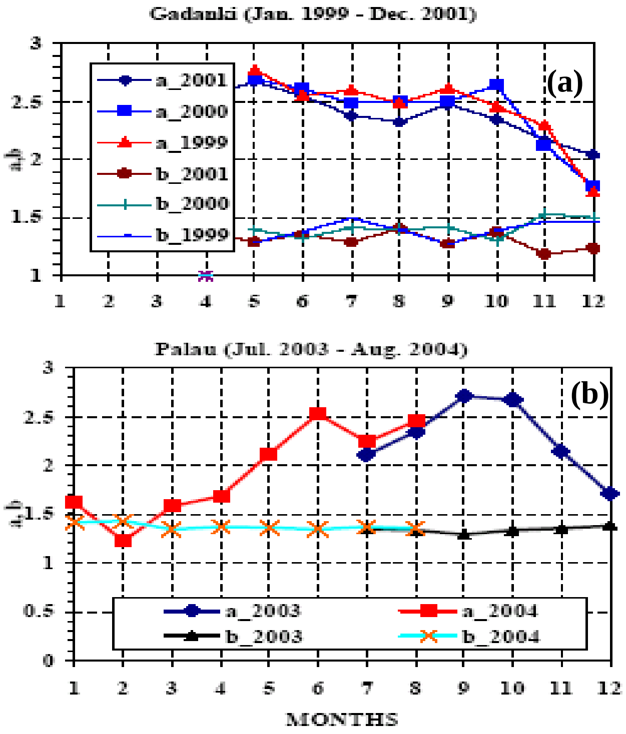


**Fig.6**: Seasonal variation of the coefficient "a" and exponent "b" of $Z = 10^{a}R^{b}$ at (a) Gadanki and (b) Aimeliik.

The constants "a" and "b" are related to the intercept and slope of the best-fit line through a plot of rain rate versus radar reflectivity [on a log $Z$ – log $R$ plot]. In the present study a clear seasonal dependence in $Z$–$R$ relations (i.e. DSD characteristics) was found at Gadanki and Aimeliik as shown in Figure 6. Figure 6 [(a) and (b)] show the seasonal dependence of the coefficient "*a*" and exponent "*b*" in the $Z$–$R$ relation [Eq. (1)]. It is seen from Fig.6 during summer/westerly monsoon periods, "*a*" (the usual coefficient in $Z$–$R$ relation) ranges between about 250 and 500, while during easterly monsoon, "*a*" decreases drastically. The exponent "*b*" also changes somewhat, which may be related to seasonal changes of light and heavy rains in winter and summer monsoons. The present results strongly suggest that this type of seasonal dependence should be taken into account to improve the accuracy of the TRMM precipitation radar algorithm.

## 5. Concluding Remarks

In this paper we have illustrated the structure of diverse precipitating cloud systems observed at several tropical locations using ground-based Wind profilers. Such measurements of the detailed vertical structure of precipitating cloud systems contribute valuable information to space-based precipitation retrievals. In addition the retrieval of drop-size distributions is needed for determining precipitation parameters.

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