ISCCP observed Mid-level Clouds and its relationship with Indian Summer Monsoon Rainfall

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1. Introduction

One of the main factors significantly influencing socioeconomic development in India is the Summer Monsoon Rainfall (ISMR) (Gadgil, 2003), which is precipitation averaged over the country during the summer monsoon season (June–September, JJAS). Distributions of cloud type, which make up nearly two thirds of the earth's surface, are responsible for widespread rainfall. Clouds are typically produced over warm and moist regions with the assistance of atmospheric motions. The vertical structure of the clouds is particularly indicative of the motions producing the clouds and associated rainfall (Rossow and Schiffer, 1999). The International Satellite Cloud Climatology Project (ISCCP) has been used in the past to investigate the effects of external remote influences on cloud dispersion and summer monsoon rainfall over India (Prabhu et al., 2018). In this study, seasonal climatology of mid-level cloud amount across various seasons over the Indian region has been observed. Further, its temporal variability, both on interannual and decadal timescales, over the Indian region has been evaluated during summer monsoon season (June through September - JJAS). Furthermore, the importance of mid-level clouds on summer monsoon rainfall over India is assessed using spatial correlation analysis.

2. Data

ISCCP D2 data has been utilised for the period 1984-2009 for observing the distribution of large-scale mid-level cloud features. The seasonal climatology of cloud amount (%), which represents the fractional area covered by clouds, is developed for the boreal seasons, defined as spring [March-May (MAM)], summer [June-September (JJAS)], autumn [October-November (ON)] and winter [December-February (DJF)]. As per ISCCP cloud classification (Rossow and Schiffer, 1999), mid-level clouds are estimated from the cloud top pressure, which is in the range of 680 to 440 hPa, while the cloud optical thickness is in the range of 0–379. The cloud amount estimation is done by evaluating each pixel of 5 km across for a particular level by counting the number of pixels that are marked as cloudy and dividing by the total number of pixels in a region of about 280 km across (http://isccp.giss.nasa.gov/products/products.html). Rainfall (mm) data at 0.25° x 0.25° latitude-longitude spatial resolution, which has been constructed from a well distributed rain gauge network over the Indian region, is acquired from India Meteorological Department (IMD) (Pai et al., 2014). Statistical trend for the inter-annual time series of mid-level cloud amount index constructed by averaging over the Indian region [8°-38°N, 68°-98°E] during the period 1984-2009 is examined by using a standard *F* test statistic that assesses the null hypothesis of zero slopes (Kendall and Stuart, 1979). Additionally, gridded correlation coefficients (cc) are computed to determine the spatial relationship between the standardised series of mid-level clouds and rainfall at each grid for the above period, and verified for its significance at 95% confidence level employing student's T test statistic (Kendall and Stuart, 1979).

3. Results

Following inferences are drawn considering the connection between ISCCP's mid-level clouds and summer monsoon rainfall over India as shown in Figure 1:

1) The seasonal climatology of mid-level clouds over the tropical longitudes depicts larger magnitude of cloud amount (%) over the land as compared to ocean across all the seasons (Fig. 1, Set I (a,b,c,d)). However, over the Indian region, maximum values of cloud amount for mid-level clouds are observed during summer monsoon season (JJAS) (Fig. 1, Set I (b)).

2) An increasing trend in standardised time series of mid-level cloud amount index is observed over the period 1984-2009, which is significant at 95% confidence level. Decadal analysis shows two epochal periods, with below (above) normal years of cloud amount during pre (post) 1997 era.

3) Further, spatial distribution of correlation between detrended standardised mid-level clouds averaged over the Indian domain with that of detrended IMD rainfall at each grid level depicts larger spread of positive relationship between the two, covering the states of Gujarat, Maharashtra and Andhra Pradesh, implying excessive summer monsoon rainfall over these Indian regions for larger distribution of mid-level clouds.

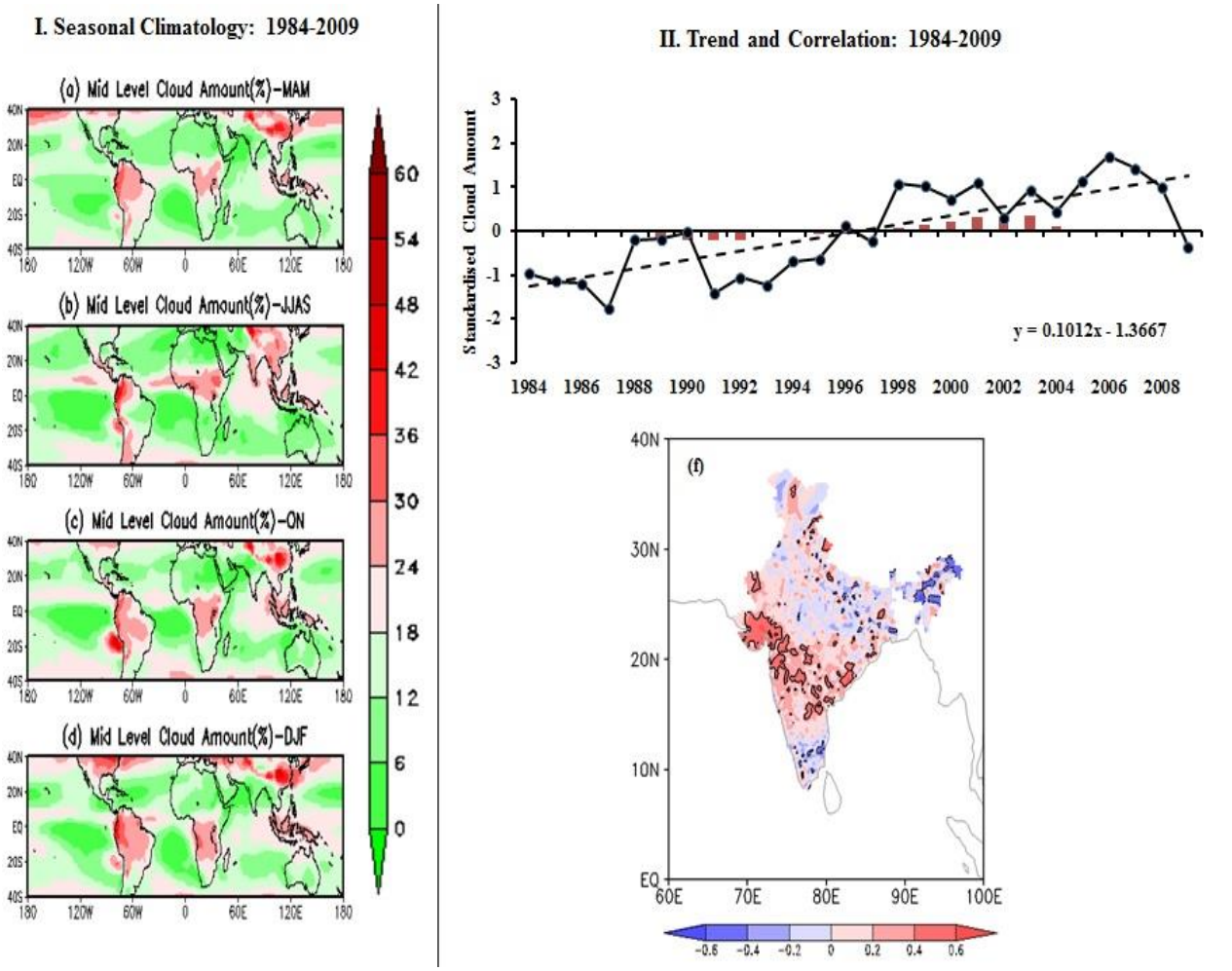

Figure 1. Set I. Seasonal Climatology of mid-level cloud amount (%) constructed over the period 1984-2009 for the seasons (a) MAM, (b) JJAS), (c) ON, and (d) DJF; Set II. (e) Inter-annual (decadal) time series in black (maroon) line (bar) for mid-level cloud amount index averaged over the Indian region [8°-38°N, 68°-98°E] during the period 1984-2009, wherein dotted line indicates trend. (f) Spatial Correlation of detrended standardised mid-level cloud amount index (JJAS) with that of detrended standardised rainfall at each grid point over the Indian region are shaded, while contours in black indicate correlations significant at 95% confidence level.

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