MONSOON VARIABILITY IN RELATION TO ENSO AND NAO

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Introduction

North Atlantic Oscillation (NAO) and Southern Oscillation (SO) are two large-scale atmospheric alterations in northern and southern hemispheres respectively. These two oscillations exist through out the year simultaneously and are known to affect the Indian summer monsoon rainfall individually. Many earlier studies by Sikka (1980), Pant (1981), Shukla (1983), Rasmusson (1983), Verma (1990), have shown the effect of SO on the monsoon activity over India. Kripalani R.H. (1997) studied the connections of Indian monsoon with ENSO extremes. Recently, Dugam et al (1997) have studied the effect of NAO on Indian summer monsoon rainfall. The study reveals an inverse relationship between NAO and Indian summer monsoon rainfall. All these studies are mainly confined to the individual effect of NAO and SO on Indian summer monsoon rainfall.

Van Loon (1978), Chen (1982), Rojers J.C. (1984), Alexander (1992), Dugam et al (1999), Hurrel J.W. (1996) etc. have suggested an interactive mechanism between these two oscillations. Moreover the observational evidences of behavior of these two oscillations during contrasting monsoon years of India (Kakade et al 2000) suggest the necessity to understand and consider the simultaneous impact of NAO and SO on Indian summer monsoon rainfall activity. Therefore, in the present paper an attempt has been made to find the predictive skill of the simultaneous impact of NAO and SO in predicting summer monsoon rainfall activity over Indian sub-continent.

The prediction of Indian summer monsoon rainfall (ISMR) has a long history. About 80% of the annual rainfall over a large part of India occurs during the summer monsoon period (June-September). Therefore, it is important to forecast ISMR well in advance. In the present paper an attempt has been made to forecast ISMR using the simultaneous impact of NAO and SO.

2. Data used For this study following data has been used.

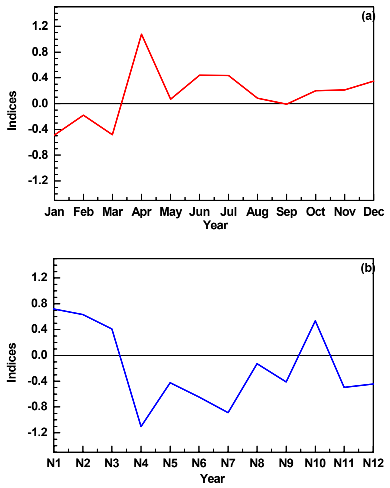
1. North Atlantic Oscillation (NAO)
The NAO data has been taken up from the www.cpc.ncep.noaa.gov.
2. Southern Oscillation (SO)
The SO data has been taken up from the www.cpc.ncep.noaa.gov.
3. Indian summer monsoon rainfall (ISMR)
The summer monsoon rainfall (June-September) data has been taken up from www.tropmet.res.in . The anomaly of this data from long term mean is further normalized by long tern standard deviation.These indices of ISMR are used for calculations in this paper.

3. Discussion

In order to understand the simultaneous impact of NAO and SO on ISMR, an index called effective strength index (ESI) has been defined on the basis of monthly indices of NAO and SO. This ESI is computed as: the algebraic difference between monthly indices of NAO and SO is calculated for each month for the period 1951-95. The deviation from the annual mean difference series, for the period 1951-95, is calculated for each month and this anomaly series is then normalized by the standard deviation of the annual mean difference series for the above mentioned period. This ESI series is then updated up to 2001.

3.1 Tendency of ESI from January to April.

Kakade et al (2000) have suggested that during excess monsoon years the ESI decreases from January to April where as during deficient monsoon years there is a rising tendency of ESI from January to April. Thus the tendency of ESI from January to April is the distinguishing character between excess and deficient monsoon activity over Indian sub-continent. The tendency of ESI from January to April is computed as the difference between April-ESI and January-ESI. During recent 52-year period, 1951-2002, there were 28 years when this tendency of ESI increases (positive) and 24 years when this ESI tendency decreases (negative). Figure-1 depicts the monthly composite of ESI during increasing and decreasing tendency of ESI.



It reveals that when tendency is positive then monthly ESI values are also positive during the monsoon season (June-September) of that year and vice versa. Thus the ESI tendency is indicating the simultaneous behavior of two oscillations (NAO, SO) during and just before the beginning of the monsoon season.

3.2Relationship between ESI tendency and Indian summer monsoon rainfall.

Up till now we have seen the distinguishing characteristic of ESI tendency during extreme monsoon years (excess, deficient). Every year is not an extreme monsoon year and so we must see whether similar type of relationship between ESI tendency and Indian summer monsoon rainfall also exists during all years or not. This is done by correlation analysis and for this purpose 30 year data, 1961-90, have been used.

Figure-2 depicts the variability of ESI tendency and Indian summer monsoon rainfall. The correlation coefficient is found to be negative and is statistically significant at 1% level. The stability of the relationship is tested by computing 30 year running correlation coefficients between them for 1951-2001. Figure-2: Association of summer monsoon rainfall over All India and ESI tendency from January to April for 1961-90.

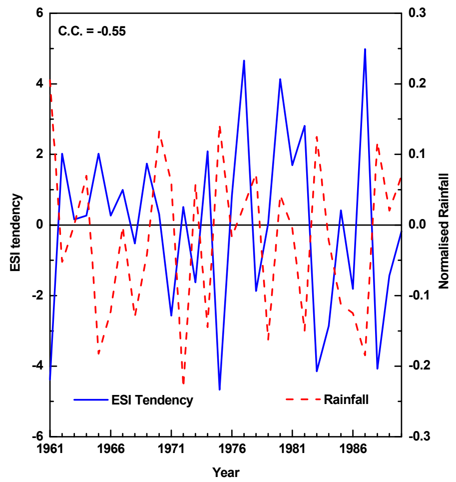
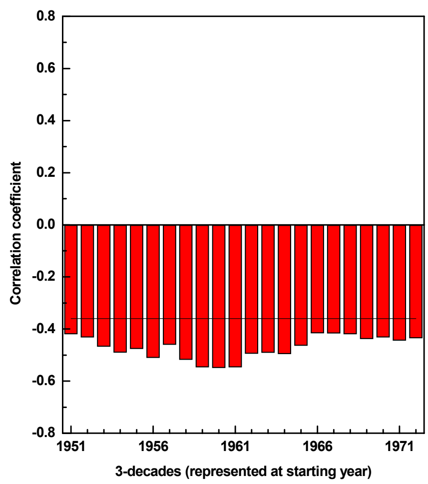


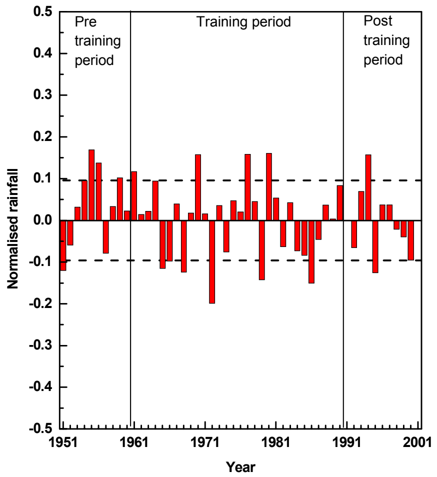
Figure-3 depicts the same. It reveals that the relationship is statistically significant at 5% level for all 30 year period which means that the relationship is statistically stable. This suggests that the ESI tendency can be used as a pre-cursor for predicting Indian summer monsoon rainfall.



3.3 Simple regression approach.

In order to understand the predictive potential of ESI tendency, simple regression model is developed for predicting normalized rainfall over India as a whole. For this purpose 30-year data, 1961-90, have been used. The bias, absolute error and root mean square error are computed and are found to be almost zero.

Figure-4 depicts the difference between actual and estimated normalized rainfall (residual series) over India as a whole for the period of 1951-2001.



If the residual value is in allowable range (between mean +/- standard deviation of the residual series for 1961-90) then that particular year is considered as correctly predicted. With this convention the skill score (SS) is calculated by the formula

$$SS= (C-E) / (T-E),$$

Where C= Number of years correctly predicted,

E= Number of years predicted by chance and

T= Total number of years.

For the period 1961-2001 the SS= 0.71 and for independent test sample period, (1991-2001), the SS= 0.81. The drought condition during 2002 was well predicted by the ESI tendency. The ESI tendency from January to April, for 2002, is 3.16 that suggest reduced rainfall activity over India as a whole. For this year most of the conventional parameters failed to predict drought conditions over India where as this parameter (ESI tendency) alone is indicating some signal of reduced rainfall activity over India. Therefore we can expect that the use of this parameter in multiple regression models, along with already existing parameters, may improve the forecasting skill.

4. Conclusions

This study mainly deals with the understanding of simultaneous effect of NAO and SO on Indian summer monsoon rainfall, quantitative representation of this simultaneous effect (ESI) and the predictive potential of ESI tendency in forecasting of monsoon rainfall activity over Indian sub-continent. The following conclusions can be drawn from this study.

a) Indian summer monsoon rainfall depends upon both the oscillations (NAO and SO) simultaneously. Therefore the joint effect of these two oscillations plays an important role in the summer monsoon circulation over Indian region. Hence the simultaneous impact of NAO and SO should be considered rather than their individual impact on Indian monsoon rainfall activity.
b) The positive tendency of ESI from January to April is linked with the positive phase of ESI during the monsoon season of the year and vice versa. Thus ESI tendency is indicating the simultaneous behavior of NAO and SO during monsoon season.
c) The tendency of ESI from January to April can be used as a pre-cursor for predicting Indian summer monsoon rainfall.

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