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Summer monsoon rainfall over Bangladesh in relation to Multivariate ENSO Index

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सार - मानसून ऋतु के दौरान पिछले माह के पहले सप्ताह से विचारधीन माह के पहले सप्ताह की अवधि मे बंगलादेश में हुई मासिक वर्षा और द्विमासिक बहुचर एनसो इंडेक्स (एम.ई.आई.) के परस्पर संबंध की जाँच की गई है। उष्णकटिबंधीय प्रशांत महासागर के - समुद्र सतह तापमान, समुद्र सतह दाब, सतह पवन के क्षेत्रीय और रेखांशिक घटक, सतह वायु तापमान और आकाश के पुर्णतया मघाच्छादित भाग जैसे छः परिवर्तनशील घटकों में से एम.ई.आई. को पहले मुख्य घटक (पी.सी.) के रूप में परिकलित किया गया है। पूर्वानुमान प्रयोजन के लिए एम.ई.आई. मान प्रत्येक माह के पहले सप्ताह में उपलब्ध हो जाते हैं। एनसो के मॉनीटरन के लिए दक्षिणी दोलन तालिका (एस.ओ. आई.) अथवा विभिन्न समुद्र सतह तापमान जैसी तालिकाओं से एम.ई.आई. बेहतर है क्योंकि इससे एनसो के संबंध में पूरी जानकारी मिलती है और यह महासागरीय वातावरण की पद्धति की प्रकृति को पूरी तरह से प्रतिबिम्बित करता है। एम.ई.आई. के सकारात्मक मान उष्ण एनसो अवस्था (इल- निनो) और नकारात्मक मान शीत अवस्था (ला - निना) दर्शाते हैं।

इस अध्ययन के परिणामों से पता चलता है कि बंगलादेश में जून में होने वाली वर्षा पर एनसो का प्रतिकूल प्रभाव पड़ता है। परन्तु यह रोचक बात है कि बंगलादेश में एनसो वर्षों के दौरान अगस्त माह में सामान्य से अधिक वर्षा होती है। बंगलादेश में जुलाई और सितंबर माह में होने वाली वर्षा पर एनसो का कोई उल्लेखनीय प्रतिकूल प्रभाव नहीं पड़ता है। इस अध्ययन के परिणाम बंगलादेश में होने वाली मानसून वर्षा के पूर्वानुमान को मासिक पैमाने पर दर्शाने में सहायक होंगे।

ABSTRACT. The relationship between monthly rainfall over Bangladesh during monsoon season and bi-monthly Multivariate ENSO Index (MEI) pertaining to the period from first week of previous month to first week of the month under consideration, has been investigated. The MEI is calculated as the first Principal Component (PC) of six variables over the tropical Pacific, *viz.* sea surface temperature, sea level pressure, zonal and meridional components of the surface wind, surface air temperature and total cloudiness fraction of the sky. The MEI values for prognostic purposes are available by the first week of every month. MEI is better for monitoring ENSO than other indices like Southern Oscillation Index (SOI) or various SST indices as it integrates complete information on ENSO and reflects the nature of complete ocean atmosphere system. Positive values of MEI indicate warm ENSO phase (El-Nino) and negative ones represent cold phase (La-Nina).

The results of the present study show that June rainfall of Bangladesh is adversely affected by the ENSO. But interestingly Bangladesh seems to receive more than normal rainfall during August of ENSO years. ENSO does not seem to have any significant adverse impact on July and September rainfall of Bangladesh. The results of the study may find applications in foreshadowing monsoon rainfall over Bangladesh on a monthly scale.

Key words – El-Nino/Southern Oscillation (ENSO), Multivariate ENSO Index (MEI), Principal Component (PC), Summer monsoon, Covariance, La-Nina.

1. Introduction

El-Nino/Southern Oscillation (ENSO) is known to cause weather anomalies all over the globe. Indian summer monsoon is adversely affected by ENSO (Ramage and Hori, 1981; Rasmusson and Carpenter, 1983; Shukla and Paolino, 1983; Chang and Krishnamurti, 1987; Thapliyal, 1990; Gowariker *et al.*, 1991). However, there is no one-to-one correspondence between the ENSO and monsoon rainfall. In a recent study (Kripalani & Kulkarni, 1997) it has been shown that the impact of ENSO on Indian monsoon rainfall is modulated by the decadal variability of monsoon rainfall. When we consider the rainfall on subseasonal and smaller spatial scales different relationships emerge. For instance ENSO does not seem to have any significant impact on the monsoon rainfall of eastern region of India (especially Orissa). Singh *et al.*, (1999) have found that there is a tendency for development of more number of monsoon depressions in the Bay of Bengal during July-August of ENSO years. The enhanced frequency of depressions dampens the adverse impact of ENSO on the rainfall of Orissa which falls in the track of monsoon depressions.

No attempt has, so far, been made to find out the impact of ENSO on the monsoon rainfall of Bangladesh on a monthly scale which is prone to the vagaries of monsoon. However, some earlier studies (Kripalani, *et al.*, 1996) have shown that seasonal rainfall over Bangladesh is not related with darwin pressure. The main objective of present study is to look into the relationship between ENSO and monsoon rainfall of Bangladesh on a monthly scale.

Southern Oscillation Index (SOI) or various sea surface temperature (SST) anomalies over the Pacific are, generally, taken as measure of ENSO while linking different weather anomalies to ENSO. It is felt that these indices may be more suitable for the weather anomalies over the Pacific rim region including Australia. For World-wide correlation's the MEI which integrates complete ENSO information would be more appropriate. Therefore, MEI may provide better understanding of the relationship between ENSO and the monsoon rainfall over the Indian subcontinent. In the first phase the relationships between MEI and Bangladesh rainfall has been investigated. In the next phase it is proposed to study the relationships between MEI and monsoon rainfall over India on monthly and subdivisional scales.

1.1. *Multivariate ENSO Index (MEI)*

ENSO is the most important coupled ocean-atmosphere phenomenon to cause global climate variability (Rasmusson and Carpenter, 1982; Wolter, 1987). The MEI is computed by normalizing the total variance of each variable (mentioned in the abstract) and then performing the extraction of the first PC on the covariance matrix of the combined fields (Wolter and Timlin, 1993). In order to keep the MEI comparable, all values are standardized with respect to each bi-monthly period and to the 1950-93 reference period. The MEI is extended during the first week of following month. In other words all MEI values are bi-monthly and pertain to the period from first week of a particular month to the first week of the following month. For example the MEI for June will pertain to first week of May to first week of June. Due to normalization all 44 values of MEI from 1950 to 1993 have an average of "0" and a standard deviation of "1", *i.e.*, each MEI value represents the standardized anomaly.

1.2. *Monsoon rainfall of Bangladesh*

Monthly rainfall departures over Bangladesh has been computed forJune, July, August and September for the period 1951-96. Correlation's of percentage departures with MEI values pertaining to the period from the first week of previous month to the first week of the month under consideration have been computed.

2. Data source

MEI data for the period 1951-96 have been obtained from NOAA – CIRES Climate Diagnostics Centre, Boulder, U.S.A. and the summer monsoon rainfall data for the same period have been obtained from the Bangladesh Meteorological department. MEI values alongwith rainfall departures have been presented in Table 1.

3. Results and discussion

The correlation coefficients (CCs) between monthly rainfall of Bangladesh and MEI have been presented in Fig.1. Keeping in view the nature of MEI values all CCs are lag CCs. The CCs for June is – 0.2 which is significant at 90% level. This CC has been computed between MEI of first week of May to first week of June and Bangladesh rainfall of 1st to 30th June. The computation method is similar for July, August and September also. This has been done keeping in view the forecasting utility of MEI. The negative CC indicates that Bangladesh receives less than normal rainfall during June of ENSO years. The time series of MEI and the percentage rainfall departures of Bengladesh during June have been presented in Fig.2. It is seen from Fig.2 that highest positive value of MEI +2.223 occurred in June, 1983 during the severe ENSO epoch of 1982 - 83.

TABLE 1

MEI and rainfall departure over Bangladesh for monsoon season

S. No.	Year	Month							
		MEI (1st week of May to 1st week of Jun)	% rainfall departure (1-30 Jun)	MEI (1st week of Jun to 1st week of Jul)	% rainfall departure (1-31 Jul)	MEI (1st week of Jul to 1st week of Aug)	% rainfall departure (1-31 Aug)	MEI (1st week of Aug to 1st week of Sep)	% rainfall departure (1-30 Sep)
1	1951	0.366	-25	0.788	-14	0.911	-22	0.851	-20
2	1952	-0.653	-8	-0.195	4	-0.139	-30	0.344	9
3	1953	0.273	7	0.439	1	0.249	-27	0.576	26
4	1954	-1.512	61	-1.419	-24	-1.446	-12	-1.183	-40
5	1955	-2.242	-19	-1.87	11	-1.966	-8	-1.787	-13
6	1956	-1.514	32	-1.173	-18	-1.117	19	-1.359	4
7	1957	0.762	-23	0.969	-24	1.124	-44	1.129	-23
8	1958	0.888	-42	0.684	-40	0.393	-19	0.07	-19
9	1959	-0.035	-12	-0.228	-21	0.066	14	-0.007	13
10	1960	-0.257	-35	-0.318	16	-0.248	-28	-0.515	8
11	1961	-0.141	10	-0.251	-24	-0.351	-9	-0.356	-24
12	1962	-0.823	-6	-0.81	-30	-0.551	-22	-0.512	-29
13	1963	-0.082	7	0.393	-5	0.643	-39	0.758	-20
14	1964	-1.123	-10	-1.375	12	-1.54	-29	-1.293	-18
15	1965	0.924	11	1.432	-8	1.522	19	1.448	-7
16	1966	-0.186	-13	-0.133	-28	0.161	-4	-0.118	5
17	1967	-0.295	-34	-0.652	-21	-0.521	-17	-0.709	37
18	1968	-0.781	16	-0.502	1	-0.158	-18	0.174	-41
19	1969	0.789	-13	0.433	-13	0.286	30	0.235	0
20	1970	-0.65	-14	-1.128	15	-1.014	-22	-1.237	9
21	1971	-1.437	4	-1.231	-9	-1.262	11	-1.458	-3
22	1972	1.086	-24	1.824	-43	1.761	-8	1.571	-51
23	1973	-0.747	-4	-1.064	-31	-1.347	-33	-1.684	16
24	1974	-0.647	-5	-0.771	37	-0.703	-11	-0.631	9
25	1975	-1.157	-46	-1.482	15	-1.659	-41	-1.808	-18
26	1976	0.284	16	0.615	2	0.724	0	1.021	-25
27	1977	0.483	31	0.841	2	0.692	-20	0.776	-40
28	1978	-0.542	12	-0.353	-24	-0.224	-14	-0.357	25
29	1979	0.485	-17	0.354	-16	0.636	3	0.805	-3
30	1980	0.878	-34	0.81	-13	0.359	-20	0.294	-37
31	1981	0.01	-28	0.005	17	-0.157	-9	0.113	-4
32	1982	0.962	17	1.592	-16	1.756	26	1.809	-7
33	1983	2.223	-27	1.804	2	1.273	37	0.546	-4
34	1984	-0.082	53	-0.211	13	-0.232	1	-0.068	7
35	1985	-0.153	-5	-0.224	-10	-0.407	-11	-0.525	-8
36	1986	0.31	-15	0.38	1	0.682	-31	1.076	58
37	1987	1.922	-32	1.827	50	2.035	45	1.902	27
38	1988	-0.62	27	-1.236	-7	-1.323	12	-1.539	1
39	1989	-0.318	-25	-0.445	4	-0.566	-60	-0.302	24
40	1990	0.414	-2	0.097	20	0.105	-40	0.422	-4
41	1991	1.034	30	0.987	-11	0.945	-7	0.652	46
42	1992	1.818	-27	0.997	-16	0.619	-33	0.476	-5
43	1993	1.598	25	1.102	-15	1.042	7	1.025	3
44	1994	0.626	4	0.814	-30	0.591	-17	0.649	-45
45	1995	0.479	-7	0.28	3	0.074	-9	-0.329	5
46	1996	0.012	-8	-0.183	-16	-0.251	5	-0.314	-5

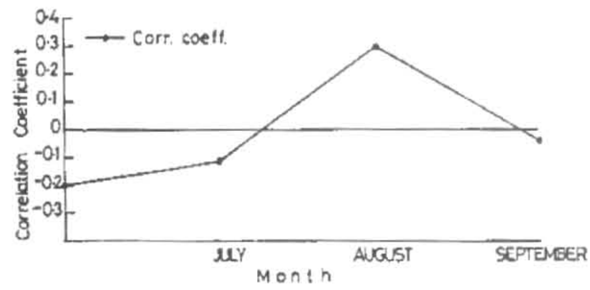

Fig.1. Monthly correlation coefficients between MEI and monsoon rainfall over Bangladesh (MEI values pertain to the period from 1st week of previous month to the 1st week of the month under consideration)

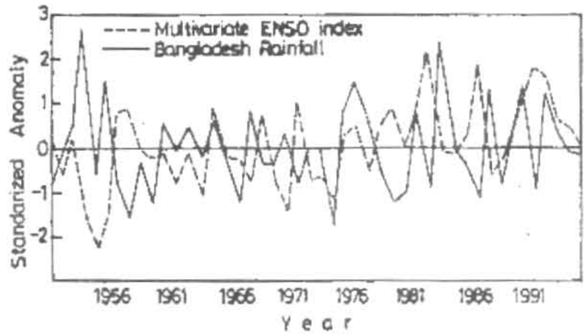

Fig.2. Time-series of MEI and standardized anomaly of rainfall departure over Bangladesh during June

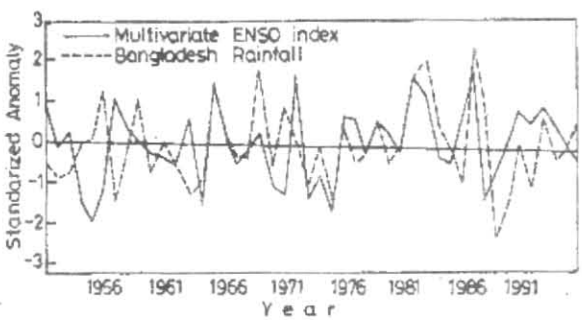

Fig.3. Time-series of MEI and standardized anomaly of rainfall departure over Bangladesh during August

The rainfall over Bangladesh during June, 1983 was highly deficient; *i.e.*, – 27%. The second highest value of MEI (+1.922) was observed during June, 1987, another ENSO year. The corresponding rainfall departure was – 32%. June rainfall was highly deficient over Bangladesh during severe ENSO years, 1957 and 1972 also. During June of recent ENSO year, 1997 the rainfall departure over Bangladesh was – 27%. But it would not be correct to expect always a one-to-one relationship between rainfall and ENSO. However, from the data of 1951-96 there seems no ambiguity that Bangladesh tends to receive below normal rainfall during June of ENSO years. Care should, however, be taken to correlate the actual MEI value of June instead of qualitative categorization of ENSO and non-ENSO years. MEI values may not be positive in all months of so called ENSO years. Similarly, the severity of ENSO phenomenon may not be similar in all calendar months.

The CC between MEI and Bangladesh rainfall for July is only – 0.11 which is statistically not significant. However, existing data shows that there is a tendency for subdued rainfall over Bangladesh during July of ENSO epochs but the impact of ENSO is not significant. Maximum deficiency in July rainfall (-43%) during the period 1951-96 was observed in 1972, a severe ENSO year and highest excess rainfall (+50%) was also observed in an ENSO year (1987). The highest positive value of MEI (+1.804) for July was observed in 1987. This only shows that ENSO does not have any significant adverse impact on July rainfall of Bangladesh.

Most interesting aspect of the relationship between ENSO phenomenon and Bangladesh rainfall is positive CC for August. The CC is +0.3 which is significant at 95% level. It shows that Bangladesh receives excess rainfall during August of ENSO epochs. This is probably because of higher frequency of monsoon depressions during August of ENSO years.

Fig.3 depicts the rainfall departures and MEI values for August during the period 1951-96. The highest MEI value for August of + 2.035 was observed during severe ENSO year 1987. The rainfall over Bangladesh during August, 1987 was excess (+ 45%). Incidentally + 45% is the maximum rainfall in August, during the entire period 1951-96. Not only this, the highest deficiently in August rainfall (– 60%) was observed during the La-Nina year 1989. Therefore, it is not correct to generalize the adverse impact of ENSO through out the monsoon season. The results of the present study clearly show that Bangladesh tends to receive more than normal rainfall during August of ENSO epochs.

The CC for September is very insignificant – 0.04, showing that ENSO does not have any significant adverse impact on September rainfall of Bangladesh.

An attempt has been made to test the significance of difference of mean rainfall for each month of monsoon season for MEI > +1 and < – 1. It is observed that during August mean rainfall departure over Bangladesh for MEI > +1 is 11.7% whereas for MEI < – 1 it is – 11.4%. Using Cramer's test this difference means is statistically significant at 95% level. Therefore positive impact of ENSO on August rainfall of Bangladesh appears to be a reality. The significance levels for remaining monsoon months are not very high. However, Mean departures for June are worth noting which for MEI > +1 and < – 1 are – 9.2% and + 3.6% respectively.

Therefore, when we integrate the impact of ENSO on seasonal monsoon rainfall of Bangladesh, it could be safely stated that ENSO does not seem to have any significant impact on it. Although, it is evident that one-to-one relationship generally do not exist in case of such complex atmospheric phenomenon, it is certain that ENSO need not necessarily imply a bad monsoon over Bangladesh in all monsoon months. As a matter of fact, during August of ENSO epochs Bangladesh receives enhanced rainfall due to increased frequency of monsoon depressions which wipes out the deficiency of June rainfall.

4. Conclusions

The following conclusions are drawn from the study.

(*i*) Bangladesh tends to receive deficient rainfall during June of ENSO epochs.

(*ii*) Interestingly, August rainfall of Bangladesh is higher than normal during warm phase of ENSO.

(*iii*) ENSO does not have any significant impact on July and September rainfall of Bangladesh.

(*iv*) ENSO does not necessarily imply a monsoon failure over Bangladesh.

(*v*) Bi-monthly values of Multivariate ENSO Index *i.e.*, from 1st week of one month to the 1st week of following month could be used in forecasting monsoon rainfall over Bangladesh during following month especially during August and June.

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