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# Association of El Niño and La Niña episodes with local/regional monsoon rainfall in Haryana subdivision (India)

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## ABSTRACT

Regional monsoon behaviour (1970-1999) in relation with El Niño and La Niña episodes, for the meteorological sub-division # 13 comprising of the areas of Haryana, Delhi and Chandigarh in India. The monthly monsoon rainfall data of different locations in the region and corresponding data on El Niño and La Niña episodes for the period of 30 years (1970-99) were used. Different locations received excess rainfall in monsoon season during El Niño years and excess rainfall years ranged between 11 and 22 per cent. Under the influence of La Niña episodes, the frequency of excess monsoon rainfall at different locations ranged between 13 and 25 per cent. No significant association was observed between El Niño and La Niña and monsoon rainfall at different locations in the entire sub-division under study.

*Key words:* El Niño and La Niña, monsoon rainfall, sub division

It has been recognized that the global scale climatic changes have widely varying regional manifestations with indirect influence on the social and economic prosperity of the affected human population. Predictions of regional scale climate variations are still on a loose ground, because of the problems faced by the current climate models in realistically simulating the atmospheric and surface processes with a fine resolution and the air-sea interaction. Climatic resource endowment plays major role in planning agricultural production in tropical and sub-tropical environment especially under rainfed agriculture (Singh *et al.*, 2000). Thus, in order to make realistic impact assessment on regional scale, we need transition from global generalities to regional specifics.

In recent years, there have been major advances in predicting and simulating monsoon on a wide range of time scales using Global Climatic Models (GCMs) together with an increased understanding of climatic response to few promising global warming signals like El Niño (EN) and Southern Oscillation Index (SOI). The negative phenomenon of El Niño is called La Niña or El Viejo. The "ENSO" system involves ocean and atmospheric phenomena with the appearance of warm current off the coast of Peru in the Eastern Pacific and affects weather in many places like Australia, Philippines, India, Canada etc. (Philander, 1983).

Ropelewski and Halpert (1987) investigated the "typical" global and large-scale regional precipitation patterns that are associated with the ENSO. This study expands previous results by placing the regional precipitation relationships into a global framework and provides a consistent methodology for the definition of the geographical regions and the temporal phase of ENSO related precipitation. Cheang (1993) found 7 out of 11 El Niño years to have recorded very much below median annual rainfall at many stations and 8 out of 10 La Niña years recorded above median annual rainfall during the period of 41 years (1951-1991). Mooley and Paolino (1989) favoured the association between warming of equatorial south east (ESE) Pacific and below normal Indian Monsoon Rainfall (IMR) over that of El Niño. The monsoon variability in the recent decade studied in the global climate perspective (Verma, 1990) showed it to be mainly due to ENSO. A vast majority of the models currently used are derived by using multiple linear regression methods (Krishna Kumar *et al*., 1995). Later on Chattopadhyay and Bhatla (1996) while re-examining the ENSO/anti-ENSO events and their relationship with Indian summer monsoon for the period 1901-1990, concluded that the 70 per cent drought events during the above period were ENSO related. Mooley (1997) further investigated that El Niño in which the ESE region experiences the warming phase have high potential in causing large deficiency in monsoon rainfall of the sub-divisions in northwest India and in central parts of India. Periodicities and ENSO relationships of the seasonal rainfall over six major divisions of India for the period 1848-1995 showed overwhelming association between warm events with drought and cold events with floods (Kane 1999). However, the effects are by no means uniform but vary with space and time and the maximum climatic variations have been reported in last decade (Anon, 2000). Bhalme *et al*. (1990) and Mohanty and Ramesh (1993) established some links between ENSO/anti-ENSO and monsoon rainfall over India, but this relationship is not necessarily uniform on regional scale.

Therefore, the present study was planned to deal specifically with El Niño and La Niña episode's impact on regional monsoon pattern.

**Table 1 :** Selected locations with their code, coordinates and period of data series used

| S.No. | Locations | Code | Latitude °N | Longitude °E | Altitude m a.m.s.l. | Data series |
|---|---|---|---|---|---|---|
| 1. | Sirsa | SRS | 29°32' | 75°27' | 218 | 1970-99 |
| 2. | Hisar | HSR | 29°10' | 75°46' | 215 | 1970-99 |
| 3. | Bhiwani | BHN | 28°48' | 76°08' | 227 | 1970-99 |
| 4. | Narnaul | NRL | 28°03' | 76°06' | 221 | 1970-99 |
| 5. | Rohtak | RTK | 28°54' | 76°35' | 226 | 1970-99 |
| 6. | Gurgaon | GGN | 28°28' | 77°02' | 230 | 1970-99 |
| 7. | Delhi | DEL | 28°35' | 77°10' | 228 | 1970-99 |
| 8. | Karnal | KNL | 29°43' | 76°58' | 245 | 1970-99 |
| 9. | Ambala | AMB | 30°22' | 76°47' | 247 | 1970-99 |
| 10. | Chandigarh | CHD | 30°40' | 76°45' | 261 | 1970-99 |

**Table 2 :** List of El Niño, La Niña and neutral years (1970-99)

| Sr. No. | El Niño years | La Niña years | Neutral years |
|---|---|---|---|
| 1. | 1972 | 1970 | 1971 |
| 2. | 1976 | 1973 | 1978 |
| 3. | 1977 | 1974 | 1979 |
| 4. | 1982 | 1975 | 1980 |
| 5. | 1983 | 1988[+] | 1981 |
| 6. | 1987 | 1989 | 1984 |
| 7. | 1991 | 1998 | 1985 |
| 8. | 1995 | 1999 | 1986 |
| 9. | 1997* | | 1990 |
| 10. | | | 1992 |
| 11. | | | 1993 |
| 12. | | | 1994 |
| 13. | | | 1996 |
| Total | 9 | 8 | 13 |

## MATERIAL AND METHODS

The sub-division under study is situated in sub-tropics and extends from 27°38' to 30°55' N latitude and 74°27' to 77°36'E longitude. The altitude in the sub-division ranged between 215 to 261 meters above mean sea level. The region is land locked from all sides and is a part of the Indo-Gangetic plains. The various locations for the investigation along with their codes, coordinates and period of data used are presented in Table 1.

### *Climatic features of the region*

The sub-division has semi-arid climate in the South-West and Gangetic plain environment in the remaining parts. The climate is generally very hot in summers and remarkably cold in winters. High temperatures of 45°C magnitude are recorded during May month, whereas, in winters the temperature goes down to –2 to –3°C for a few days. Most of the rainfall (75 to 80%) is received in SW monsoon season from July to September. Rainfall ranges from below 300 mm on the Rajasthan border and shows increasing trend towards the border adjoining Punjab and Himachal Pradesh where about 1200 mm of rainfall is received annually. About half of the sub-division can be classified as moisture deficit, whereas, the remaining half can be put in the category of adequate moisture status.

### Data used:

### *Monsoon rainfall data*

The mean monthly monsoon rainfall data were collected from Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar and Meteorological Center, Chandigarh of India Meteorological Department.

### *Global climatic data*

The SST and SOI values used in this study were prepared by Climate Analysis Center of the National Oceanic and Atmospheric Administration (NOAA), Washington, DC, USA.

### *El Niño and La Niña anomalies data*

The SST anomalies used were from the Niño 3 region of equatorial eastern Pacific ocean (5°N to 5°S and 90°W to 150°W) and were taken from climate prediction centre, (NOAA), Washington, DC, USA.

### *Southern oscillation index data*

The SOI, the difference in standardized sea-level pressure between Tahiti (17° 33'S and 149° 37'W) and Darwin (12° 24'S and 132° 52'E) used in this study were taken from Bureau of

**Table 3:** Frequency (%) of excess/deficient monsoon rainfall years* at different locations in El Niño and La Niña episodes (1970-99)

| Locations | El Niño episodes | | La Niña episodes | |
|---|---|---|---|---|
| | Excess | Deficient | Excess | Deficient |
| SRS | 22 | 33 | 13 | 0 |
| HSR | 11 | 11 | 13 | 25 |
| BHN | 22 | 22 | 13 | 13 |
| NRL | 22 | 22 | 13 | 0 |
| RTK | 11 | 11 | 13 | 0 |
| GGN | 11 | 11 | 25 | 25 |
| DEL | 22 | 11 | 25 | 12 |
| KNL | 0 | 22 | 25 | 0 |
| AMB | 11 | 22 | 25 | 25 |
| CHD | 0 | 22 | 13 | 13 |
| Sub Div | 11 | 33 | 13 | 25 |
| NW Ind | 22 | 44 | 25 | 25 |
| All Ind | 0 | 11 | 13 | 0 |

* Following Parthasarathy *et al.* (1992)

Meteorology, Darwin, Australia.

## RESULTS AND DISCUSSION

### *El Niño and La Niña episodes*

The El Niño and La Niña episodes identified on the basis of specific criteria applied to sea-surface temperature (SST) anomaly off Peru-Ecuador Coast following Quinn *et al*. (1978) have been presented in Table 2. Based on the above criteria, there were 9 El Niño episodes, 8 La Niña episodes and remaining 13 years identified as neutral year during the 30 years study period (1970-99).

The strongest El Niño episode occurred in 1997 and strongest La Niña was observed in the year 1988 as per the criteria of strength of these episodes (Rasmusson and Carpenter, 1982).

### *Excess and deficient monsoon rainfall*

The per cent excess and deficient monsoon rainfall years at different locations in the sub-division under El

**Table 4:** Locations receiving excess/deficient monsoon rainfall* during El Niño episodes (1970-99)

| El Niño year | Locations received | |
|---|---|---|
| | Excess monsoon rainfall | Deficient monsoon rainfall |
| 1972 | -- | BHN, NW Ind, All Ind |
| 1976 | SRS, HSR, BHN, NRL, DEL, NW Ind | -- |
| 1977 | DEL, NW Ind | -- |
| 1982 | -- | SRS, BHN, NRL, KNL, CHD, Sub Div, NW Ind |
| 1983 | BHN | -- |
| 1987 | -- | SRS, HSR, BHN, NRL, RTK, GGN, DEL, KNL, AMB, CHD, Sub Div, NW Ind |
| 1991 | -- | SRS, AMB, NW Ind |
| 1995 | HSR, BHN, NRL, RTK, GGN, AMB, Sub Div | -- |
| 1997 | SRS | -- |

*Following Parthasarathy *et al.* (1992).

Niño and La Niña episodes are presented in Table 3. During the El Niño episodes, excess monsoon rainfall in monsoon ranged between 11 and 22 per cent of the years except at Karnal and Chandigarh where no excess rainfall was observed under El Niño episodes. Frequency of deficient monsoon years in the sub-division under El Niño episodes ranged between 11 and 33 per cent. This may be attributed to the linkage of deficient rainfall with El Niño episodes. The frequency of deficient rainfall years was equal or more than the excess monsoon rainfall under El Niño episodes except at Delhi where excess rainfall years (22%) exceeded the deficient rainfall years (11%) under El Niño years.

Under the influence of La Niña episodes, the frequency of excess monsoon rainfall years at different locations in the sub-division ranged between 13 and 25 per cent. However,

**Table 5:** Locations receiving excess/deficient monsoon rainfall* during La Niña episodes (1970-99)

| La Niña year | Locations received | |
|---|---|---|
| | Excess monsoon rainfall | Deficient monsoon rainfall |
| 1970 | NW Ind | -- |
| 1973 | -- | HSR, RTK |
| 1974 | -- | GGN, DEL, AMB, CHD, SubDiv, NW Ind |
| 1975 | GGN, KNL, AMB, NW Ind | -- |
| 1988 | SRS, HSR, BHN, DEL, KNL, AMB, CHD, Sub Div, All Ind | -- |
| 1989 | -- | BHN, GGN, AMB, Sub Div |
| 1998 | GGN, DEL | -- |
| 1999 | -- | HSR, NRL, NW Ind |

**Table 6:** Exceptional years when monsoon rainfall did not follow the normal influence of SST anomalies (1970-99)

| Sr. No. | SST anomaly with monsoon pattern | Years |
|---|---|---|
| 1. | El Niño episodes (many locations received excess rainfall) | 1976, 1995 |
| 2. | El Niño episodes (many locations received normal rainfall) | 1972, 1977, 1997 |
| 3. | Neutral years (many locations received deficient rainfall) | 1979, 1986 |
| 4. | La Niña episodes (many locations received normal rainfall) | 1970, 1973, 1975 |
| 5. | La Niña episodes (many locations received deficient rainfall) | 1974 |
| 6. | Neutral years (many locations received excess rainfall) | 1978, 1996 |

many locations viz., Hisar, Bhiwani, Gurgaon, Delhi and Chandigarh received deficient monsoon rainfall which was contrary to the global observation of association between SST anomalies and rainfall distribution.

### *Spatial distribution of excess/deficient monsoon rainfall in El Niño episodes*

The different locations in the sub-division with excess/deficient rainfall under El Niño episodes have been given in Table 4. During the El Niño years of 1976 and 1995 only, many locations received excess monsoon rainfall. In the year of strongest El Niño episode (Table 2), only one location Sirsa experienced excessive rainfall. These observations were contrary to the strong association between El Niño episodes and deficient Indian summer monsoon rainfall. However, in the years of El Niño episodes 1982 and 1987, many locations experienced deficient monsoon rainfall.

### *Spatial distribution of excess/deficient monsoon rainfall in La Niña episodes*

Monsoon rainfall was not deficient at any location in the La Niña years 1975 and 1988 (Table 5). However, in other La Niña years (1974 and 1989), some locations received even deficient rainfall. In the strongest La Niña year, all the locations experienced excess monsoon rainfall. Such aberrant behaviour of regional monsoon under SST anomalies was contrary to the general belief and quite complex to understand. The findings reported by Cheang (1993) while studying Malaysian rainfall corroborates the results of present study.

### *Episodes with exceptional influence on monsoon rainfall*

There were certain exceptional years of El Niño and La Niña episodes in which spatial complexity in monsoon rainfall behaviour at different locations in the sub-division over the period (1970-99) was observed (Table 6). In the two El Niño years (1976 and 1995) many locations reported excess rainfall but in the El Niño episodes of 1972, 1977 and 1997, most of the locations received normal rainfall. In La Niña years (1970, 1973 and 1975) most of the locations received normal rainfall in the monsoon season. But in 1974 (La Niña year) most of the locations received deficient monsoon rainfall also.

### *Monsoon rainfall categorization under strongest episodes*

During 1997, the strongest El Niño year, all locations received normal monsoon rainfall (Sirsa received excess), thus, indicating no influence of strongest El Niño on the regional behaviour of monsoon rainfall.

**Table 7:** Categorization of monsoon rainfall at different locations during extreme El Niño and La Niña episodes (1970-99)

| Sr. No. | Locations | Strongest El Niño (1997) | Strongest La Niña (1988) |
|---|---|---|---|
| 1. | SRS | *Excess* | Excess |
| 2. | HSR | Normal | *Normal* |
| 3. | BHN | Normal | Excess |
| 4. | NRL | Normal | *Normal* |
| 5. | RTK | Normal | *Normal* |
| 6. | GGN | Normal | *Normal* |
| 7. | DEL | Normal | Excess |
| 8. | KNL | Normal | Excess |
| 9. | AMB | Normal | Excess |
| 10. | CHD | Normal | Excess |
| 11. | Sub Div | Normal | Excess |
| 12. | NW Ind | Normal | *Normal* |
| 13. | All Ind | Normal | Excess |

Likewise, during 1988, the strongest La Niña episode, locations received either excess or normal monsoon rainfall (Table 7). Further exhaustive studies need to be done under extreme conditions of El Niño and La Niña episodes because of their dynamism and their anticipated affect on agriculture based economies so that the results can be used in a profitable way.

***Extreme monsoon rainfall years and corresponding SST anomalies***

The highest and lowest monsoon rainfall years with their corresponding SST anomalies have been presented in Table 8. It may be noticed that Sirsa, Rohtak and Gurgaon received their highest rainfall during El Niño years. However, Bhiwani and Narnaul received their highest monsoon rainfall in the year of no episodes (neutral year).

Similarly, lowest monsoon rainfall at Ambala was observed in the year of La Niña episode. The remaining other

**Table 8:** Extreme monsoon rainfall years at different locations and their corresponding SST anomaly (1970-99)

| Sr.No. | Locations | Year of highest monsoon rainfall | SST anomaly | Year of lowest monsoon rainfall | SST anomaly |
|---|---|---|---|---|---|
| 1. | SRS | 1997 | *El Niño* | 1987 | El Niño |
| 2. | HSR | 1988 | La Niña | 1987 | El Niño |
| 3. | BHN | 1993 | Neutral | 1987 | El Niño |
| 4. | NRL | 1996 | Neutral | 1987 | El Niño |
| 5. | RTK | 1995 | *El Niño* | 1987 | El Niño |
| 6. | GGN | 1995 | *El Niño* | 1987 | El Niño |
| 7. | DEL | 1988 | La Niña | 1987 | El Niño |
| 8. | KNL | 1988 | La Niña | 1987 | El Niño |
| 9. | AMB | 1988 | La Niña | 1975 | *La Niña* |
| 10. | CHD | 1988 | La Niña | 1987 | El Niño |
| 11. | Sub Div | 1988 | La Niña | 1987 | El Niño |
| 12. | NW Ind | 1994 | *Neutral* | 1987 | El Niño |
| 13. | All Ind | 1988 | La Niña | 1972 | El Niño |

locations received their respective lowest monsoon rainfall in the year of El Niño episode.

### *Association between monsoon rainfall pattern and El Niño/La Niña episodes*

The strength of the association between SST anomalies (El Niño/La Niña episodes) was tested by applying $c^2$ (chi-square) test. Three classes of SST anomalies in the pacific ocean viz., El Niño, La Niña and neutral years were tested with three categories of monsoon rainfall viz., excess, normal and deficient rainfall by preparing 3x3 contingency table and the values, thus, calculated have been given in Table 9. The calculated values of $c^2$ ranged between 1.42 and 9.77. The calculated value of $c^2$ on All India scale (9.77) was higher than the tabulated value of $c^2$ (9.49) at 5 per cent level. The remaining other locations produced $c^2$ values lower

**Table 9:** Chi-square ($\chi^2$) values between monsoon rainfall at different locations and SST anomalies (1970-99)

| Sr. No. | Locations | Data series | $\chi^2_{cal}$ value |
|---|---|---|---|
| 1. | SRS | 1970-99 | 2.15 |
| 2. | HSR | 1970-99 | 7.16 |
| 3. | BHN | 1970-99 | 5.40 |
| 4. | NRL | 1970-99 | 5.40 |
| 5. | RTK | 1970-99 | 1.42 |
| 6. | GGN | 1970-99 | 4.34 |
| 7. | DEL | 1970-99 | 2.21 |
| 8. | KNL | 1970-99 | 1.72 |
| 9. | AMB | 1970-99 | 4.76 |
| 10. | CHD | 1970-99 | 4.17 |
| 11. | Sub Div | 1970-99 | 6.85 |
| 12. | NW Ind | 1970-99 | 8.23 |
| 13. | All Ind | 1970-99 | 9.77 |

$\chi^2_{tab}$ (d.f.= 4) value at 5% level of significance = 9.49

than the tabulated values. As the $c^2_{cal}$ was lower than $c^2_{tab}$ indicating no association between SST anomalies and monsoon rainfall behaviour at different locations in the entire sub-division. However, association was observed between these anomalies and All India monsoon rainfall as evident from $c^2$ test. While studying the El Niño and Indian monsoon relationship (Krishna Kumar *et al.*, 1995) observed occasions of droughts in India in absence of El Niño and vice-versa. They advocated identification of a major non-ENSO phenomenon on the monsoon, which so far has remained elusive. Mooley and Paolino (1989) also observed exceptional/no influence of ENSO episodes.

## CONCLUSIONS

During the El Niño episodes, many of the locations under study recorded excess rainfall in 11 to 22 per cent except for Karnal and Chandigarh. Even in 1997, the year of strongest El Niño episode, all locations received normal or excess monsoon rainfall in the entire sub-division. Only in 11 to 33 per cent episodes, the deficient rainfall monsoon was observed which corroborated the general linkage between El Niño episodes and deficient rainfall over India.

The broadly drawn conclusions from present investigation can be summarized as:

No significant association was observed between El Niño and La Niña episodes and monsoon rainfall behaviour at different locations in the entire study region

Spatial and temporal rainfall variability observed was quite high in the entire study region.

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