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# The aerosol-induced impacts on South Asian monsoon estimated from Fengyun-2 observations of the cloud effective particle radius

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## Introduction

Recent studies have shown that a marked increase of absorbing aerosols in South Asia has altered the characteristic of Asian monsoon (Ramanathan et al., 2005; Lau et al., 2006). However, it is not easy to explain the aerosol effects on Asian monsoon water cycle in total, because it depends on many factors; especially the indirect effect of aerosols and the possible interaction with the monsoon dynamics remains unknown. Therefore, it is important to obtain observational data of cloud particle properties such as an effective radius over South Asia toward the deeper understanding of interaction between aerosol and Asian monsoon circulation.

In this study, the cloud effective particle radius is estimated using geostationary satellite Fengyun-2E data in order to evaluate aerosol indirect effects over South Asia and its impact on Asian monsoon.

Observations of the cloud effective particle radius have conducted over South Asia in 2012.

## Data and Model

### Geostationary satellite / Fengyun-2E (FY-2E)

- Channel and wavelength :
  IR1 (10.3-11.3 μm), IR2 (11.5-12.5 μm),
  IR3 (6.3-7.6 μm), IR4 (3.5-4.0 μm), VIS (0.50-0.75 μm)
- Position: 35,800km above the equator at **105°E**
- Resolution: 1.25 km (VIS) and 5 km (IR) at SSP
- Observation schedule: 1 time/hour (Full-disk scan) + 0~1time/hour (Hemisphere scan)
- Area: **60°S~60°N, 45°E~165°E**
- IR channel calibration: **Done** according to GSICS method
- VIS channel calibration: Undone
- Geometric correction: **Done**

### Geostationary satellite / MTSAT-2

- Channel and wavelength :
  IR1 (10.3-11.3 μm), IR2 (11.5-12.5 μm),
  IR3 (6.5-7.0 μm), IR4 (3.5-4.0 μm), VIS (0.55-0.90 μm)
- Position: 35,800km above the equator at **145°E**
- Resolution: 1 km (VIS) and 4 km (IR) at SSP
- Observation schedule: 1 time/hour (Full-disk scan) + 1~2time(s)/hour (Hemisphere scan)
- Area: **60°S~60°N, 85°E~155°W (205°E)**
- IR channel calibration: **Done** according to GSICS method
- VIS channel calibration: **Done** according to JMA method
- Geometric correction: No need (Good condition)

### Terra / MODIS

- MOD06 cloud products (the cloud effective particle radius retreived from 3.7μm channnel )

### Rstar6b

- Radiative transfer code (Nakajima and Tanaka, 1986;1988)

**Analysis period:**
**February. 2012 ~ October. 2012**

## Retrieval of the cloud effective particle radius from FY-2E data

**For optically thick water cloud, the cloud effective particle radius can be determined solely from reflection function measurements at 3.7 μm** (Nakajima and King, 1990; Kaufman and Nakajima, 1993).

### Step1: Choosing cloud pixels appropriate for analysis

- **Choosing optically thick clouds** (Choi et al., 2009)

$$\begin{cases} T_{IR1}^{clear} - T_{IR1} > 12[K] \\ L_{VIS} - L_{VIS}^{clear} > 6[\%] \end{cases}$$

- $T_{IR1}$: Observed IR1 Brightness Temperature [K]
- $T_{IR1}^{clear}$: Clear sky IR1 Brightness Temperature [K]
- $L_{VIS}$: Observed VIS albedo [%]
- $L_{VIS}^{clear}$: Clear sky VIS albedo [%]

- **Choosing water clouds** (Choi et al., 2009)

**Ice cloud:**
$T_{IR1} < 238[K]$ *or* $T_{IR1} - T_{IR2} \geq 4.5[K]$ *or* $T_{IR3} < 228[K]$

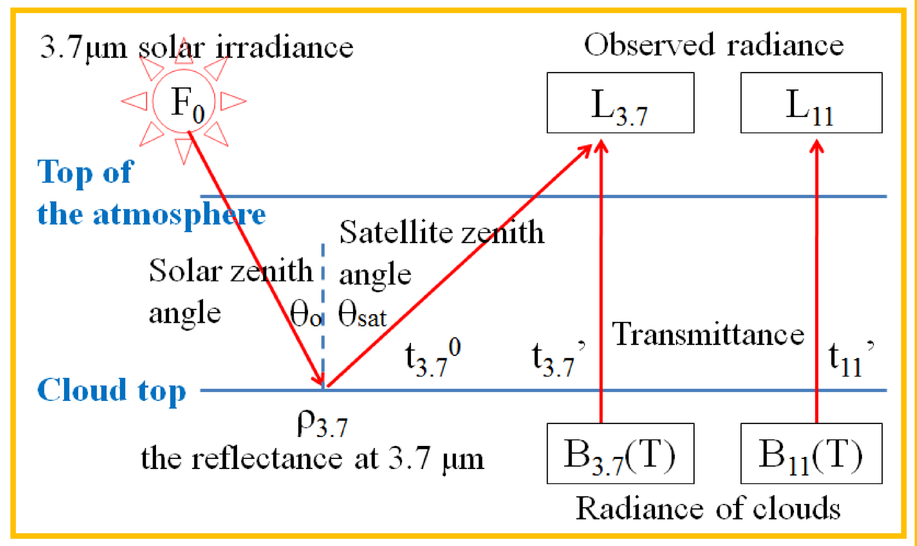
**Mixed cloud:**
For no ice, $238[K] \leq T_{IR1} < 268[K]$ *and* $228[K] \leq T_{IR3} < 239[K]$

**Water cloud:**
For no ice/mixed, $T_{IR1} \geq 268[K]$ *or* $T_{IR3} \geq 239[K]$

### Step2: Calculating the cloud reflectance at 3.7 μm band

These equations are solved for the cloud reflectance at 3.7 μm band, $\rho_{3.7}$.

$$\begin{cases} L_{3.7} = t_{3.7}^{o}\left(\frac{F_0 cos\theta_0}{\pi}\right)\rho_{3.7} + t_{3.7}' B_{3.7}(T)(1-\rho_{3.7}) \\ L_{11} = t_{11}' B_{11}(T) \end{cases}$$




Where,

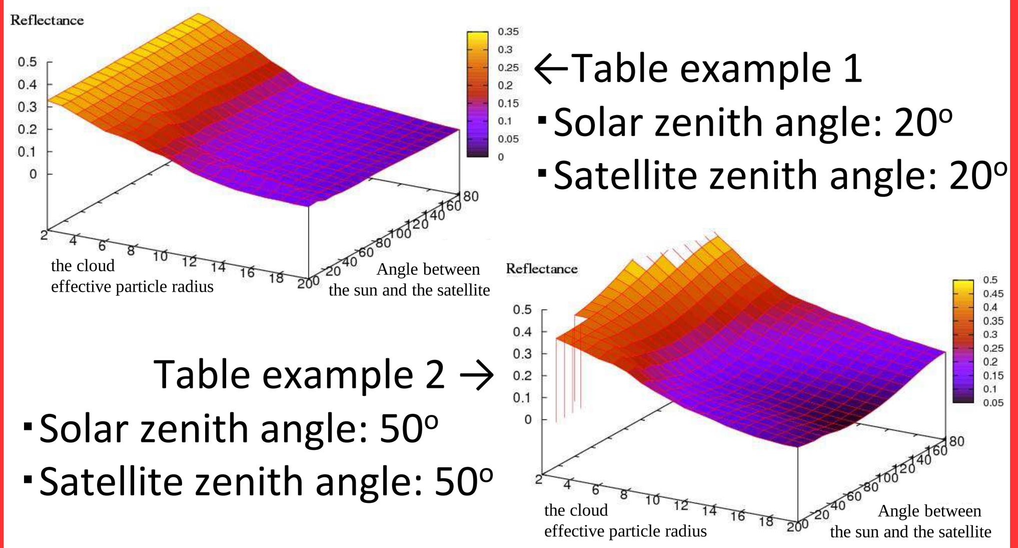
$$\begin{cases} F_0 = 11.11[W/m^2] \\ t_{3.7}^{o} = 0.96^{\frac{1}{cos\theta_0}+\frac{1}{cos\theta_{sat}}} \\ t_{3.7}' = 0.96^{\frac{1}{cos\theta_{sat}}} \\ B_\lambda(T): \text{Sensor planck function} \end{cases}$$

These parameters are calculated for FY-2E using Rstar6b model.

### Step3: Converting to the effective radius

The reflectance at 3.7 μm is converted to the effective radius according to conversion tables estimated from Rstar6b.

Conversion tables are developed by considering solar zenith angles, satellite zenith angles, and angles between the sun and the satellite.



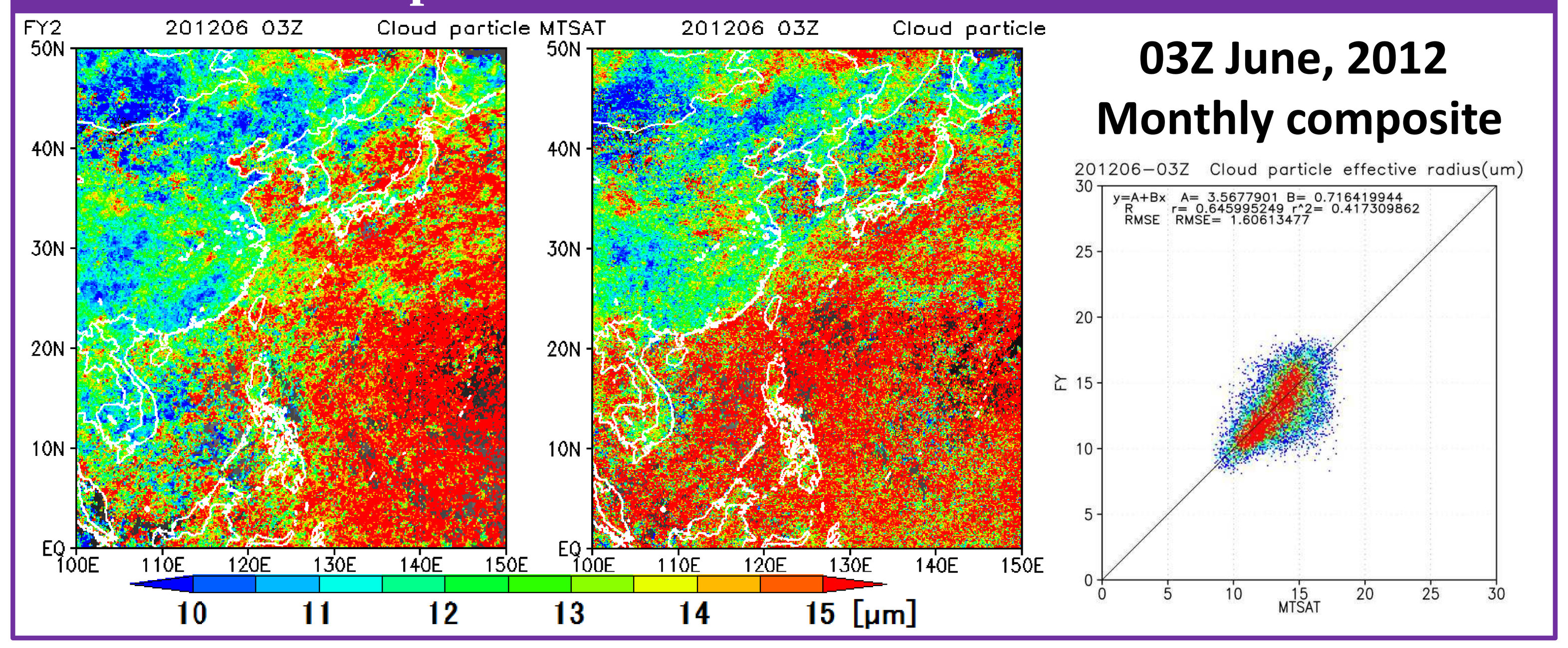

←Table example 1
・Solar zenith angle: 20°
・Satellite zenith angle: 20°

Table example 2 →
・Solar zenith angle: 50°
・Satellite zenith angle: 50°

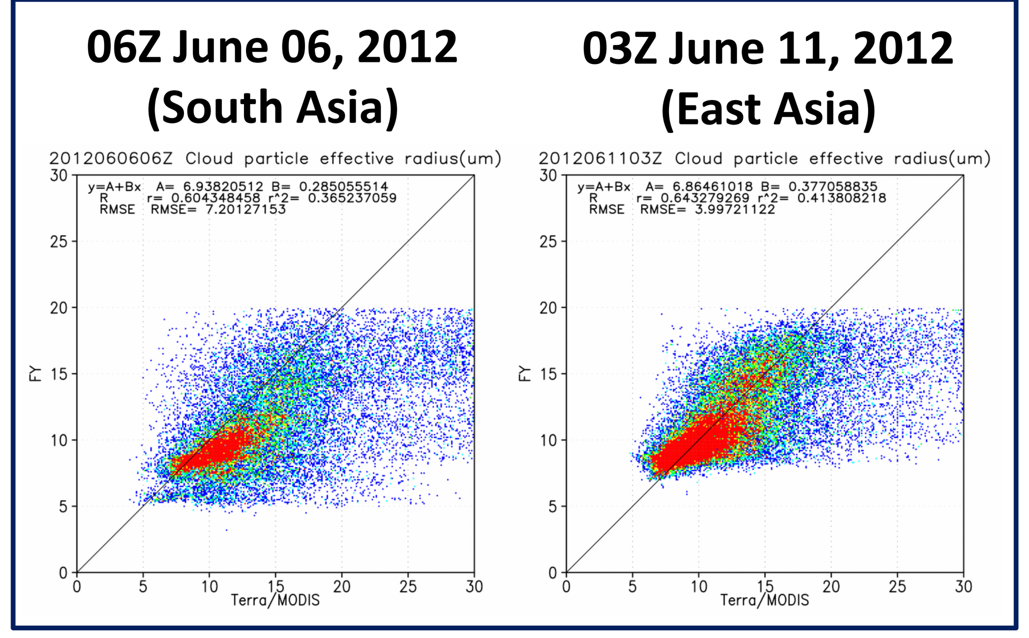
## Inter-comparison of satellite-derived cloud effective radius

To validate the accuracy of the analysis of FY-2E data, we conduct inter-comparison of satellite-derived cloud effective radius.

### Comparison between FY-2E and MTSAT-2




### Comparison between FY-2E and MODIS



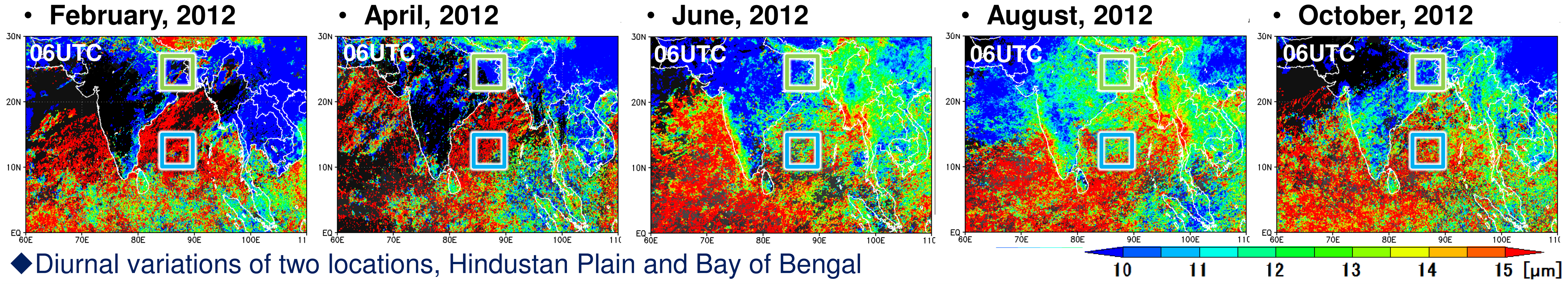

Adequate correlations have been confirmed between the result from FY-2E and those from MTSAT-2 or MODIS cloud products.

## FY-2E observation results over South Asia

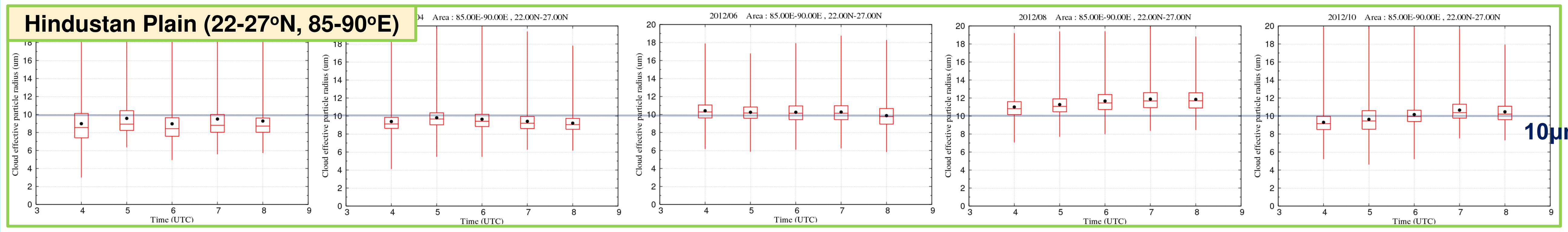
The cloud effective particle radius over South Asia is estimated from FY-2E satellite data from Feb. to Oct., 2012.

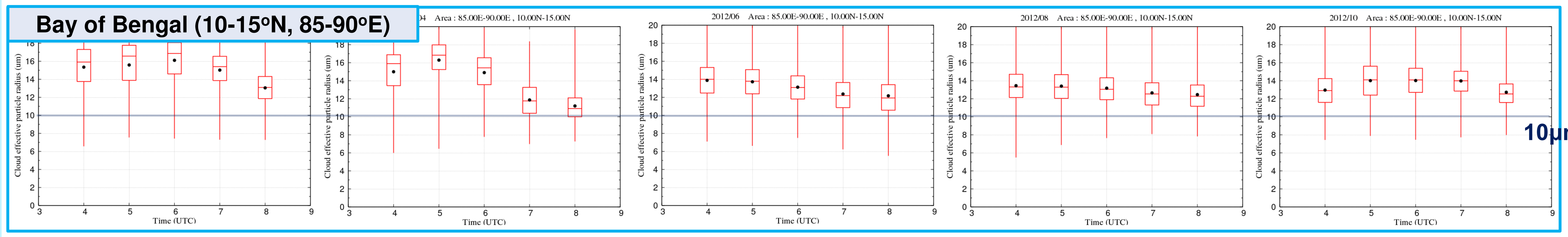
◆The cloud effective particle radius (Monthly composite values)

- February, 2012
- April, 2012
- June, 2012
- August, 2012
- October, 2012




◆Diurnal variations of two locations, Hindustan Plain and Bay of Bengal




## Summary

- **We develop the new method to estimate the cloud effective particle radius from a geostationary satellite, Fengyun-2E.**
- The validity of cloud effective particle radius obtained by this procedure has been confirmed by comparing the results from multi-satellites.
- General characteristics, the cloud effective particle radius is smaller in continental clouds than in maritime clouds, are confirmed from FY-2E observations.
- It is suggested that the cloud effective particle radius over the Indian subcontinent becomes larger during monsoon season. Its diurnal variation also observed, but the reason is not explored yet.
- The investigation on aerosol-induced impacts on South Asian monsoon will be continued by these data.