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Decadal and epochal variation of frequency and duration of monsoon disturbances and their secular relationship with rainfall over India

J. RAJENDRA KUMAR, V. THAPLIYAL* and S. K. DASH**

India Meteorological Department, New Delhi - 110 003, India

**India Meteorological Department, Pune - 411 005, India*

***Indian Institute of Technology, New Delhi - 110 016, India*

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सार – इस शोध–पत्र में 110 वर्षों (1890–1999) के आँकडों की सहायता से भारतीय क्षेत्रों में निम्न दाब क्षेत्र और चक्रवातीय तूफान जैसे मानसून विक्षोभों की आवृति और अवधि में दशकीय और कालिक परिवर्तन का अध्ययन किया गया है। 110 वर्षों की अवधि के दौरान उनकी किसी भी आवृति के समय रैखिकीय प्रवृति में घट/बढ़ नहीं होती देखी गई है। तथापि मानसून के विभिन्न विक्षोभों के दौरान दशकीय आवृतिताओं अथवा अवधियों में कालिक रैखिकीय प्रवृतियों में घट/बढ़ देखी गई है। हाल ही में समाप्त हुए 1990 से 1999 तक के दशक तक अवदाबों की दशकीय आवृतियाँ, चक्रवाती तूफान और अवदाब 1970–79 से कम हो रहे हैं। वर्ष 1970–79 के दशक की तुलना में हाल ही के दशक में अवदाबों ओर चक्रवातीय तूफानों की कुल संख्या के आधे से भी कम अवदाब और चक्रवातीय तूफान बने हैं। वहीं दूसरी और जब 1960 से 1969 के दशक के दौरान बने निम्न दाब क्षेत्रों की संख्या दोगुनी से अधिक होती है, 1960 से लेकर 1969 के दशक से लेकर हाल ही के दशक तक निम्न दाब क्षेत्रों की कुल संख्या में विशेष रूप से बढ़ोतरी हो रही है।

चूँकि भारतीय ग्रीष्मकालीन मानसून वर्षा सामान्य से कम और सामान्य अवस्थाओं से ऊपर अंतरदशकीय विविधता भी दर्शाती है, अतः विभिन्न मानसून विक्षोभों की बारम्बारताओं में विविधता और उनकी कुल अवधियों की समान समयक्रम की जाँच, भारतीय ग्रीष्मकालीन मानसून की अंतदशकीय परिवर्तनशीलता के साथ उनके संबंध का पता लगाने के लिए की गई है। 1890 से लेकर 1999 तक की अवधि के दशकीय तथा दस वर्ष के प्रभावी सहसंबंध गुणांक के आधार पर इन संबंधों के स्थायित्व और दीर्घकालिक प्रकृति की जाँच भी की गई है। भारतीय ग्रीष्मकालीन मानसून वर्षा के अंतः दशकीय विविधता के साथ उनकी बारम्बारताओं की दशकीय विसंगति के संबंध में यह पता चलता है कि भारतीय ग्रीष्मकालीन मानसून वर्षा सामान्य से अधिक वर्षा के दौरान अवदाब और चक्रवातीय तूफान की संख्या सामान्य से अधिक होती है और भारतीय ग्रीष्मकालीन मानसून वर्षा के दौरान वर्षा के सामान्य से कम रहने वाले दशकों के दौरान यह संख्या कम होती है। निम्न दाब क्षेत्रों की संख्या इससे ठीक विपरीत होती है। भारतीय ग्रीष्मकालीन मानसून वर्षा एवं विभिन्न मानसून विक्षोभों और मानसून के विक्षोभ वाले कुल दिनों के बीच दशकीय और दस वर्षों के दीर्घकालिक सहसंबद्ध गुणांक (सी.सी.) से ग्रीष्मकालीन मानसून वर्षा के साथ अंतः दशकीय समय मान में उनके संबंधों में स्पष्ट रूप से कालिक परिवर्तन का पता चलता है। अतः इस अध्ययन से यह पता चलता है कि सह संबंध गुणांक की दीर्घकालिक विविधता न केवल भारतीय ग्रीष्मकालीन मानसून वर्षा और भारतीय ग्रीष्मकालीन मानसून वर्षा के दीर्घकालिक पूर्वानुमान में प्रयुक्त होने वाले विभिन्न क्षेत्रीय और विश्वस्तरीय प्राचलों के बीच होती है बल्कि भारतीय ग्रीष्मकालीन मानसून वर्षा और उसकी मुख्य सिनॉप्टिक विशेषताओं जैसे कि मानसून विक्षोभों के बीच भी होती है।

ABSTRACT. Decadal and epochal variation of frequency and duration of monsoon disturbances like low pressure areas (lows), depressions and Cyclonic Storms (CS) over Indian region are studied by using 110 years (1890-1999) data. No linearly decreasing/increasing trend is observed during 110 years period in any of their frequencies. However, epochal linearly decreasing/increasing trends are noticed in decadal frequencies or duration of different monsoon disturbances. Decadal frequencies of depressions, CS and depressions are decreasing from 1970-79, till recently ended decade of 1990-99. During recent decade, less than half of the total number of depressions and CS are formed compared with 1970-79. On the other hand, total number of lows are increasing significantly from 1960-69 to recent decade, when more than double the number of lows of 1960-69 are formed.

Since Indian Summer Monsoon Rainfall (ISMR) also shows interdecadal variation of below normal and above normal phases, variation of frequencies of different monsoon disturbances and their total durations are also examined in similar time scale to understand their relationship with interdecadal variation of ISMR. Stability and secular nature of these relationships are also examined based on their decadal and 10-year moving Correlation Coefficients (CC) for the

period 1890-1999. Relationship of decadal anomaly of their frequencies with interdecadal variation of ISMR shows that number of depressions and CS, are higher than the normal during the above normal ISMR decades and less during the below normal decades of ISMR. Reverse is true for the number of lows. The decadal and 10-years moving CC between ISMR and frequencies of different monsoon disturbances and total monsoon disturbance days clearly show epochal variation of their relationship in interdecadal time scale with ISMR. Hence present study shows that secular variation of CC not only exists between ISMR and its various regional and global parameters used in long range forecast of ISMR but also between ISMR and its main synoptic features *e.g*., monsoon disturbances.

Key words – Cyclonic storms, Depressions, Lows and ISMR.

1. Introduction

Monsoon disturbances such as low pressure areas (lows), depressions and cyclonic storms (CS) which generally form over the Bay of Bengal and move westwards or westnorthwestwards along monsoon trough over Indian region, produce large amounts of rainfall (Rao, 1976). Meteorologists, both in India and abroad, have been trying to look into various aspects of these monsoon disturbances such as their intensification. structure, associated instabilities, westward movement, dissipation and their relation to Indian summer monsoon rainfall (ISMR). Mooley and Shukla (1989a) have studied 96 years of data (1888-1983) and found a good positive correlation with ISMR. Jenamani and Desai (1999) have studied influence of these monsoon disturbances on ISMR for 1987-96 and found that years of good ISMR are having higher number of such disturbance days compared with other years.

Thapliyal and Kulshrestha (1991) were first to indicate by quantitative analysis of past hundred years of data that ISMR has alternate epochs of above normal and below normal rainfall phases of unequal period. This is an important characteristic found by analysing 11-year running means of ISMR. In interdecadal time scale, similar results were also reported by many other authors (Parthasarathy *et al*., 1994; Thapliyal, 1997; Webster *et al*., 1998; Krishnamurthy and Goswami, 1998).

Updating the earlier series of ISMR, decadal means of ISMR have been prepared for past 110 years (1890-1999) and percentage departure of ISMR from normal are shown in Fig. 1. It is seen from the figure that ISMR was in below normal rainfall phases continuously for three decades in two epochs (*i.e*., from 1900-09 to 1920-29 and 1960-69 to 1980-89) while it was in above normal phase continuously for three decades in one epoch (*i.e*., 1930-39 to 1950-59). In the recent decade 1990-99, the ISMR appears to have entered in the above normal rainfall epoch. It is interesting to note that epochal pattern appeared towards the end of the last century.

Considering these decadal and epochal patterns an attempt is made here to study the interdecadal variation of frequencies of CS, depressions and lows and their durations in monsoon season over Indian region. To find out their trends and epochal variations and also variation of their relationship with ISMR, a detailed study has been carried out by using their decadal values. In addition, quantitative measures of relationship of ISMR with frequency of various monsoon disturbances and their total monsoon disturbance days have been carried out by analyzing their decadal correlations and decadal running correlation coefficients.

2. Data

Frequency of the number of CS (includes intensity of CS and above) and depressions for monsoon season over Indian region for the period 1890-1990, are collected from the "Tracks of depressions and storms in the Bay of Bengal and Arabian Sea" published by India Meteorological Department (IMD) (1979) and IMD (1996). Similar data for recent years (1991-99) are collected from India daily weather report and Monsoon Summaries prepared by the Office of the Deputy Director General of Meteorology (Weather Forecasting), IMD, Pune. However, for finding frequency of lows which are relatively weakly systems, no other documented data source except Mooley and Shukla (1987) is available readily for referring seasonal frequency of low pressure areas. Mooley and Shukla (1987) have prepared an exhaustive document of all monsoon disturbances which includes well marked lows and lows for Indian region and the area under consideration is 60° E to 100° E and 5° N to 35° N. This area includes north Indian Ocean and adjoining Indian sub-continent. Further, the data source of Mooley and Shukla (1987) is Indian Daily Weather Report for the period 1888-1983 published by IMD. This report is till now still remained as a very regular and standard publication for documenting details of all synoptic systems passing through or forming over Indian region. Surface charts with isobaric analysis of 0300 UTC for Indian region are also available in this daily IMD report and while finalizing the frequency or tracks of lows from these IMD source, respective authors have followed a stringent method. Details of such method are available in this report of Mooley and Shukla (1987) published by COLA USA and subsequently in an article published in

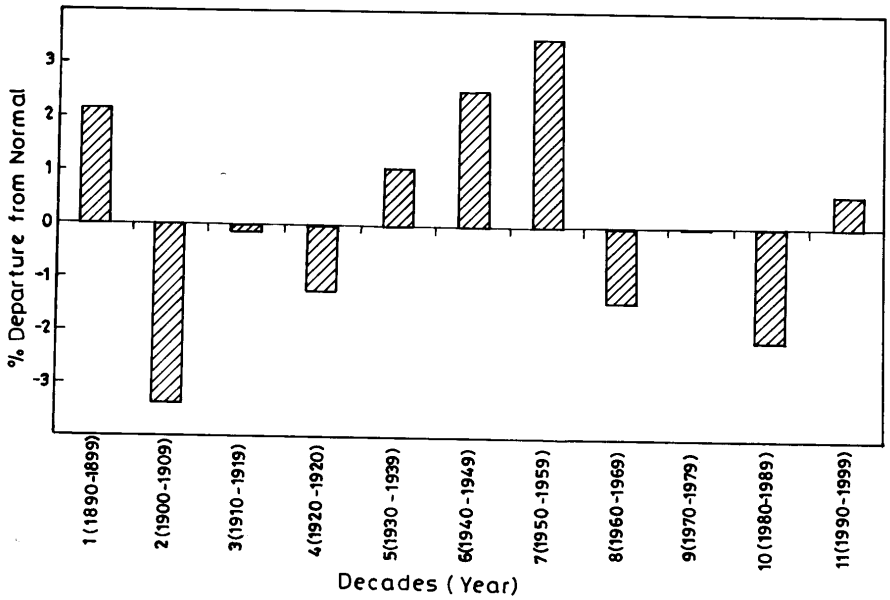

Fig. 1. Interdecadal variation of ISMR % departure from normal

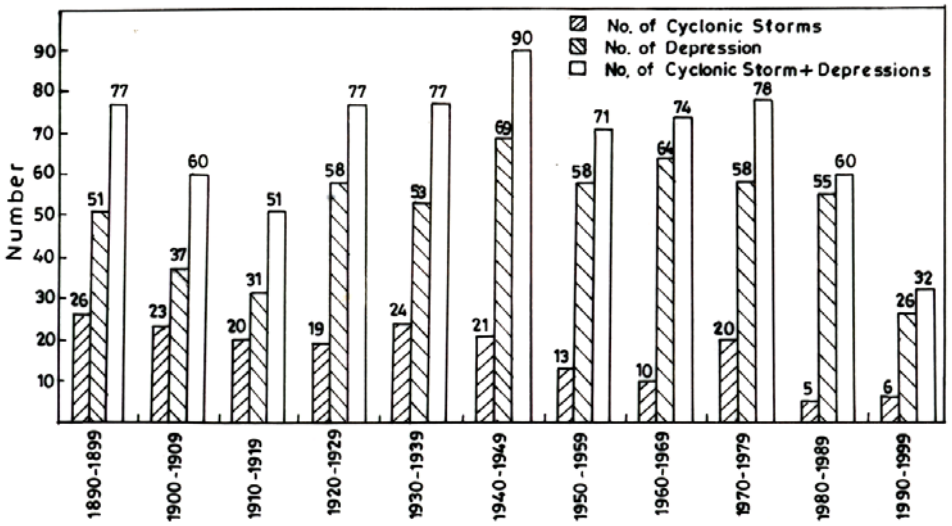

Fig. 2. Interdecadal variation of number (No.) of monsoon disturbances over India (CS, Depressions, CS + Depressions)

the journal "Mausam" by Mooley and Shukla (1989a). Since in Mooley and Shukla (1987), synoptic systems such as lows, depressions & CS which are not feeble and have life period of 2 days or more have been considered for counting their number and duration, we have only consider those monsoon disturbances including CS and depressions which has satisfied these conditions. Jenamani and Desai (1999) have also followed similar method while presenting their details statistics for 1987-1997. Present authors have followed such method while updating similar data from 1983 available in Mooley and Shukla (1987) to 1999 by going through different IMD publication as referred before to keep the homogeneity in the data set available with Mooley & Shukla (1987) particularly for

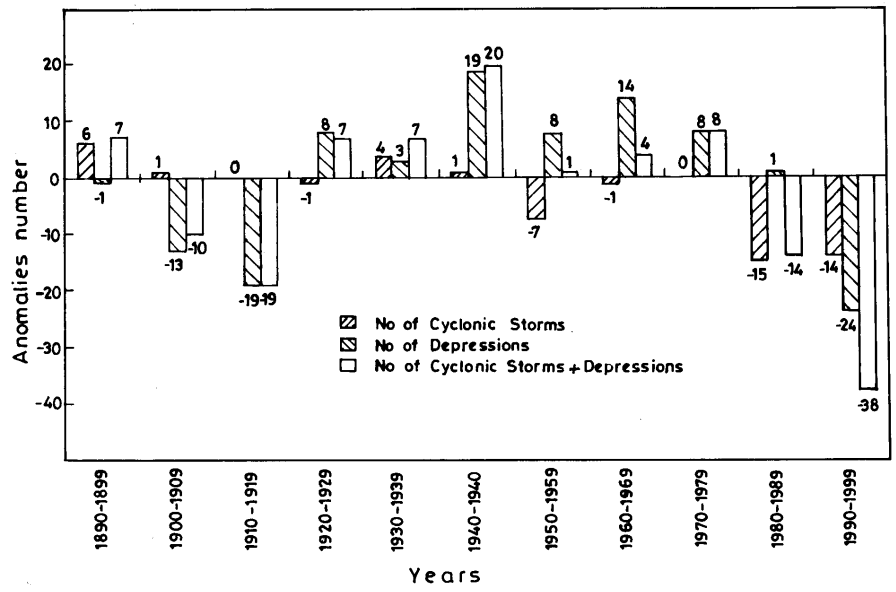

Fig. 3. Interdecadal variation of number (No.) of monsoon disturbances over India (CS, Depressions, CS + Depressions) and their anomalies

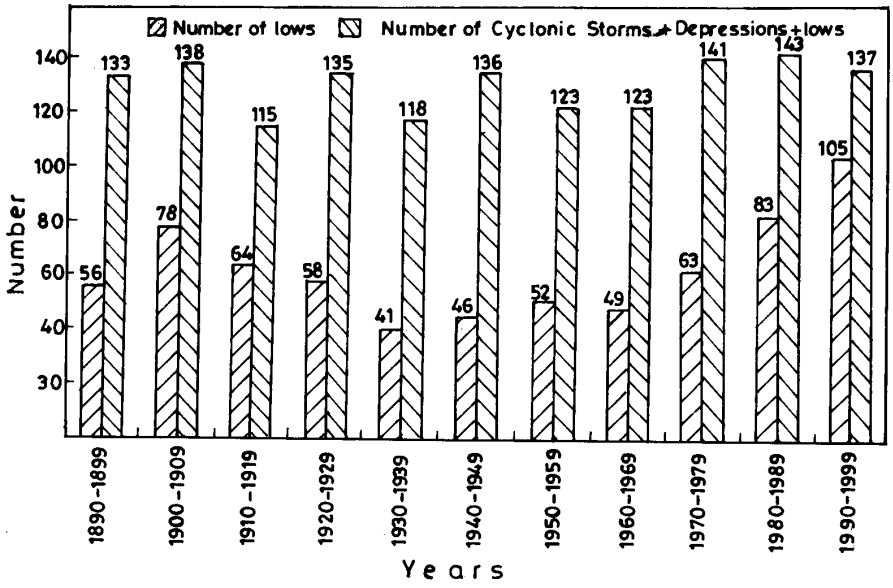

Fig. 4. Interdecadal variation of number (No.) of monsoon disturbances over India (lows, lows + Depressions + CS)

data related to frequency of lows and their durations. Hence the decadal frequency of different monsoon disturbances particularly CS and depressions found in the present study may differ significantly from other authors results *e.g.*, Singh (2001 & 2003) published before.

3. Methodology

First, frequencies of different monsoon disturbances namely CS, depressions and lows together or separately are computed year wise. Total duration of these systems is

also determined. For all these systems, decadal frequencies are calculated in the decadal time scale, which has been used for ISMR in Fig. 1. This has been done to facilitate comparison with ISMR decadal variation and also to study the relationship in different epochs of ISMR (*i.e.*, above and below normal rainfall epoch). From Fig. 1, it is seen that the 1st decade (1890-1899) is characterized by above normal ISMR. Then the 2nd decade (1900-09), 3rd decade (1910-19) and 4th decade (1920-29) are characterized by below normal ISMR. The 5th decade (1930-39), 6th decade (1940-49) and 7th decade (1950-59) are characterized by above normal ISMR. The 8th decade (1960-69), 9th decade (1970-79) and 10th decade (1980-89) are characterized by below normal ISMR. Finally in the last 11th decade (1990-99), the ISMR is found as above norma1. These decadal time scales are strictly followed in the present study for determining the epochal variation of characteristics of monsoon disturbances (frequency and duration) in decadal time scale along with their relationship with ISMR. Attempt is also made to study the pattern in relationship in interdecadal time scale during past 110 years (1890-1999). Association of frequencies of different monsoon disturbances and total monsoon disturbance days variation with ISMR are also studied by analysing decadal and 10 years running correlation coefficients. For this purpose, Thapliyal's (1997) updated series (as % departure from normal) of ISMR during 1890-1999 are used.

4. Decadal and epochal trends in frequency of monsoon disturbances

4.1. *Frequency of CS and depressions*

Decadal frequencies of CS, depressions and depressions and CS together are shown in Fig. 2. Anomalies of decadal frequencies of CS, depressions and CS together are shown in Fig. 3. On examining both the figures, no linearly decreasing/increasing trend is observed for the frequencies of these systems during 110 years. However, epochal linearly decreasing/increasing trends are noticed in all the 3 categories.

From Fig. 2, number of CS is maximum (26) in 1st decade (1890-99) and minimum (5) in 10th decade (1980-89). Decreasing trend in number of CS is noticed from 1st decade (1890-99) to 4th decade (1920-29) when their frequencies have decreased from 26 to 19. In subsequent 4th decades (5th to 8th), which covers 40 years period from 1930 to 1969, their frequencies again decreased from 24 to 10. However, the decreasing trend is more during the last 3rd decades because number of CS has been decreased from 20 during 9th decade (1970-79) to 5 in 10th decade (1980-89) and 6 in 11th decade (1990-99). Abrupt increasing tendency of number of CS is seen twice in the period. The first abrupt change is from fourth decade (1920-29) to 5th decade (1930-39) with significant increase of their number from 19 to 24. The second abrupt change is from 8th decade (1960-69) to 9th decade (1970-79) with significant increase of their numbers from 10 to 20. Similar pattern of variations is noted when anomalies of these different systems are studied from Fig. 3.

Number of depressions (Fig. 2) is maximum (69) in the 6th decade (1940-49) and minimum (26) in 11th decade (1990-99). Number of depressions also decreases initially from 1st decade (51) to 3rd decade (31) and then no regular trend is observed upto 7th decade. Afterwards it decreased from 8th decade (64) till presently ended 11th decade (26). But such decrease from the 10th decade to the present decade is very much high (55 to 26). During present decade, only 26 monsoon depressions are formed which is half the number in the earlier decade.

Number of CS and depressions together (Fig. 2) show almost similar decadal variation as have been reported above for CS and depressions separately. These two systems together have the highest decadal frequencies (90) during 6th decade (1940-49) and lowest frequencies (32) in the 11th decade. Fig. 2 also shows that decadal frequencies of CS and depressions have been decreased from 78 in 9th decade to 32 in the 11th decade which is less than half of the frequencies of 9th decade. On the basis of decadal variation of ISMR, it is found that 6th decade (1940-49) was above normal ISMR decade when highest number of intense disturbances formed.

4.2. *Frequency of lows, depressions and CS*

Figs. 4 and 5 shows decadal variation of number of lows alone and the total number of lows, depressions and CS and their anomalies respectively. None of their decadal frequencies shows linearly increasing/decreasing trend throughout past 110 years period. However, epochal linearly decreasing/increasing trends are noticed. From Fig. 4, frequency of lows is maximum (105) in 11th decade (1990-99) when minimum number of CS and depressions has formed. Minimum frequencies of lows (41) is noted in 5th decade (1930-39). Number of lows has decreased from 78 in the 2nd decade to 41 in the 5th decade and then almost an increasing trend is found till 11th decade. In this decade, their frequencies reached to 105, the highest during the entire 11 decades. During 5th decade (1930-39), the lowest number of lows (41) are formed, although the decadal ISMR is higher than normal. From Fig. 4 the total no. of lows, depressions and CS together has the highest frequencies of 143 in the 10th decade and lowest frequency of 115 in the 3rd decade.

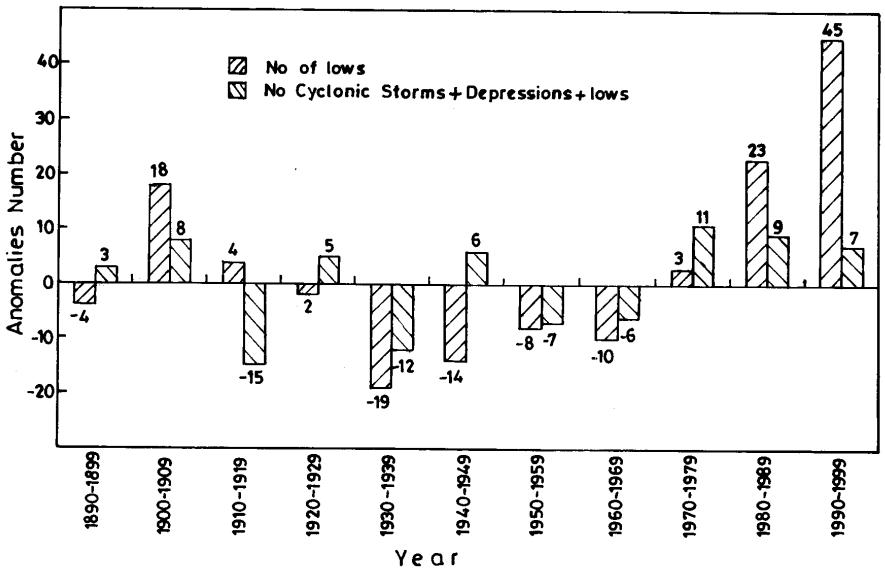

Fig. 5. Interdecadal variation of number (No.) of monsoon disturbances over India (lows, lows + Depressions + CS) and their anomalies

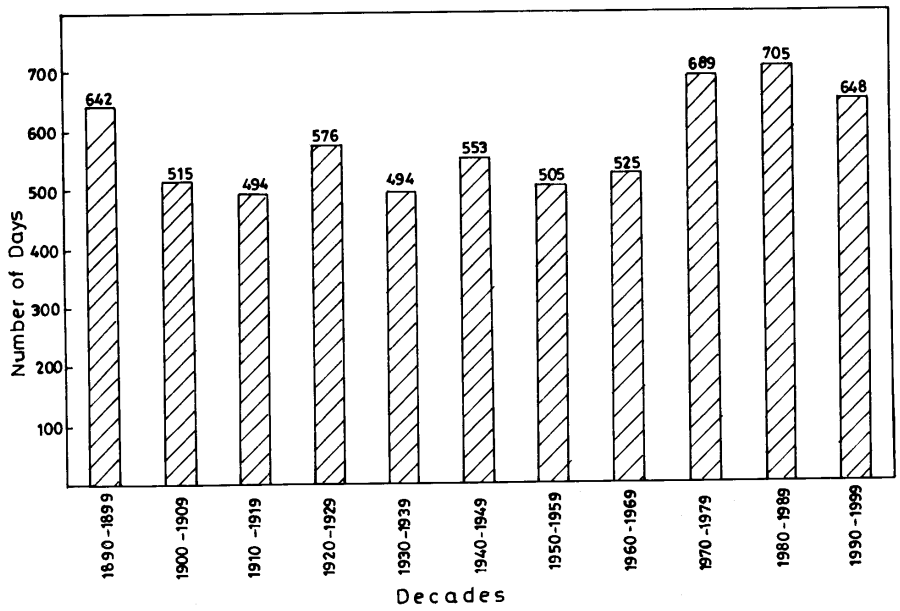

Fig. 6. Interdecadal variations of total number of monsoon disturbance days

5. Decadal and epochal trends in number of monsoon disturbance days

Figs. 6 and 7 shows interdecadal variation of total number of days of monsoon disturbances and their anomalies respectively. None of their decadal frequencies shows linearly increasing/decreasing trend throughout past 110 years period. The highest number of disturbance days (705) is found in the 10th decade (1980-89) and the lowest number of days (494) is found in 3rd decade (1910-19) and 5th decade (1930-39). The decadal number of days only has been fallen from 1st decade (642) to 3rd decade

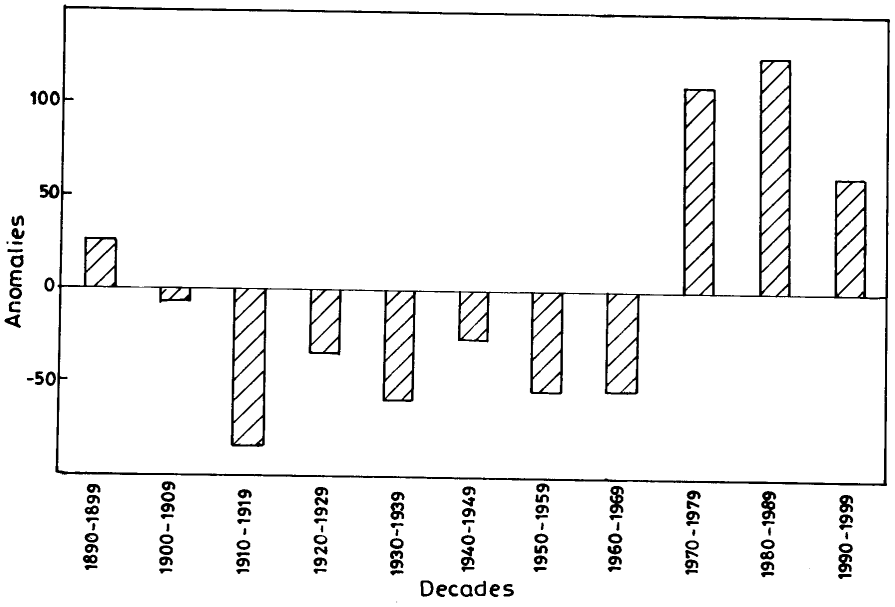

Fig. 7. Interdecadal variations of total number of monsoon disturbance days and their anomalies

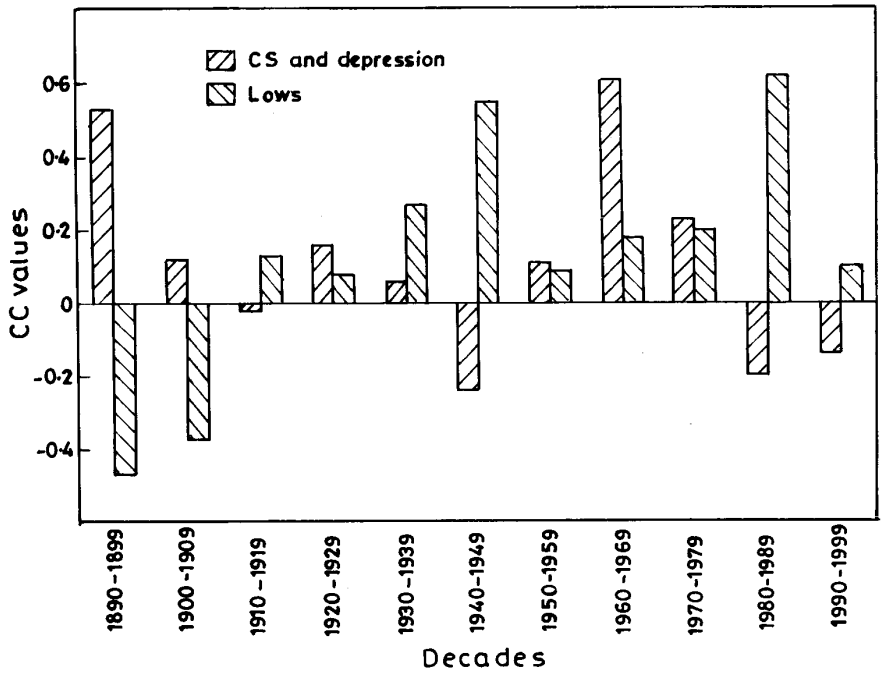

Fig. 8. Decadal CC for the period 1890-1999 (total 11 decades) between seasonal anomaly of ISMR and anomalous frequencies of CS and depressions and between seasonal anomaly of ISMR and anomalous frequencies of lows

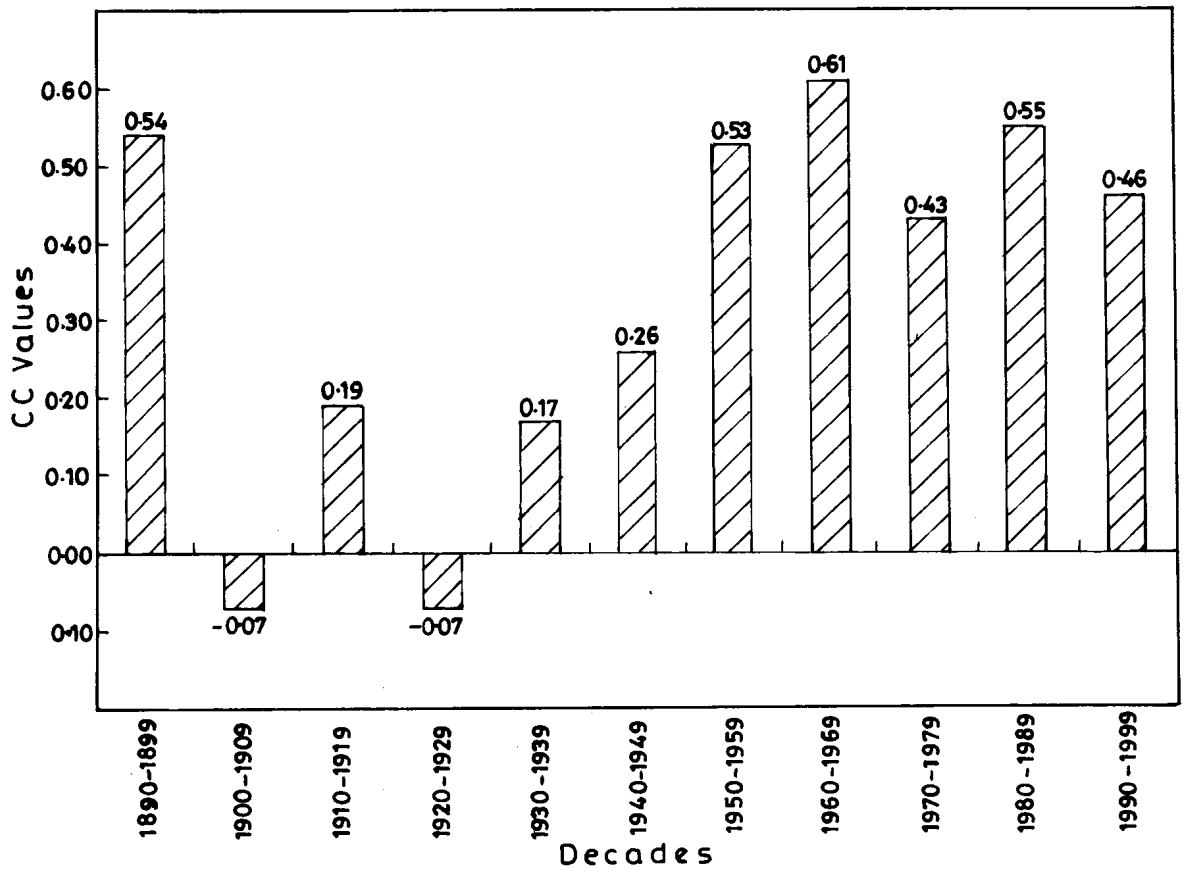

Fig. 9. Decadal CC for the period 1890-1999 (total 11 decades) between seasonal anomaly of ISMR and total monsoon disturbance days anomaly

(494) and increased from 7th decade (505) to 10th decade (705).

6. Association with ISMR anomaly

6.1. *Number of different monsoon disturbances and ISMR anomaly*

Comparison of decadal anomalies of frequencies of CS (Fig. 3) and ISMR (Fig. 1) shows that out of 5 above normal ISMR decades (*i.e.*, 1st, 5th, 6th, 7th and 11th), 3 decades (*i.e.*, 1st 5th and 6th) are having above normal frequencies of CS while out of 6 below normal ISMR decades (*i.e.*, 2nd, 3rd, 4th, 8th , 9th and 10th), only 1 decade (*i.e.*, 9th) is having little above normal CS. Thus, analysis shows that more number of CS is formed in above normal ISMR. Similarly comparison of decadal anomalies of frequencies of depressions (Fig. 3) and ISMR anomalies (Fig. 1) shows out of 5 above normal ISMR decades, only 1 decade (*i.e.*, 11th) is having significantly below normal frequencies of depressions while out of 6 below normal ISMR, only 2 decades (2nd and 3rd) are having significantly below normal frequencies of depressions. The analysis shows that more number of depressions like in case of CS are also formed in above normal ISMR.

Comparison of decadal variation of ISMR anomalies (Fig. 1) with frequency of monsoon depressions and CS anomalies together (Fig. 3) shows that out of 5 above normal ISMR decades, only 4 decades (*i.e.*, 1st, 5th, 6th and 7th) except the recent one of 1990-99 are having above normal frequencies of CS and depressions together while out of 6 below normal ISMR, only 3 decades (*i.e.*, 2nd, 3rd and 10th) are having significantly below normal frequencies of CS and depressions. Thus, more number of intense monsoon disturbances (depressions and CS) has formed during the above normal phases of ISMR. It has been observed that the number of CS and depressions

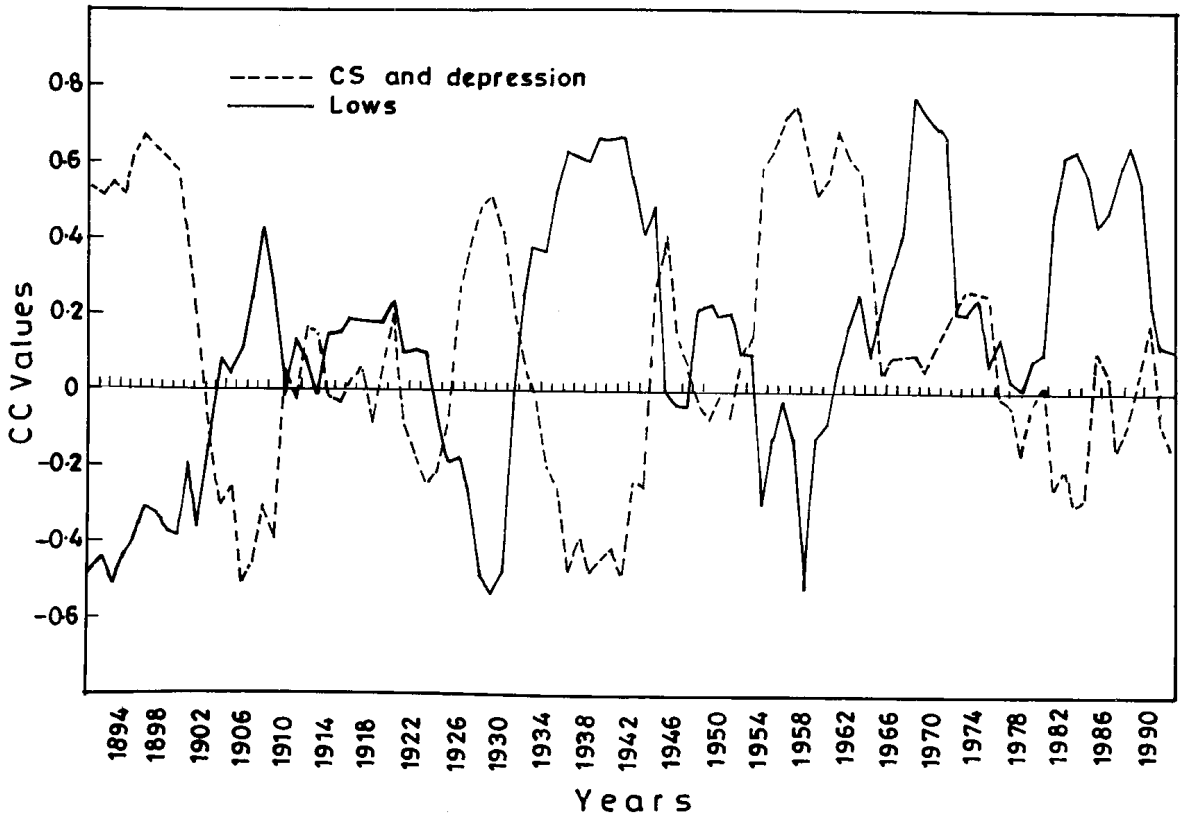

Fig. 10. CC in 10 year moving window for the period 1890-1999 between seasonal anomaly of ISMR and anomalous frequencies of CS and depressions and between seasonal anomaly of ISMR and anomalous frequencies of lows

together (32) is lowest during recent 11th decade (1990-99) amongst all the 11 decades, though decadal ISMR is in above normal during this decade. This is a unique feature and is being examined separately.

Comparison of decadal variation of ISMR anomalies (Fig. 1) with frequency of lows anomalies (Fig. 5) shows out of 5 above normal ISMR decades, 4 decades (*i.e.*, 1st, 5th, 6th and 7th decade) except the recent 11th decade (1990-99) are having significantly below normal frequencies of lows while out of 6 below normal ISMR, only 1 decade (*i.e.*, 8th) is having significantly below normal frequencies of lows. So during the above normal rainfall decade, normally more number of depressions and CS and relatively less number of lows form *i.e.*, more number of systems intensify into depression during the above normal ISMR decades. But in the present decade, record lowest and highest number of depressions and CS, lows are formed respectively.

6.2. *Number of days of monsoon disturbances and ISMR anomaly*

Comparison of decadal variation of ISMR anomalies (Fig. 1) with frequency of number of days anomalies (Fig. 7) shows out of 5 and 6 above normal and below normal ISMR decades respectively as mentioned earlier, 3 decades (*i.e.*, 5th to 7th) and 4 decades (*i.e.*, 2nd to 4th and 8th) respectively are having below normal number of monsoon disturbances days. Hence, it is very difficult to conclude whether below normal ISMR decades have above normal number of monsoon disturbance days or *vice-versa*.

7. Quantitative measures of relationship with ISMR anomaly

Out of different monsoon systems and duration in days as mentioned earlier, decadal correlation coefficient (CC) of ISMR anomaly have been calculated only with

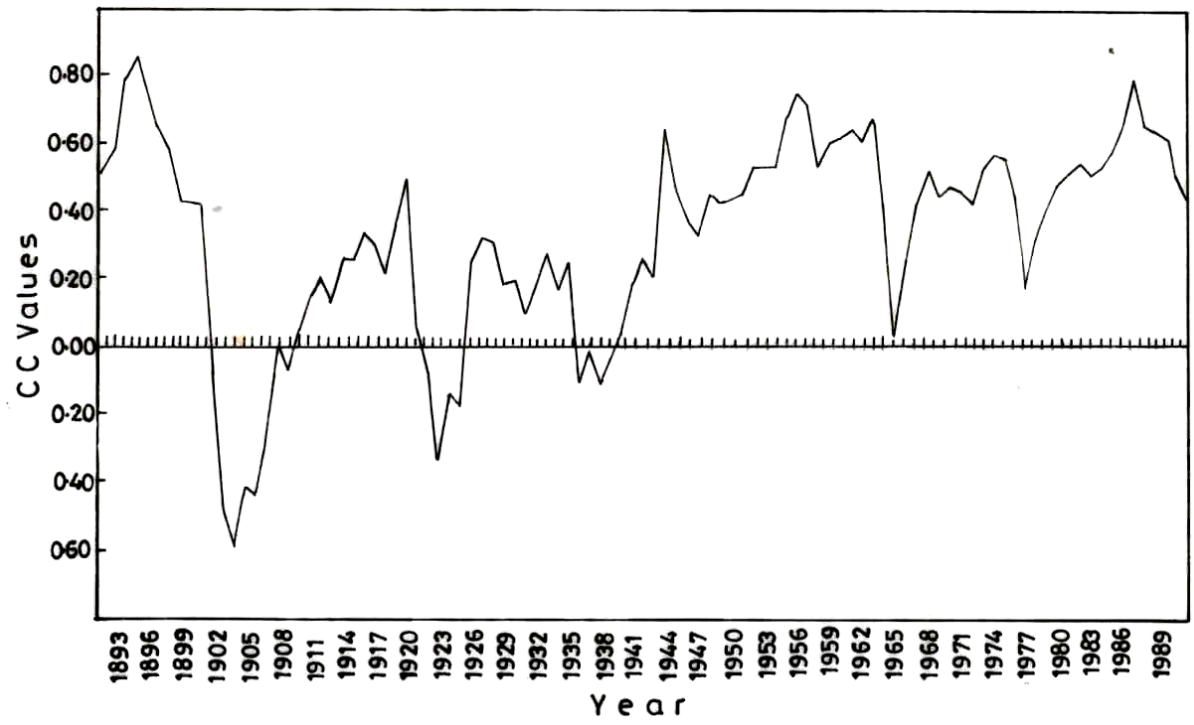

Fig. 11. CC in 10 year moving window for the period 1890-1999 between seasonal anomaly of ISMR and total monsoon disturbance days anomaly

anomalous frequency of intense monsoon systems (CS and Depressions), lows and their total days separately. Fig. 8 shows decadal correlations between ISMR anomaly with total number of lows, CS and depressions anomalies, and Fig. 9 shows decadal correlations between ISMR anomaly with total number monsoon disturbance day's anomalies. None of their decadal correlations shows linearly increasing/decreasing trend throughout past 110 years period. However, epochal linearly decreasing/ increasing trends of their CC are interesting to note. In Fig. 8, the highest correlation (0.61) between CS and depressions and ISMR anomaly is found in 8^{th} decade (1960-69) and lowest correlation (-0.21) is found in 6^{th} decade (1940-49). The highest correlation (0.61) between lows and ISMR anomaly is found in 10^{th} decade (1980-89) and lowest correlation (-0.45) is found in 1^{st} decade (1890-99). In Fig. 9, the highest correlation (0.61) between total disturbances days anomaly and ISMR anomaly is found in 8^{th} decade (1960-69) and lowest correlation (-0.07) is found in 2^{nd} decade (1900-09) and 4^{th} decade (1920-29). In case of CS and depressions (Fig. 8), decadal decreasing trends of their CC with ISMR are continuously observed thrice in total 110 years and these trends are from 1^{st} to 3^{rd}, 4^{th} to 6^{th} and 8^{th} to 10^{th} decades while in case of lows, decadal increasing trends of their CC with ISMR are continuously observed twice in total 110 years. These trends are from 1^{st} to 6^{th} decade which was observed for a longer period and from 7^{th} to 10^{th} decade with presence of highest and lowest CC at 1^{st} decade and at the 10^{th} decade respectively. In case of total disturbance days (Fig. 9), decadal increasing trend of their CC with ISMR is observed only once from 4^{th} decade (1920-29) to 8^{th} decade (1960-69) continuously when their correlation values increased significantly from the lowest value of –0.07 to the highest value of 0.61. CCs have also been calculated between frequency of intense monsoon systems (CS and depressions), lows and their total days with ISMR separately for the whole period of 110 years and their values are 0.11, 0.05 and 0.25. This shows that only monsoon disturbance days have significantly higher CC with ISMR amongst all irrespective of their decadal/epochal changes. Average correlations from 5 above normal and 6 below normal ISMR decades shows that CC between total disturbances

days anomaly and ISMR anomaly are 0.39 for above normal decades of ISMR and 0.27 for below normal decades of ISMR respectively. It shows that monsoon disturbance days have high correlation with ISMR in above normal ISMR decades. However, it is interesting to note that correlations are of much lower values in first phase (average is 0.05) of 3 below normal ISMR decades (2^{nd} decade to 4^{th} decade) compared to 2^{nd} phase (average is 0.53) of below normal decades (8^{th} decade to 10^{th} decade) while not such much change of value of correlations are found in case of above normal ISMR decades.

Fig. 10 shows decadal correlations between ISMR anomaly and frequency of CS and depressions and lows and Fig. 11 shows decadal correlations between ISMR anomaly monsoon disturbance day's anomalies in a 10 years moving window in the interannual time scale. It is seen from these figures that these correlations undergoes secular variation in interdecadal time scale like correlation of SOI and NINO 3 SST with ISMR. The figure also shows variation of all of their CCs in magnitude and sign in their 10 years moving CCs. In case of CS and depressions (Fig. 10) the highest correlation around 0.70 is found at beginning and around 1960s with lowest correlation in start of last century and 1940s with value –0.50. In case of lows, the highest correlation around 0.80 is found around 1970s with lowest correlation in 1890s and 1930s with value –0.50. In case of total disturbances days (Fig. 11), the highest correlation around 0.80 is found at beginning and end of the period with lowest correlation in start of last century with value –0.60. In recent years, (Figs. 10 & 11) ISMR has high CC with disturbances days followed by CC with number of lows and then with number of CS and depressions. Thapliyal (1997) has shown similar secular variation of CC between ISMR and its various regional and global parameters used in its long range forecast. Hence present study shows secular variations of CC not only exists between ISMR and its various regional and global parameters used in its long range forecast but also exists between ISMR and its main concurrent synoptic components *e.g.*, different monsoon systems.

8. Conclusions

In 110 years of data, the 6^{th} decade (1940-49) has highest number of depressions and CS and 5^{th} decade (1930-39) has lowest number of lows while the last decade (1990-99) has lowest number of depressions and CS and highest number of lows. It is interesting to note that the most recent decade *i.e.*, 1990-99 is having highest lows and also lowest depressions and CS. The highest number of disturbance days or duration (705 days) is seen in the decade of 1980-89 and the lowest number of durations (494 days) is seen during 1910-19 & 1930-39. None of their decadal frequencies shows linearly increasing/decreasing trends during 110 years period. However, epochal linearly increasing/decreasing trends are noticed. Frequencies of depressions and CS have decreased considerably since 9^{th} decade of 1970-79. Less than half the total number of depressions and CS is formed in the recent 11^{th} decade (1990-99) compared with the 9^{th} decade (1970-79). However, frequencies of lows shows that their interdecadal number, have been increased significantly from 8^{th} decade (1960-69) to recent decade when more than double the number of lows and the record highest number of lows are formed. Though statistically not tested, the study of relationship of decadal anomaly of their frequencies with interdecadal variation of ISMR shows that number of depressions and CS, are higher than the normal during the above normal ISMR decades and less during the below normal decades of ISMR. Reverse is true for the number of lows. However, systems during the present above normal decade of ISMR, are not of same characteristics as systems formed in earlier above normal and below normal phases of ISMR. Few intense disturbances are formed with record highest number of lows in recent decade even though it falls in the decade of above normal ISMR. The decadal and 10 years moving CC between ISMR and frequencies of different monsoon disturbance and total monsoon disturbance days clearly show secular variation of their relationship in interdecadal time scale like CC of SOI, NINO 3 SST, etc. with ISMR. In recent years, ISMR has high CC with disturbance days followed by number of lows and then with number of CS and depressions. The study also shows that monsoon disturbance days have high correlation with ISMR in above normal ISMR decades compared to below normal ISMR decades. Hence present study shows secular variations of CC not only exists between ISMR and its various regional and global parameters used in its long range forecast but also between ISMR and its main synoptic components *e.g.* different monsoon systems as we discussed.

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