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SEASONAL BEHAVIOR OF THE CLOUD RADIATIVE FORCING AND ITS ASSOCIATION WITH THE INDIAN SUMMER MONSOON

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1. Introduction

Cloud Radiative Forcings (CRFs) is an important part of the energy flow of the earth-atmosphere system. They exert both cooling effect on the surface by reflecting shortwave radiation back into space and a warming effect by trapping longwave radiation emitted from the earth's surface. CRFs at the top of the atmosphere is defined as the difference between the radiative fluxes (shortwave and longwave) with and without clouds. Earlier studies demonstrated that the El Niño event affect the top of the atmosphere CRFs in the Pacific Ocean (Allan *et al* 2002; Cess *et al* 2001). These studies had focused their attention on the warm pool of the west Pacific and not on the Indian region. It is well known that during El Niño event Indian monsoon activity is also affected. It is not clear whether the CRFs undergoes major changes during the drought monsoon year associated with the El Niño event over the region. The SST anomalies cause large CRFs anomalies, both longwave and shortwave, as well as the longwave anomaly strongly enhances the precipitation anomaly in the whole tropical belt also found (Chen *et al* 1995). Patil and Yadav *(*2005) have also been noticed that there is a strong association between AISMR and CRFs during July using five years 1985-89 ERBE (Earth Radiation Budget Experiment) dataset. All-India Summer Monsoon Rainfall (AISMR) during the four months from June to September contributes about 80-90% of the total annual rainfall. The search for new parameters for predicting the AISMR has been an important aspect of long range prediction of AISMR. Extensive research work has been done on seasonal forecasting of Indian summer monsoon rainfall. Some of the noteworthy studies are Gowariker *et al* (1989,1991); Munot and Krishna Kumar (2007). There is a need to examine other factors too, for example, cloud radiative forcing, that contribute to monsoon variability because SST is not the only factor that determines monsoon. In view of this, an attempt have been made in the present study to show the association between AISMR and CRFs over the Indian region (0-30^{0}N and 60-120^{0}E) during winter (DJF), pre-monsoon (MAM) and summer monsoon (JJAS) seasons using NCEP/NCAR CRFs reanalysis data for the period 1949-2006.

2. Data

Monthly mean CRFs (longwave and shortwave) at the top of the atmosphere are available in the NCEP/NCAR reanalysis data at 2.5^0 x 2.5^0 lat/long grid resolution, (http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP-NCAR/.CDAS1/MONTHLY, Kalnay *et al* 1996). We have considered 58 years data (1949-2006) of the longwave and shortwave CRFs and computed their simple airthmatic averages, anomalies and correlation co-efficient with the AISMR during winter (DJF), pre-monsoon (MAM) and summer monsoon (JJAS) seasons over the Indian region (0-30^{0}N and 60-120^{0}E). Monthly mean rainfall data for the period 1949-2006 which is used in the study is available on IITM website http://www.tropmet.res.in.

3. Results and conclusions

We have computed the Correlation coefficients (CC) between AISMR and CRFs (shortwave and longwave) for each of the grid over Indian region (0-30^{0}N, 60-120^{0}E) during 1949-2006 for winter (DJF), pre-monsoon (MAM) and summer monsoon (JJAS) seasons to bring out the spatial pattern of the CC is presented in figure 1. Highly significant CC between AISMR and CRFs are observed over the Bay of Bengal region (15-20^{0}N and 87.5-92.5^{0}E) particularly during pre-monsoon season (MAM) that show a predictive signal and strong positive/negative relationship between longwave/shortwave CRFs. During summer monsoon season (JJAS) significant CC is more pronounced in the entire study region due to deep convection. Figure 2 shows the time series of the AISMR and shortwave/longwave CRFs during 1949-2006 for the pre-monsoon season (MAM) over the Bay of Bengal region (15-20^{0}N and 87.5-92.5^{0}E). It is revealed from the figure 2 that the year-to-year variability of rainfall and CRFs as well as CC between AISMR and longwave CRF is 0.419 (significant at 1% level) and shortwave CRF is -0.415 (significant at 1% level) are observed. The high correlations between CRFs terms and AISMR during MAM confirms the significant relationship between them. Thus, the longwave/shortwave CRFs appears to play an important role in the pre-monsoon season and may have the potential for prediction of monsoon rainfall.

We have also computed the CRFs values during excess and deficient monsoon years to bring out the contrasting features during MAM over the Bay of Bengal region, if any. There are 8 excess and 13 deficient years during the period 1949-2006 as identified by (Parthasarathy *et. al* 1994). Noticeable differences are observed between mean CRFs in the excess and deficient monsoon years which shows the contrasting behavior. The difference between eight excess and thirteen deficient years, are tested for significance by t-test for shortwave as well as longwave CRFs. The numerical t value for shortwave CRF is 2.64 (significant at 2% level) and for longwave CRF is 2.89 (significant at 1% level) which support highly significant relationship between rainfall and shortwave/longwave CRFs.

The spatial pattern of the composite excess-deficient years anomalies of the CRF (Figure not shown) has also been brought out. The composite anomalies of longwave CRF are strongly positive over the Bay of Bengal region which strongly support the strong positive relationship between AISMR and longwave CRF as revealed by figure 1. The composite anomalies of shortwave CRF are strongly negative over the Bay of Bengal region which are in accordance with the negative relationship between AISMR and shortwave CRF as seen in figure 1. Hence, this relationship is very well supported by composite anomalies and show in phase relation with the spatial pattern of CC.

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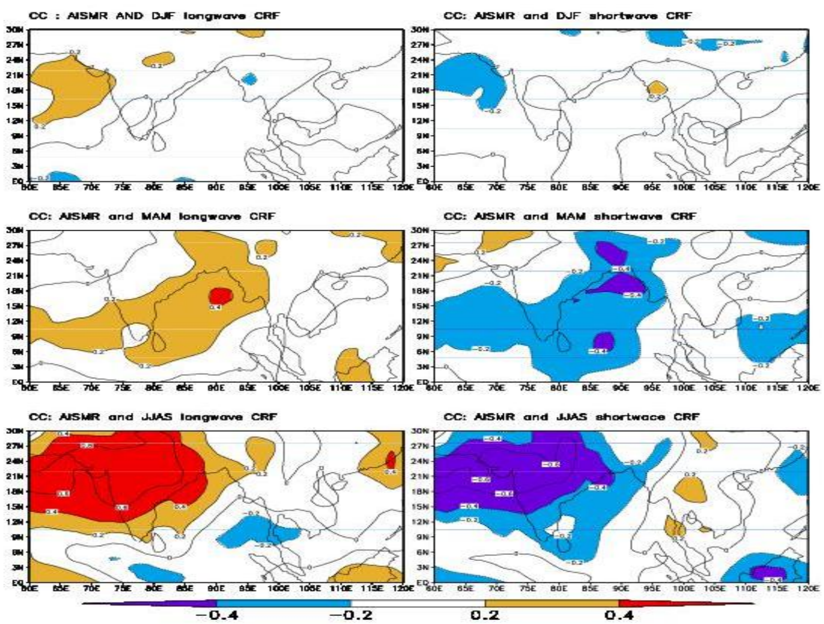

Figure 1 : CC between AISMR and longwave/shortwave CRFs during DJF, MAM and JJAS

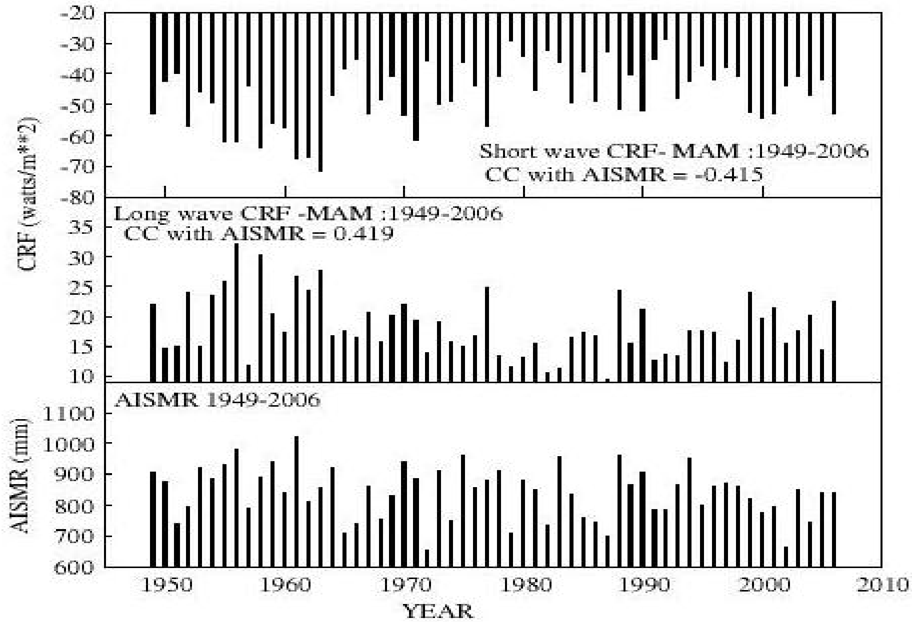

Figure 2 : Time series of AISMR and shortwave/longwave CRFs during MAM