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Study of the cloud cover variability over Indian region using Geo-Stationary Satellitedata

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ABSTRACT

In this study Cloud Mask (CMK) data of INSAT-3D geostationary satellite Imager instrument is used to estimate cloud cover amount (CCA) over the Indian longitudes at every half hourly interval on a 0.5° longitude × 0.5° latitude grid. CCA estimated from INSAT-3D CMK Imager is used to study the intra-seasonal (30-60 days) variability (ISV) of the Indian summer monsoon during 2014 – 2016 and compared it with ISV of the MODIS CCA data. Morlet wavelet transform is applied to INSAT-3D CCA data to delineate the ISV embedded in the summer monsoon cloudiness. Morlet wavelet analysis suggests that CCA from both INSAT-3D and MODIS exhibit ISV with 30-60 days periodicity along with high frequency periodicities (lower than 30 days period). Both INSAT-3D and MODIS exhibit similar type of ISV and high frequency variability during the three-year study period. Results from this study suggest that the INSAT-3D CCA data is able to capture the known characteristic variability of the Indian summer monsoon well and hence it can be used for scientific study with confidence.

Keywords: *Cloud cover amount; INSAT-3D; Wavelet Transform, Indian Monsoon, Intra-seasonal variability*

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INTRODUCTION

Clouds play an important role in modulating the radiation and water balances of the earth-atmosphere system [7, 3]. Clouds reflect a part of the incoming shortwave solar radiation back to space and thereby cool the earth atmosphere system. On the other hand, clouds trap a part of the outgoing terrestrial long wave flux from escaping to space and warm the system [5]. Rainfall from clouds is an important component of earth's water budget. Year-to-year variability in cloud cover and associated rainfall variability influences the water availability over any land region. Thus by modulating radiation and water balances, clouds become a potential influencing factor of climate. Because of the dominating role played by clouds in climate, cloud cover has been extensively studied world over. Studies suggest that minor changes in cloud cover may lead to a major change in the climate system [2]. Hence cloud cover has been monitored continuously. Besides climate monitoring, cloud cover data have been widely used to evaluate and parameterize weather and climate models.

Conventional meteorological observatories world over report visual estimates of cloud cover in 'Okta' scale. But these observations are generally limited to global land regions. Satellites can provide cloud cover information over both land and oceanic regions. Typically, geostationary meteorological satellites provide cloud cover observations at every half hourly interval whereas polar orbiting satellites typically provide twice daily observations over an area. Cloud Cover Fraction (CCF) is defined as the fractional area covered by clouds to the total area in a particular grid observed by a satellite. Long and continuous CCF data with high spatial and temporal resolution are currently unavailable over Indian sub-continent and oceans surrounding it. Such availability may lead to a better understanding of meteorological process that govern the weather and climate of this region such as summer and winter monsoons, tropical cyclones, meso-scale convective systems, thunderstorms, etc., and their variability in different (diurnal to annual) time scales.

In this study, cloud cover amount (CCA) is estimated at half degree lat./lon. gird using INSAT-3D cloud mask (CMK) data available at pixel level (4 km) at every half hourly interval. CCA data is used to study the Indian summer monsoon cloudiness and its variability during three years (2014-2016) of INSAT-3D operation.

MATERIAL AND METHODS

INSAT-3D is an advanced meteorological satellite designed and developed by Indian Space Research Organisation. It was launched into a geostationary orbit by an Airane rocket from French Guiana, India on 26 July 2013. It is a part of a series of multipurpose geostationary satellites to cater the meteorological, search and rescue needs of India. INSAT-3D consists of two instruments for meteorological observations viz., a 6-channel Imager and a 19-channel Sounder. CMK data is generated using INSAT-3D radiance and reflectance measurements from Thermal Infra-Red-1 (10.3 - 11.3 μm; TIR-1), Thermal Infra-Red-2 (11.3 - 12.5 μm; TIR-2) and Mid Infra-Red (3.70 - 3.95 μm; MIR) channels of Imager instrument. Brightness temperature threshold, brightness temperature difference, spatial variability test, and temporal uniformity test are used in the CMK retrieval algorithm. Further details of the INSAT-3D CMK product can be obtained from Pal *et.al* [6].

The INSAT-3D CMK data is available at a 4-km horizontal resolution at every half hourly interval. INSAT-3D CMK data suggest, whether a region is cloudy or not? Value of CMK may be any of the following four sky conditions over any location. They are:

(i) Clear sky
(ii) Cloudy sky
(iii) Probably clear sky and
(iv) Probably cloudy sky

CCF is calculated at 0.5-degree lat. / lon. resolution using the following method:

$$\mathbf{CCF} = \left(\frac{N_{cloudy} + N_{Probably\ cloudy}}{N_{Total}}\right) \ldots (1)$$

Where,

N_{cloudy} = Number of cloudy pixels,

$N_{Probably\ cloudy}$ = Number of probably cloudy pixels and

N_{Total} = Total number of pixels [Clear sky, Cloudy sky, Probably Clear sky and Probably Cloudy sky]

CCF is multiplied by hundred to obtain CCA. MODIS is flying onboard EOS Terra satellite with equatorial crossing times at 10:30 and 22:30 local time [1]. In the present study, MODIS Terra CCF data are used.

RESULTS AND DISCUSSION

Cloud Cover Variability

The standard deviation of INSAT-3D derived CCA for pre-monsoon, monsoon, post-monsoon and winter seasons are computed using the daily average CCA data of the three year (2014 -2016) study period. Day and night time CCA data are averaged to get the daily mean CCA data (fig.1 a-d). Overall, standard deviation is less over the persistently cloudy and persistently cloud-free regions on each season. Region of high standard deviation is spread over larger areas during pre-monsoon and winter seasons when compared to monsoon and post-monsoon seasons. In monsoon season, Cloud cover variability is more over the Arabian sea and equatorial Indian region. In post-monsoon season, cloud cover variability is more over Bay of Bengal and Equatorial Indian ocean. The northward propagating 30-60 days intra-seasonal variability and eastward propagating Madden-Julian oscillation may be the cause behind the high cloud cover variability in monsoon and post-monsoon seasons.High cloud cover variability over the northwestern part the study region in winter and pre-monsoon seasons is due to the repeated arrival of western disturbances over the region.

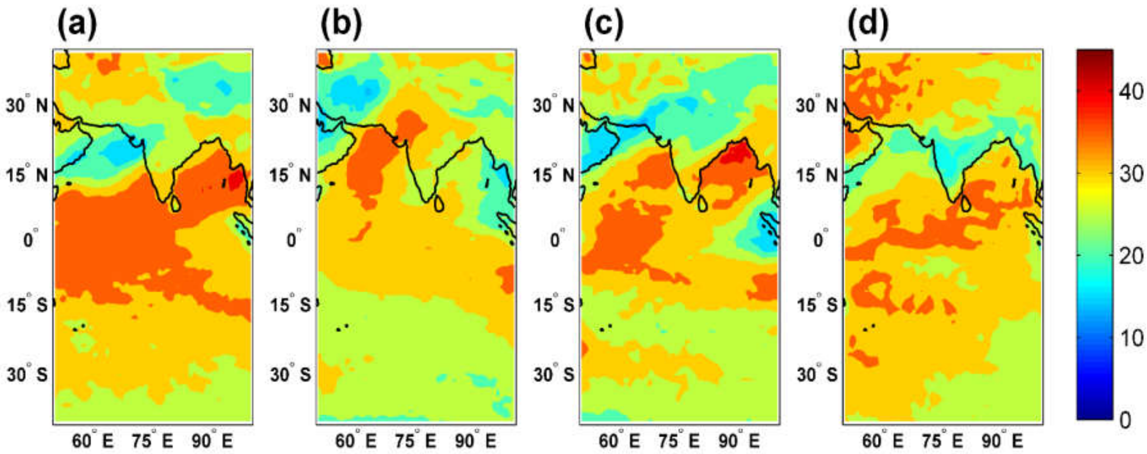

Figure 1 Standard deviation of CCA (%) during 2014 - 2016 for (a) pre-monsoon, (b) monsoon, (c) post-monsoon and (d) winter seasons obtained using daily mean CCA data.

Summer Monsoon Intra-Seasonal Variability in INSAT-3D Derived CCA data

It is well known that Indian summer monsoon exhibits intra-seasonal (30-60 days) variability in rainfall, cloudiness, wind and other meteorological parameters. This intra-seasonal variability is associated with the northward propagation of inter tropical convergence zone on 30-60 days time scale.

This oscillation appears to be related to the occurrence of active and break monsoon conditions over the Indian monsoon region. In this section, attempt is made to study the intra-seasonal variability of the Indian summer monsoon clouds using a time series analysis technique. For the analysis, the CCA is averaged over a 5^0 latitudes × 10^0 longitudes box (20-25 ^{0}N, 70-80^0 E) over the central core monsoon region during 120 days of monsoon season. The cloud cover data of 0300, 0600, 0900, 1500, 1800 and 2100 UTCs are averaged and daily means are computed for the years 2014 to 2016.

In fig.2 (a-c), time series of area averaged daily mean CCA computed from INSAT-3D and MODIS Terra for 2014, 2015 and 2016 are shown respectively during the monsoon season. The INSAT-3D and MODIS CCA shows coherent variabilities of different time periods during the monsoon season. These variabilities are marked with increased cloud cover during sometimes and decreased CCA during some other times. But the day to day variability is synchronized in both INSAT-3D and MODIS.

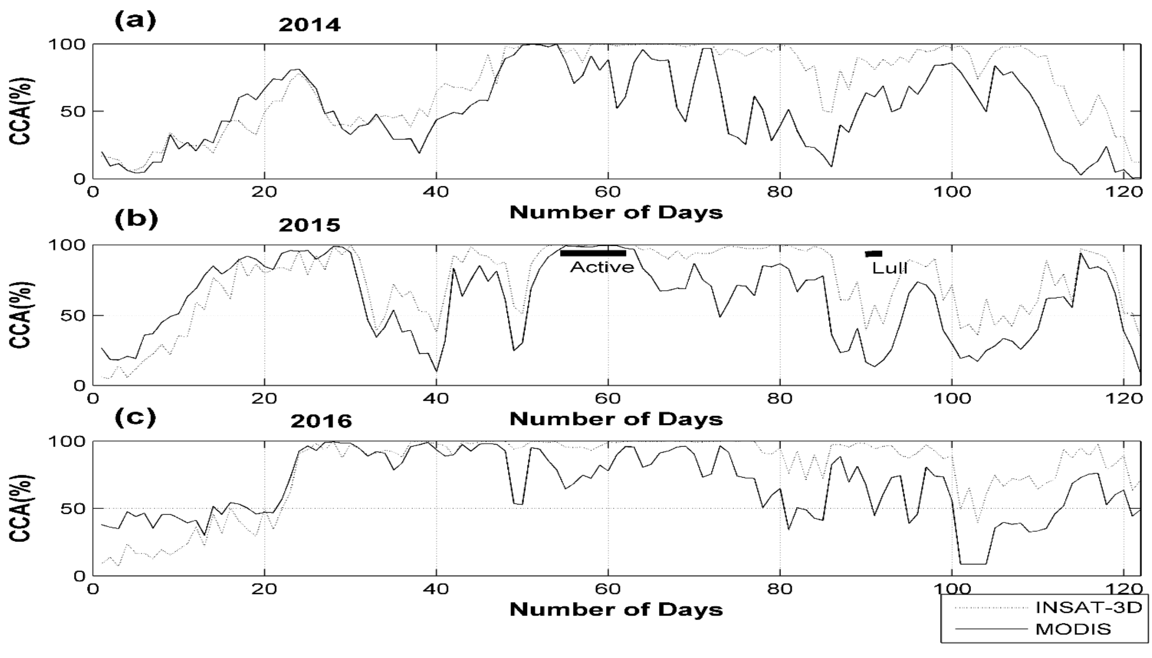

Figure 2 Time series of CCA (%), area averaged over 20-25 ^{0}N, 70-80^0 E in the core monsoon region during the monsoon season of (a) 2014 (b) 2015 and (c) 2016. Active and Lull periods considered for the further analysis are marked in Figure 2 (b)

To study the intra-seasonal time scale variability's embedded in these time series, Morlet wavelet transform is applied (see fig.3 (a-f)) The Morlet wavelet transform is a powerful tool to find out the multi-frequency non-stationary powers present in a time series [4][8]. The wavelet transform decomposes a 1-D CCA time series into a 2-D time-frequency representation [9]. The Morlet wavelet analysis suggests that the CCA fluctuates on intra-seasonal time scale with periods ranging between 30-60 days in all the three years. The intra-seasonal variability exhibits year to year variability in its period. It is interesting to note that the intra-seasonal variability in both INSAT-3D and MODIS match well. But amplitude of the intra-seasonal variability is more in case of INSAT-3D CCA than MODIS CCA as the variability in INSAT-3D CCA time series is more than MODIS CCA time series. The 30-60 days periodicity is due to the northward propagation of intra tropical conversion zone. In 2014 the time period of the 30-60 days variability appears to be nearly constant throughout the season. But this 30-60 day periodicity is slightly disturbed during mid-July to Mid-August in 2015. Besides this intra-seasonal variability, CCA exhibits irregular high frequency variabilities, possibly caused by the movement of pressure depressions over the region. Also the wavelet analysis clearly shows the scale interactions taking place between 30-60 days variability and high frequency variabilities. Cloud cover is maximum whenever these two oscillations are in positive phase(e.g. In 16 June 2014) and CCA is minimum when these two oscillations are in negative phase (e.g. 16 August 2014) or out of phase.

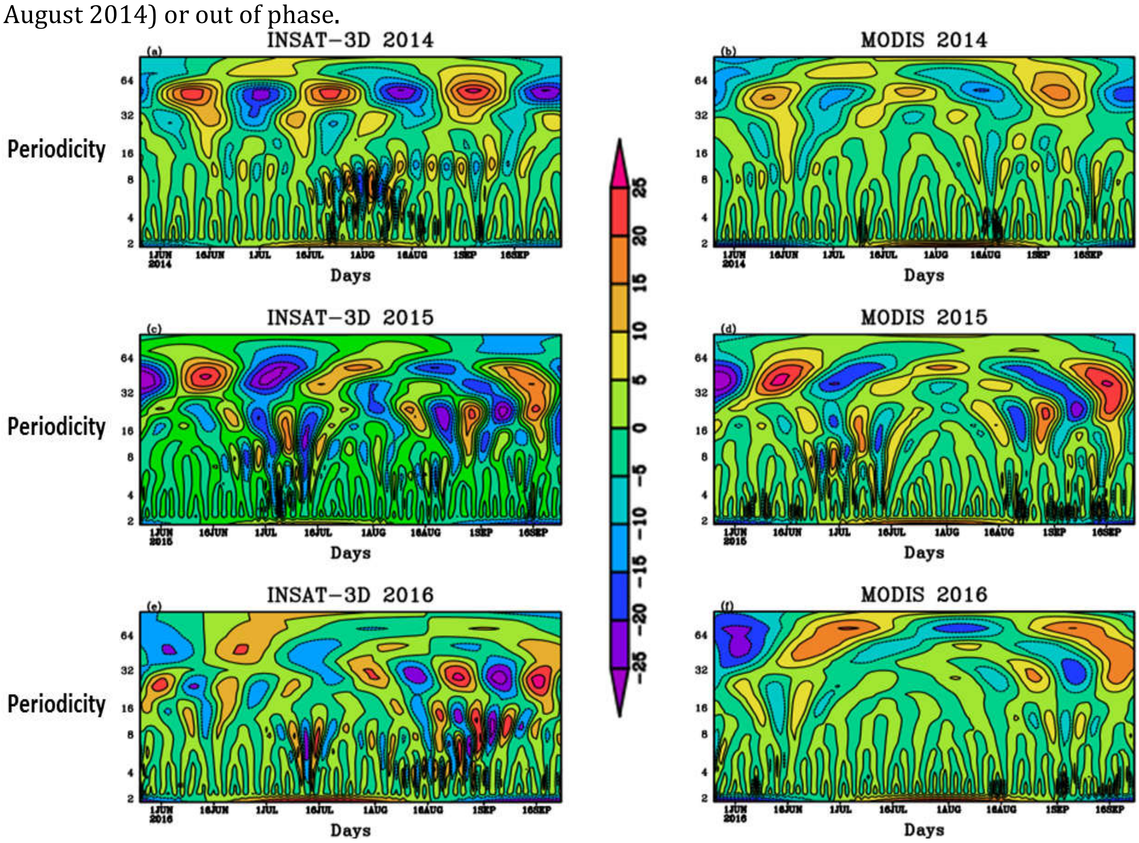

Figure3 Wavelet analysis of area averaged daily MODIS CCA (%) shown inFigure3 during monsoon season of (a) 2014, (b) 2015 and (c) 2016

CCA during Active and Lull phases of Monsoon

To find out the changes taking place in CCA between active and lull phases of Indian monsoon, daily CCA averaged during an active phase (20-25 July 2015) and a lull phase of (23-25 August 2015) monsoon season are shown in fig. 4. The active and lull phases are indicated in fig.2b. CCA lower than 50% is considered as lull phase and CCA close to 100% is considered as active phase.

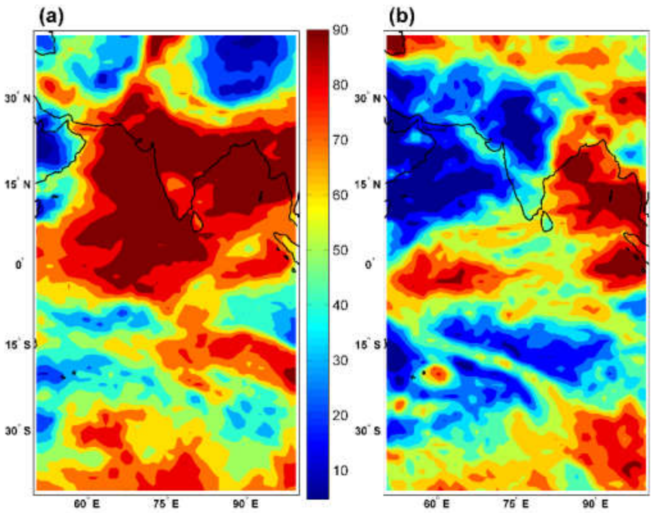

Figure 4 CCA (%) during (a) Active (20 to 25 July 2015) and (b) Lull (23 to 25 August 2015) phases of 2015 monsoon season (marked in Figure 2b)

During the active phase, cloud cover amount is more than 70% over most parts of India, Bay of Bengal and Arabian sea. But CCA is less over the east equatorial Indian ocean. On the other hand, CCA is less than 50% over most parts of Indian land region except the north east part and Arabian sea. Cloud cover amount is more over the east equatorial Indian ocean. This typical case study shows the drastic changes occur in the amount of cloudiness over the Indian monsoon region between active and lull monsoon phases.

Northward propagation of CCA over the Indian region

As mentioned earlier, Indian monsoon clouds originate over the warm equatorial Indian ocean and repeatedly propagate northward towards the monsoon trough region. Such propagations occur with a repetevity of 30-60 days. To examine the northward propagation in INSAT-3D CCA data, Hovmoller (time-latitude) plots are generated along 80°E longitude for 2014, 2015 and 2016 monsoon seasons (fig.5). From the Hovmoller plot it is clear that northward propagation starts from about 10°S latitude and goes as far as 30°N over the Indian region. Clear cases of northward propagation are marked with straight lines in fig. 5. This figure clearly suggests that northward propagation is captured well by the INSAT-3D CCA date.

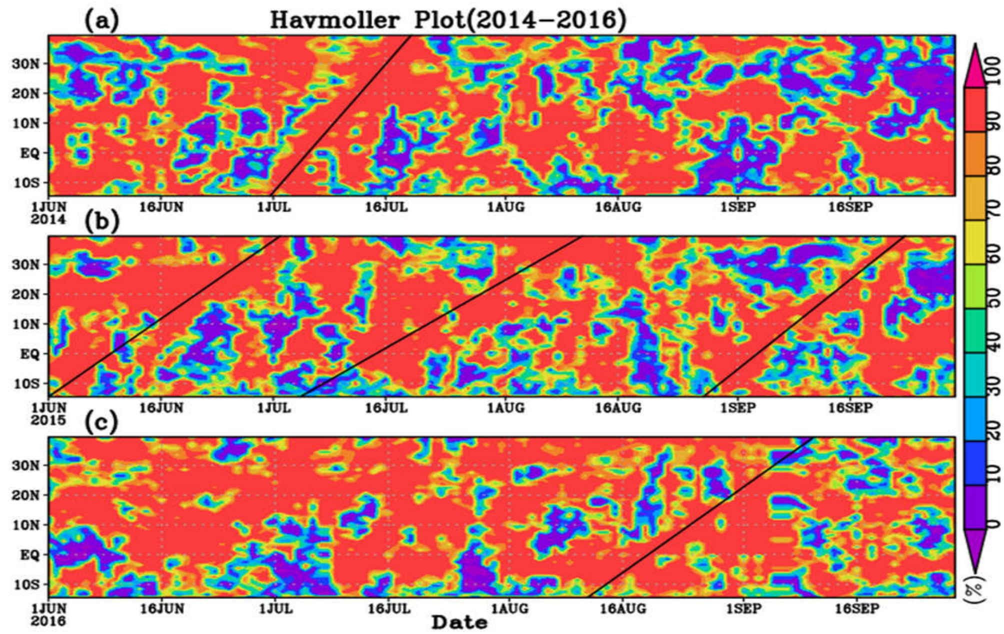

Figure 5 Havmoller (Time - Latitude) plot of INSAT-3D CCA (%) for (a) 2014, (b) 2015 and (c) 2016 along 80^0 E.

CONCLUSIONS

In this paper CCF is estimated using CMK data of INSAT-3D during 2014-2016 at a spatial resolution of 0.5° longitude × 0.5° latitude. The Morlet wavelet transform was applied to INSAT-3D and MODIS data to study the intra-seasonal and high frequency variabilities over the Indian region. INSAT-3D CCA captures all the known variabilities of the Indian monsoon and they compare well with variabilities shown by MODIS data.

The abrupt changes in CCA between active and lull phases of the Indian summer monsoon are captured well by the INSAT-3D CCA data. Also it captures the northward propagation of cloudiness on intra-seasonal time-scale. This study clearly demonstrates that the INSAT-3D derived CCA can be used for the scientific studies with confidence.

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REFERENCES

1. Ackerman, S A; Strabala, K I; Menzel, W P; Frey, R A; Moeller, C C; Gumley, L E. (1998). Discriminating clear sky from clouds with MODIS. *Journal of Geophysics , 103*, 32141-32157.
2. Coakley Jr., J. A., and F. P. Bretherton. (1982). Cloud cover from high-resolution scanner data: Detecting and allowing for partially filled fields of view. *Journal of Geophysics , 87(C7)*, 4917–4932.
3. GOSWAMI B. N AND AJAYA MOHAN R. S. (2001). Intraseasonal Oscillations and Interannual Variability of the Indian Summer Monsoon. *Journal of Climate , 14*, 1180.
4. Kiladis, G. N., & Diaz, H. F. (1989). Global climatic anomalies associated with extremes in the southern oscillation. *JournalofClimate , 2*, 1069–1090.
5. Mahakur M, Prabhu A, Sharma A. K. , Rao V. R, Senroy S, Singh Randhir and Goswami B. N. (2013). A high-resolution outgoing longwave radiation dataset from Kalpana-1 satellite during 2004–2012. *CURRENT SCIENCE , 105*.
6. Pal P.K, Shah Shivani. (May 2015). *Cloud Mask Baseline Document, INSAT-3D ATBD.* Ahmedabad: SAC.
7. Rossow, W. B. and L. C. Garder. (1993). Comparison of ISCCP and other cloud amounts. *Journal of Climate , 6*, 2394–2418.
8. Schiff, S. (1992). Resolving time-series structure with a controlled wavelet transform. *Optical Engineering , 31(1)*, 2492–2495.
9. Yokoi, S., & Satomura, T. (2005). An observational study of intraseasonal variations over southeast Asia during the 1998 rainy season. *Monthly Weather Review , 133*, 2091-2104.

