

Student Minor Research Project

**“THE RELATION BETWEEN SUMMER
MONSOON RAINFALL OVER COASTAL
ANDHRA PRADESH AND NAOI”**

BY

III BSc STUDENTS



Under the guidance of

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FEBRUARY, 2021

DECLARATION

I hereby declare that the work described in this student Minor Research Project has been carried out entirely by B.Sc students in the Department of Physics, Sri Y N College, Narsapur and further that it has not been submitted earlier either wholly or in part, to any, University or Institution.

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CERTIFICATE

This student Minor Research Project described in this project has been carried out by III BSc students under the guidance of Department of Physics. I certify that it is a bonafied work. The work is original and has not been submitted for any other Institution.



A handwritten signature in blue ink, appearing to read "A.P.V. Appa Rao".

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The Relation between summer monsoon rainfall over Coastal Andhra Pradesh and NAOI

1. Introduction

The Indian monsoon is a seasonal phenomenon in which the winds blow from the southwest half the year and from the northeast during the other half (see review by Krishnamurthy and Kinter 2003). The winds from the southwest bring copious moisture from the warm waters of the Indian Ocean over to the Indian land region. India receives most of its annual rainfall during June-July August-September (JJAS). The southwest monsoon, also known as the Indian summer monsoon, exhibits considerable variation in rainfall on intraseasonal and interannual time scales (Krishnamurthy and Shukla 2000).

The lack of long-term data for the tropics, as pointed out by IPCC AR4, has been addressed to some extent for the Indian region with the recent release of high resolution daily rainfall and temperature data by the IMD (Rajeevan et al. 2005, 2006; Srivastava et al. 2008). Using the rainfall data for 1951-2000, Goswami et al. (2006) showed that there was a significant increasing trend in the frequency and magnitude of extreme events over central India while a decreasing trend was found in moderate events. Similar increasing trend in very heavy rainfall events over central India was found on a longer time scale by Rajeevan et al. (2008). In the monthly mean rainfall over

different regions of India, Pal and Al-Tabbaa (2010) found increasing trend in the deficit rainfall and decreasing trend in the excess rainfall

Tropical cyclonic systems (mainly depressions) during SM season over the Bay of Bengal are the principal rain-bearing systems for India. Generally these systems form over Bay of Bengal north of 18°N and move in west-north-westerly direction. They produce abundant amounts of rainfall to the left of their tracks. After crossing the coast, they generally weaken due to cutoff of moisture. Many scientists studied the frequency and track of the tropical cyclones over the Pacific Ocean with respect to the warm episodes over the same ocean (Atkinson, 1977; Ramage and Hori, 1981; Pan, 1982; Chan, 1985; Wang and Chan, 2002; Chia and Ropelewski, 2002; Chu and Wang, 1997; Clark and Chu, 2002). The variability of meteorological and oceanic parameters over equatorial Pacific Ocean affects the atmospheric circulation in terms of changes in the position of heat sources and sinks. During La Nina event, the presence of well marked heat sources and sinks results in the intensification of the trade wind belt. El Nino event causes the displacements of the heat sources and sinks, the weakening of trade wind belt and shifting of the equatorial rainy area from the western equatorial Pacific to the central equatorial Pacific. This situation creates lot of adjustments in the atmosphere causing change of weather. Persistency of this type of situations leads to climate change. The El Nino affects the frequency of cyclonic systems in the Bay of Bengal. The area of formation of monsoon depressions shifts eastward over the Bay of Bengal during El Niño years. Warmer SST anomalies prevail over northwest and adjoining west-

central Bay of Bengal during pre-monsoon and monsoon seasons of El Niño years (Singh et al., 2001b & 2002).

The cyclonic systems over the North Indian Ocean are decreasing since 1970s (Bhaskar Rao et al., 2001). Their result is coinciding with the observation of GW and climate change during the last more than three decades. The GW is mainly due to an increase of CO₂ which is mostly anthropogenic. High-resolution global climate models indicate a decrease in tropical storm frequency in a CO₂ -warmed climate (Bengtsson et al., 1996 and Yoshimura et al., 1999). Some global climate models suggest an increase of intensities of the tropical cyclones with CO₂-induced warming (Krishnamurti et al., 1998).

Singh et al. (2001a) have considered the tropical cyclone frequency data over the North Indian Ocean from 1877 to 1998 and shown that there is indeed a positive trend in the enhanced cyclogenesis during November and May. These months account for the maximum number of severe cyclones over the North Indian Ocean. The coastal regions of Bangladesh, India and Myanmar have indeed become more prone to the incidence of severe cyclones during November and May.

Goswami et al. (2006), the Atlantic Multi-decadal Oscillation (AMO) produces persistent weakening (strengthening) of the meridional gradient of tropospheric temperature by setting up negative (positive) tropospheric temperature anomaly over Eurasia in the northern late summer/ autumn resulting in early (late) withdrawal of the SM and persistent decrease (increase) of seasonal monsoon rainfall. On inter-annual time scales, strong

North Atlantic Oscillation (NAO) or North Annular Mode (NAM) influence the monsoon by producing similar tropospheric temperature anomaly over Eurasia. The AMO achieves the inter-decadal modulation of the monsoon by modulating the frequency of occurrence of strong NAO/ NAM events.

NAO is a coherent north-south seesaw pattern in sea level pressures between Iceland and the Azores. When the pressures are low over Iceland (Icelandic low), they tend to be high over the Azores (Azores high) and vice versa. It is a significant regional climate fluctuation [Lamb and Pepler, 1987; Wallace and Gutzler, 1981; Bjerknes, 1964] and also an important pattern of global interannual variability [Hurrell and van Loon, 1997; Mann and Park, 1994]. Naidu et al. (2011) reported the NAOI in January and February exhibited inverse relationships with the frequency of the cyclonic systems over the Bay of Bengal in the summer monsoon season. After 1970 (i.e. in the GW era), the parameters of both Pacific and Atlantic Oceans show significant drastic changes like increase of NAOI and relaxation of SOI which are closely connected with reduction in the frequency of cyclonic systems over the Bay of Bengal in SM season

2. Data and Methodology

Summer monsoon rainfall over Coastal Andhra Pradesh is collected from the IITM Website. NAOI in months, January to May for the period 1950 to 2010 is taken from http://ioc3.unesco.org/oopc/state_of_the_ocean/atm/nao.php.

The relation between NAOI in different months starting from January to May and summer monsoon rainfall over Coastal Andhra Pradesh were examined. If the normalised value of NAOI is greater than or equal to 1 (one), it is considered as positive extreme. If the normalised value of NAOI is less than or equal to -1, it is considered as negative extreme.

The frequency of cyclonic systems (which includes depressions, storms and severe storms) generated over the Bay of Bengal in SM season for the period 1950– 2009 are collected from the report of the India Meteorological Department, India. Further, the relationships between the NAOI (January through May) and the frequency of cyclonic systems in SM season are quantified in terms of the correlation coefficients.

The correlations are tested using the t-statistic, $t = r [(n-2) / (1-r^2)]^{1/2}$, where n is the number of observations and r is the correlation coefficient between the parameters. If the t value is equal to 1.65, 1.96, 2.58 and 3.29, the relationship between the parameters is significant at 10%, 5%, 1% and 0.1% respectively.

3. Results and Discussion

The summer monsoon rainfall over Coastal Andhra Pradesh (Figure 1) is crucial for Kharif crop. This subdivision receives 535 mm rainfall in summer monsoon season with standard deviation of 124 mm. The relation between NAOI in different months starting from January to May and summer monsoon rainfall over Coastal Andhra Pradesh were examined. The relation between NAOI in April and the rainfall is significant at 10% level

with the correlation of -0.23. The time series of the normalised values of the rainfall and the NAOI are shown in Figure 2. The Figure clearly indicates the existence of the inverse relationship between them. If the normalised value of NAOI is greater than or equal to 1 (one), it is considered as positive extreme. If the normalised value of NAOI is less than or equal to -1, it is considered as negative extreme. Such extremes are tabulated (Table 1). In positive extremes, the Coastal Andhra Pradesh experiences 486.9 mm. The percentage departure of the rainfall from the mean is -9%. In negative extremes, the Coastal Andhra Pradesh experiences 569.48 mm. The percentage departure of the rainfall from the mean is +7%.

Mean Zonal Winds in Monsoon Months:

The mean zonal wind at 850hPa in the summer monsoon season showed the existences of Somali jet. The zonal wind speed of the Somali jet 30 knots. The westerly wind is particularly well marked below 20°N. The mean zonal wind at 150hPa in summer monsoon season reveals the pressure of tropical easterly jet stream in between the 3°N and 8°N. The Core touches the latitudes south of southern tip and is confined to southern Arabian Sea and the adjoining Western tropical Western Equatorial Indian ocean(>30m/s or 60 knots). The westerly wind maximum is concentrated along 40°N, particularly it is high (>60knots) over the domain 80°E-100°E, 38°N- 43°N (Figure 3).

Anomaly Zonal winds in Extremes of NAOI

For negative extremes of NAO, the composite zonal wind anomaly at 850 hPa are presented in **figure 4**. The anomaly positive wind belt extends from 6°N to 20°N. These positive anomalies have high strength (>15m/s) over SP India and surrounding oceanic area. This type of pattern indicates the intensification of low level jet. The anomalies over north India are negative. Anomalies over South China Sea are negative.

For positive extremes of NAO the composite zonal wind anomalies at 850 hPa are presented in **figure 5**. The anomalies are negative over SP India and adjoining major parts of Arabian Sea and over the eastern equatorial Indian Ocean. They are positive over Northern Bay of Bengal, Southern China and South China Sea and they are positive over north India. These type of condition indicates the weakening of westerly belt over SP India. This type of conditions reveal that the weakening of westerlies in the positive extremes of NAO leads to poor moisture transport towards India and strengthening of westerlies in the negative extremes of NAO leads to more moisture transport towards India.

At 150hPa level in the negative extremes of NAO, the anomaly winds over India as well as southern parts off India are negative. While in the positive extremes of NAO, the anomaly winds over India as well southern parts off the India are positive. The above patterns pinpoints the existence of high intensified tropical easterly jet stream in the case of negative extremes

of NAO and the existence of weakened tropical easterly jet stream in the case of positive extremes of NAO in **figure 6**.

Relationship between NAO and the FCS over the Bay of Bengal

The long term mean of frequency of cyclonic systems (including depressions, deep depressions ,storms sever-storms) over the Bay of Bengal experienced in summer monsoon is 4.2 and standard deviation 2.2 during 1950 to 2009. The frequency of cyclonic systems over the Bay of Bengal in summer monsoon season showed inversely significant relationship with the NAOI of January, February and March with the correlation values are -0.38,-0.30 and -0.30 respectively. These figures(7,8,9) show the influence of NAOI on the frequency of cyclonic storm over BOB in summer monsoon season of the values of NAOI (January, February and March) is more , we can expect less number of cyclonic systems over BOB .If the values of NAOI is less we can experience more number of cyclonic storm over BOB .The cyclonic system in summer monsoon season form over BOB (around 18N).They move towards inland crossing the east coast of India causing good amounts of rainfall to the regions lying to the left of the tracks.

Conclusions:

In the case of negative extremes of NAO the rainfall activity over India is more and the monsoon system is intensified.

In the case of positive extremes of NAO, the rainfall activity over India is poor and the monsoon system is weakened.

The frequency of cyclonic systems over the Bay of Bengal in summer monsoon season showed inverse relationship with the NAOI in January through March.

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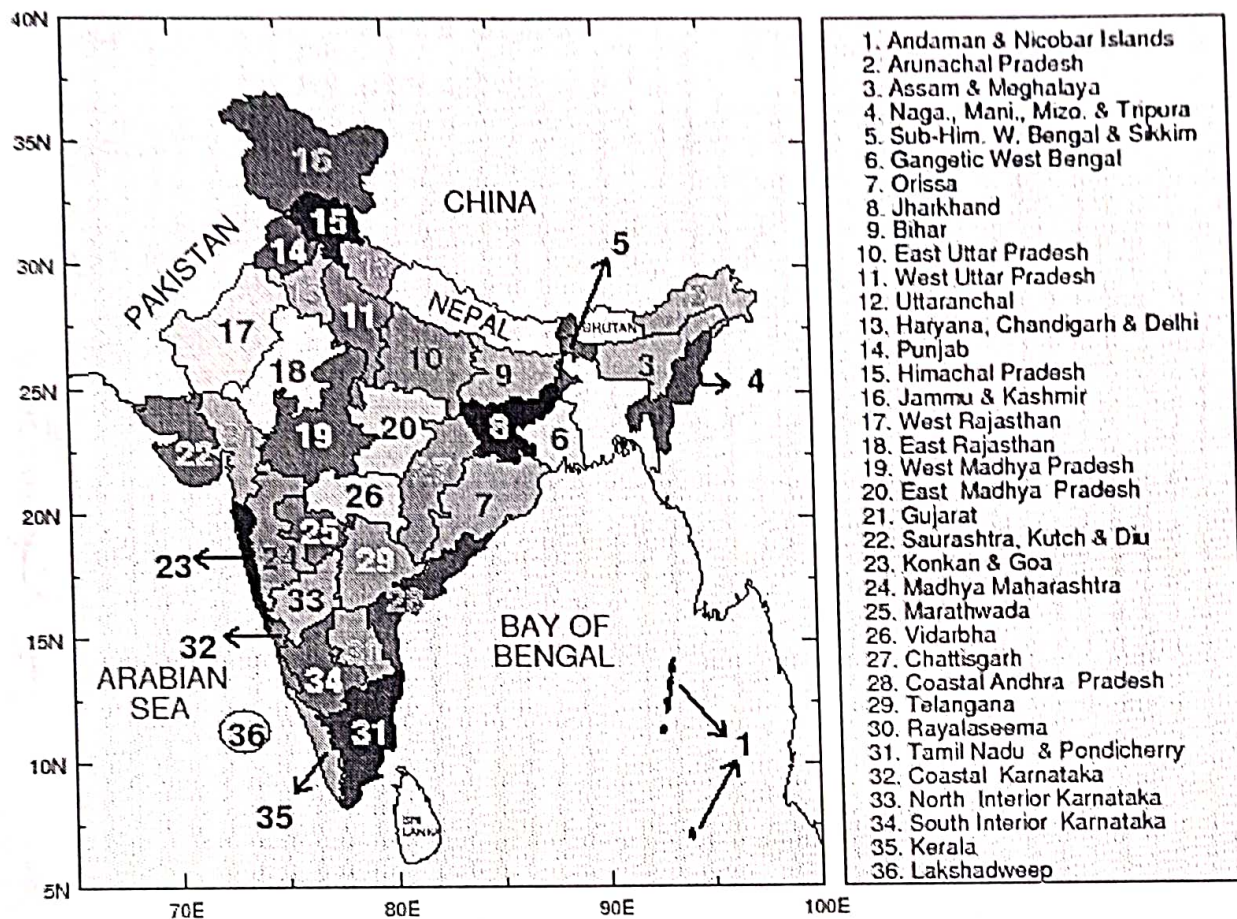


Figure 1: Meteorological Subdivisions over India

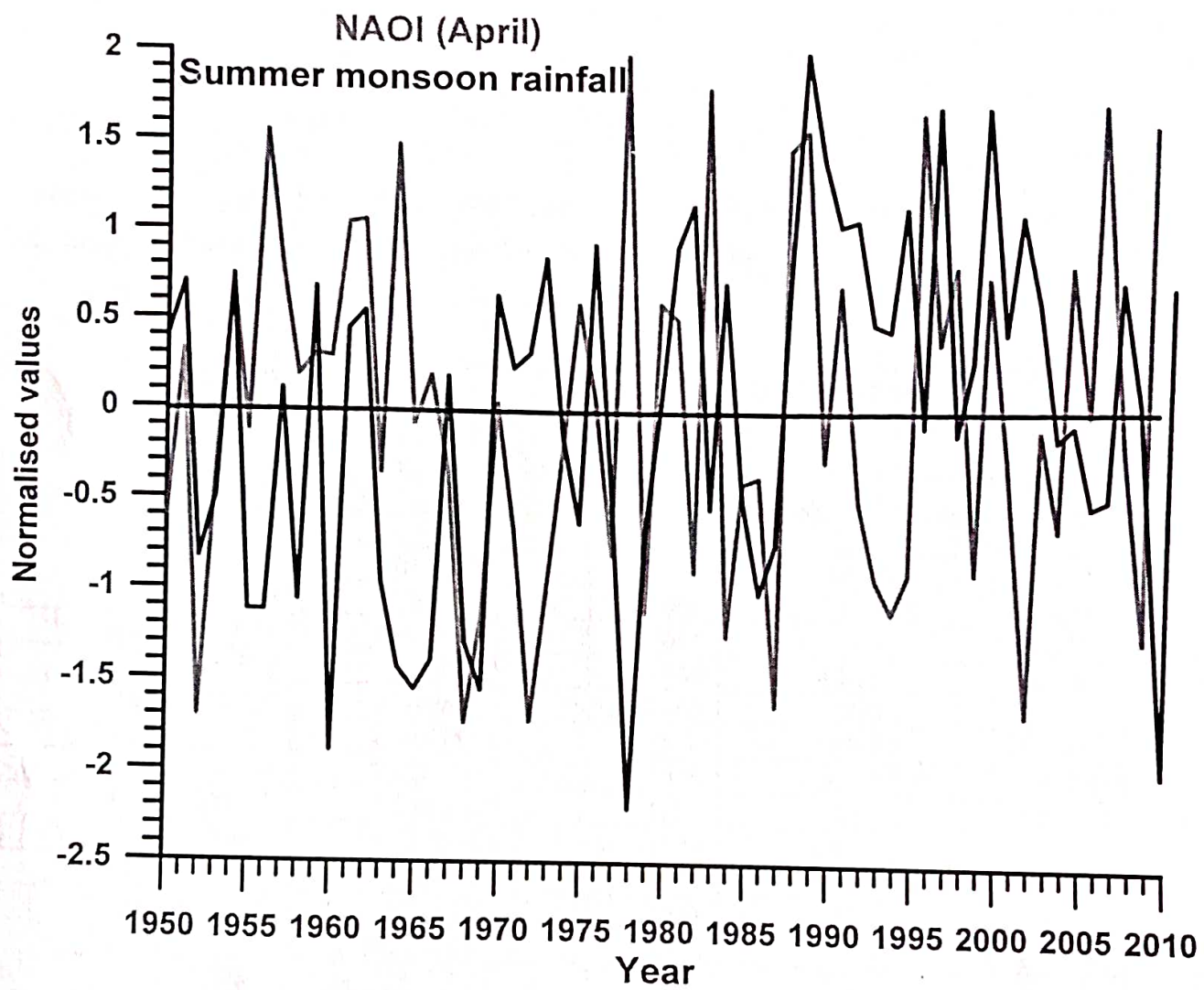
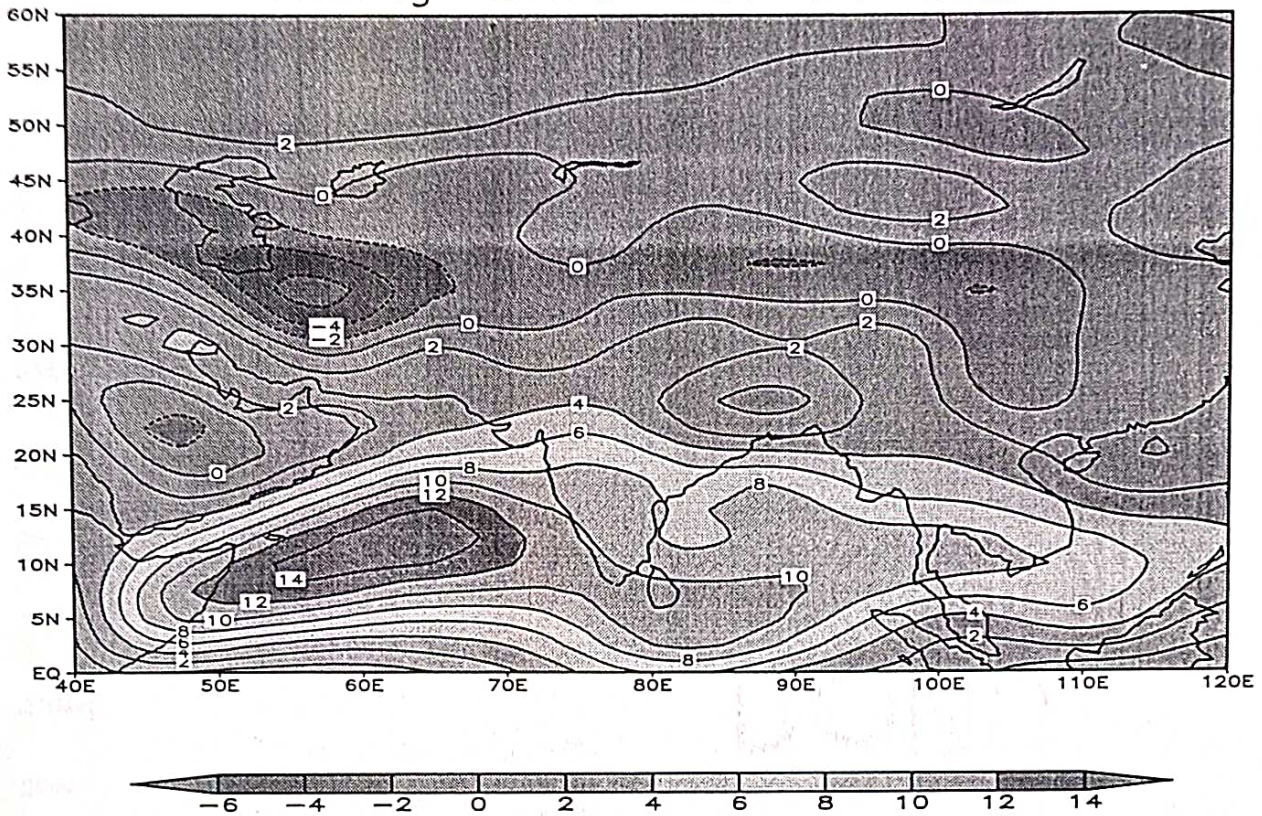


Figure 2: The time series of the normalised values of the Coastal Andhra Pradesh summer monsoon rainfall and the NAOI in April

Table 1: Extreme events of NAOI and the corresponding summer monsoon rainfall over Costal Andhra Pradesh.

+ ve extremes of NAOI				-ve extremes of NAOI		
Year	Rainfall	NORMALISED VALUES of NAOI		year	Rainfall	NORMALISED VALUES of NAOI
1952	323.6	1.014637		1953	495.1	-1.73433
1954	622	1.35313		1956	727	-1.10864
1960	571	1.373645		1961	664	-1.61125
1969	392	1.548		1963	491.3	-1.4061
1980	609.2	1.301843		1968	320	-1.12915
1987	333.4	2.030116		1970	539.7	-1.35481
1990	501.8	2.030116		1975	608.3	-1.66253
1992	774.3	1.886513		1978	780	-1.22147
1994	397.8	1.147983		1979	396.8	-1.77536
2002	328.5	1.189012		1988	715.6	-1.22147
2004	455.5	1.15824		1997	583.3	-1.06761
2006	534	1.250566		2008	512.6	-1.11889
Average	486.925 mm	1.44031675			569.475	-1.367634167
Long term mean	534.54				534.54	
Deviation from mean	-47.61				+34.94	
Percentage departure	-9%				+7%	

Average zonal wind at 850mb



Average zonal wind at 150mb

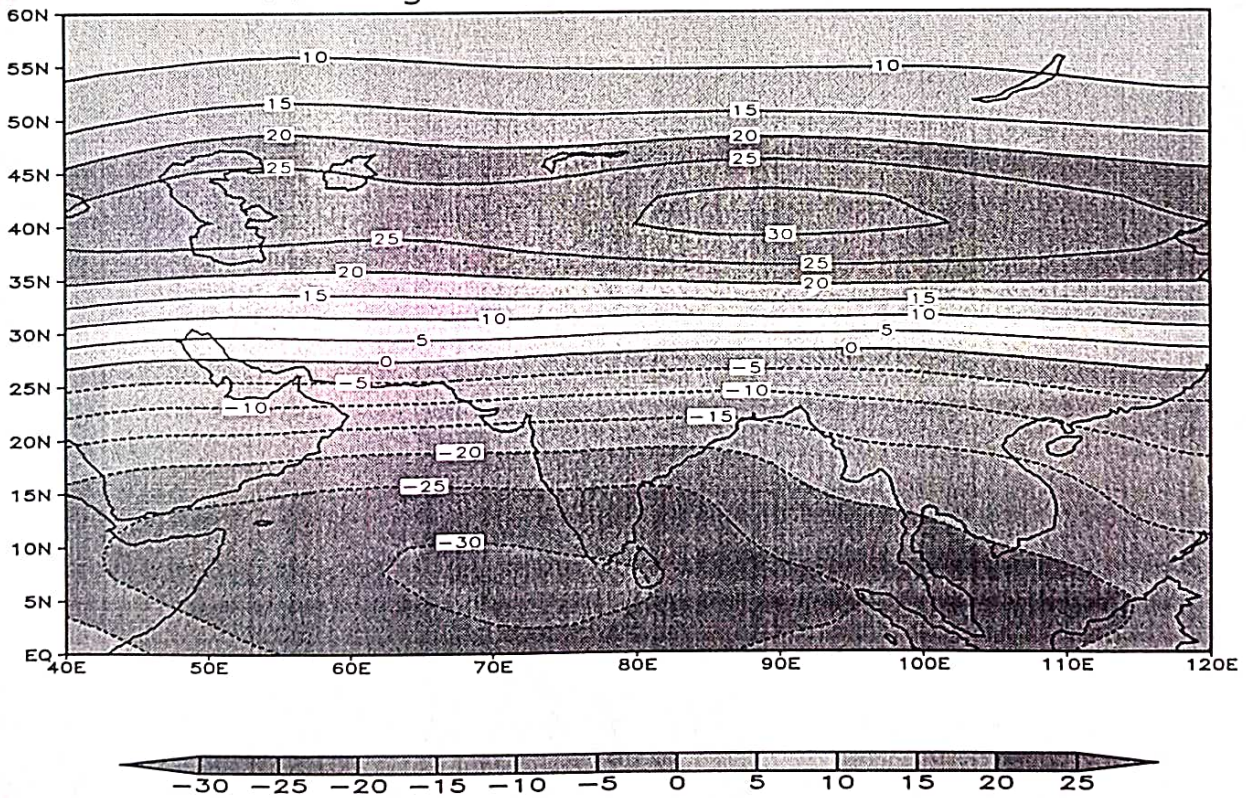


Figure 3 : The mean zonal winds at 850 hPa and 150 hPa

comp negative mean zonal wind at 850

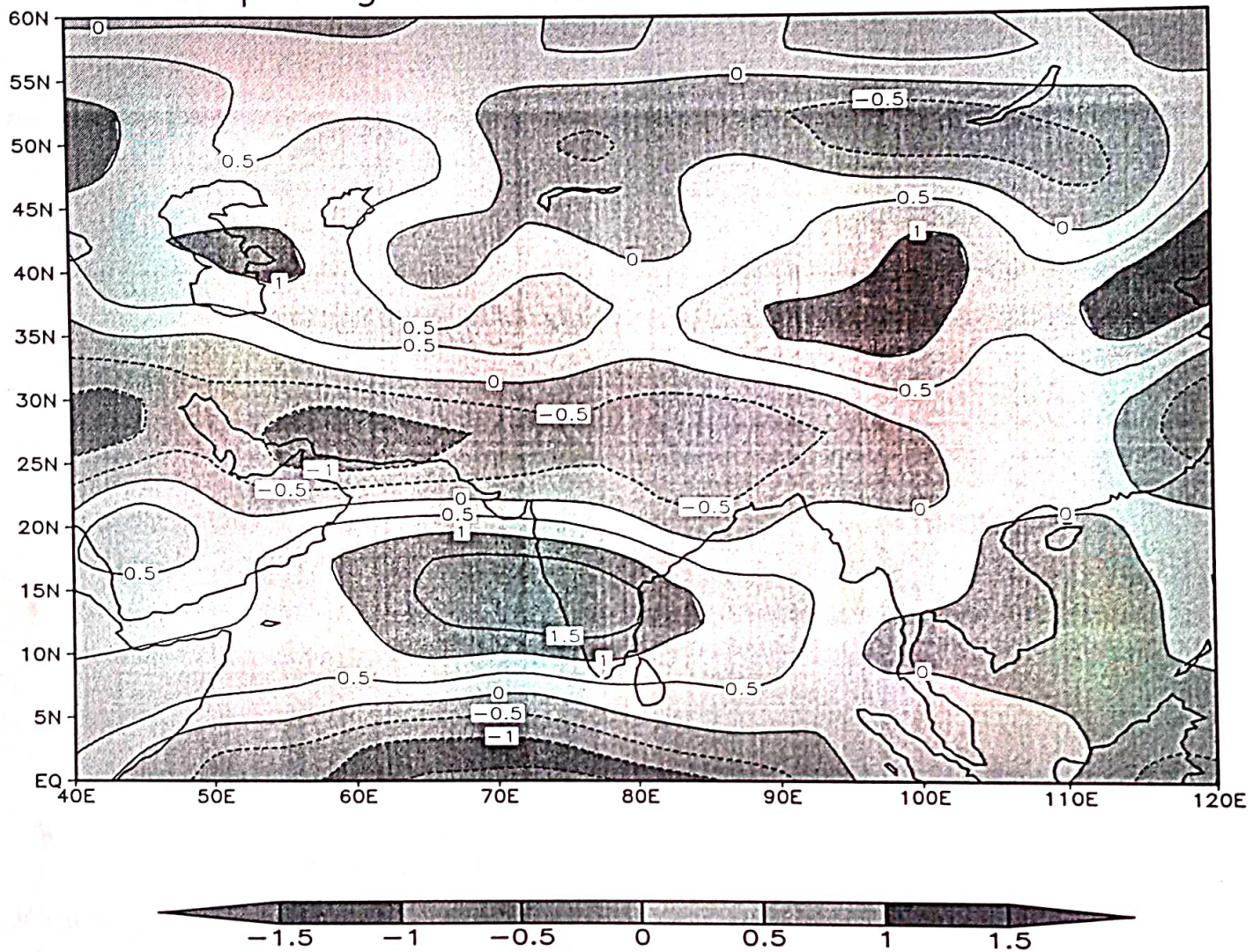


Figure 4: Anomaly zonal winds for the negative of NAOI at 850hpa

comp positive mean zonal wind at 850

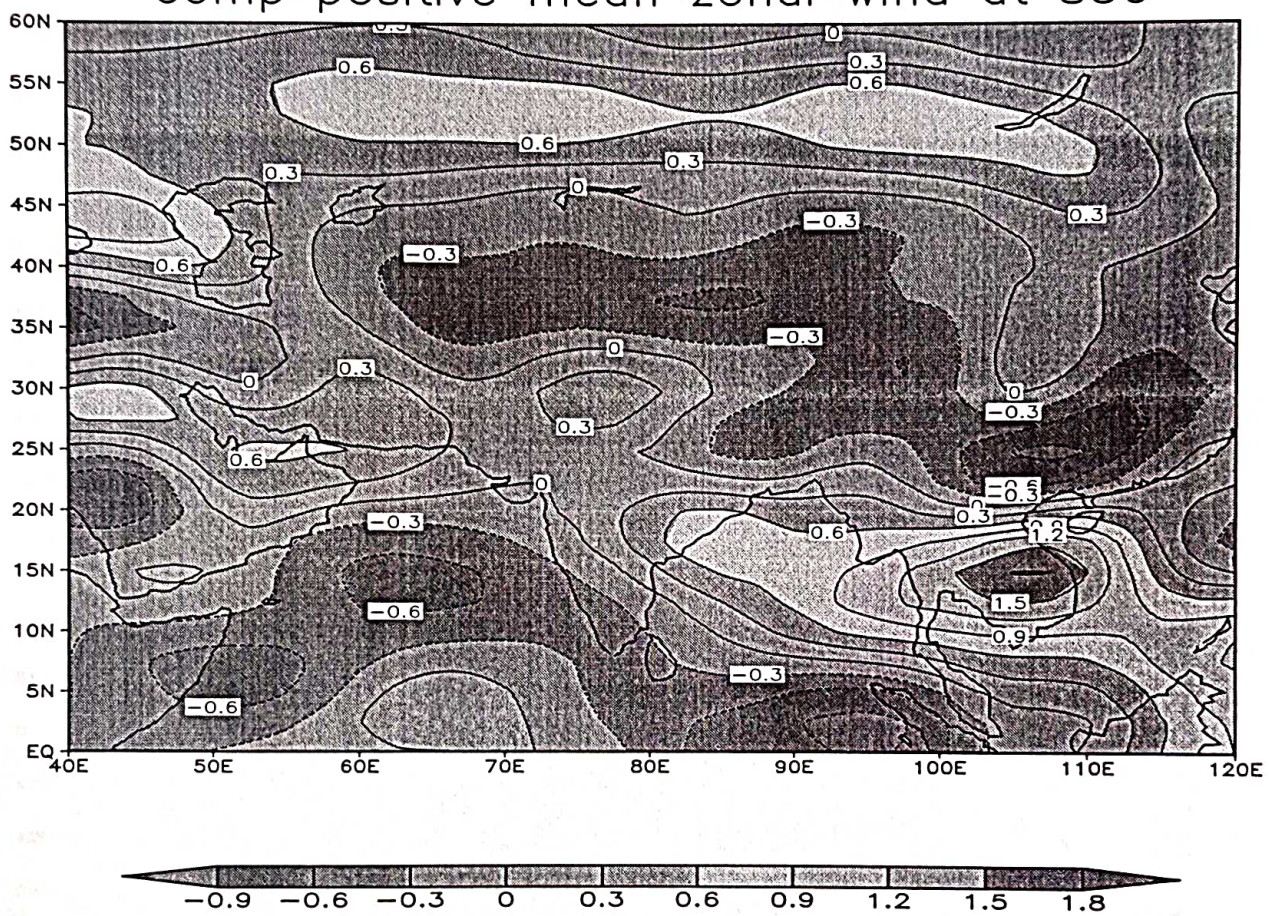


Figure 5: Anomaly zonal winds for Positive extremes of NAOI at 850 hPa

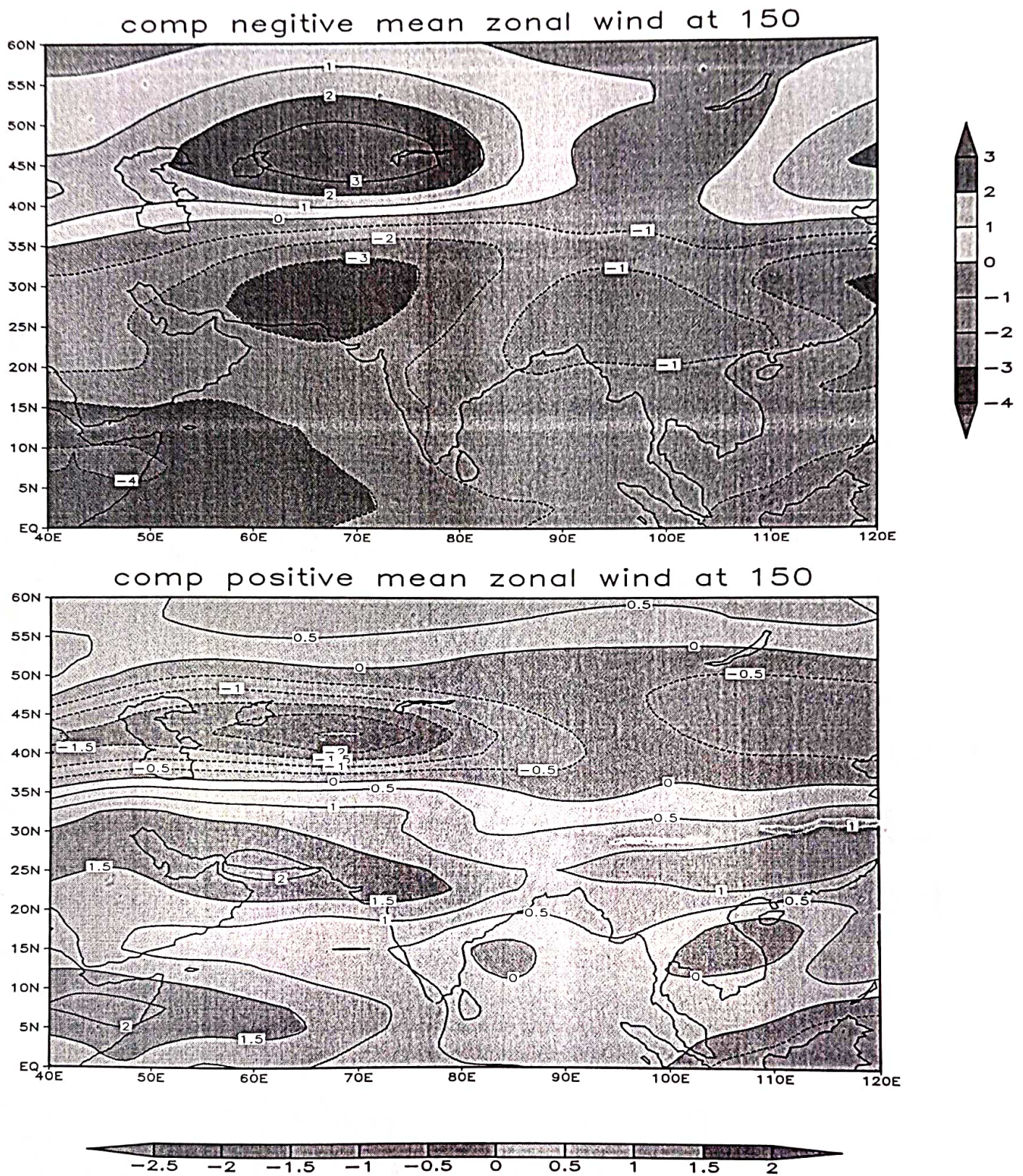


Figure 6: Anomaly zonal winds for the negative (upper panel) and Positive extremes (lower panel) of NAOI at 150 hPa

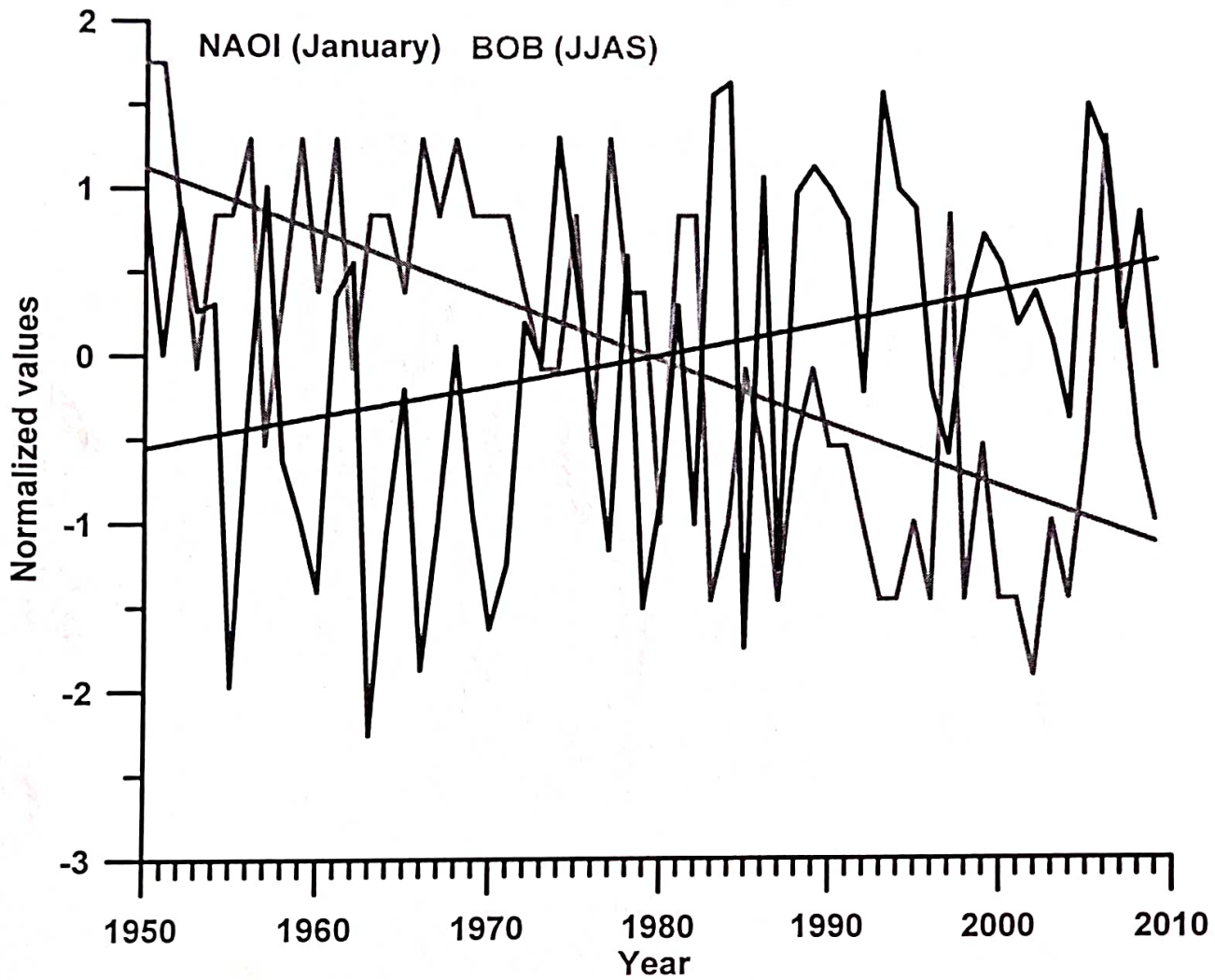


Figure 7: The time series of the normalised values of the frequencies of cyclonic storm over BOB in summer monsoon season and the NAOI in January

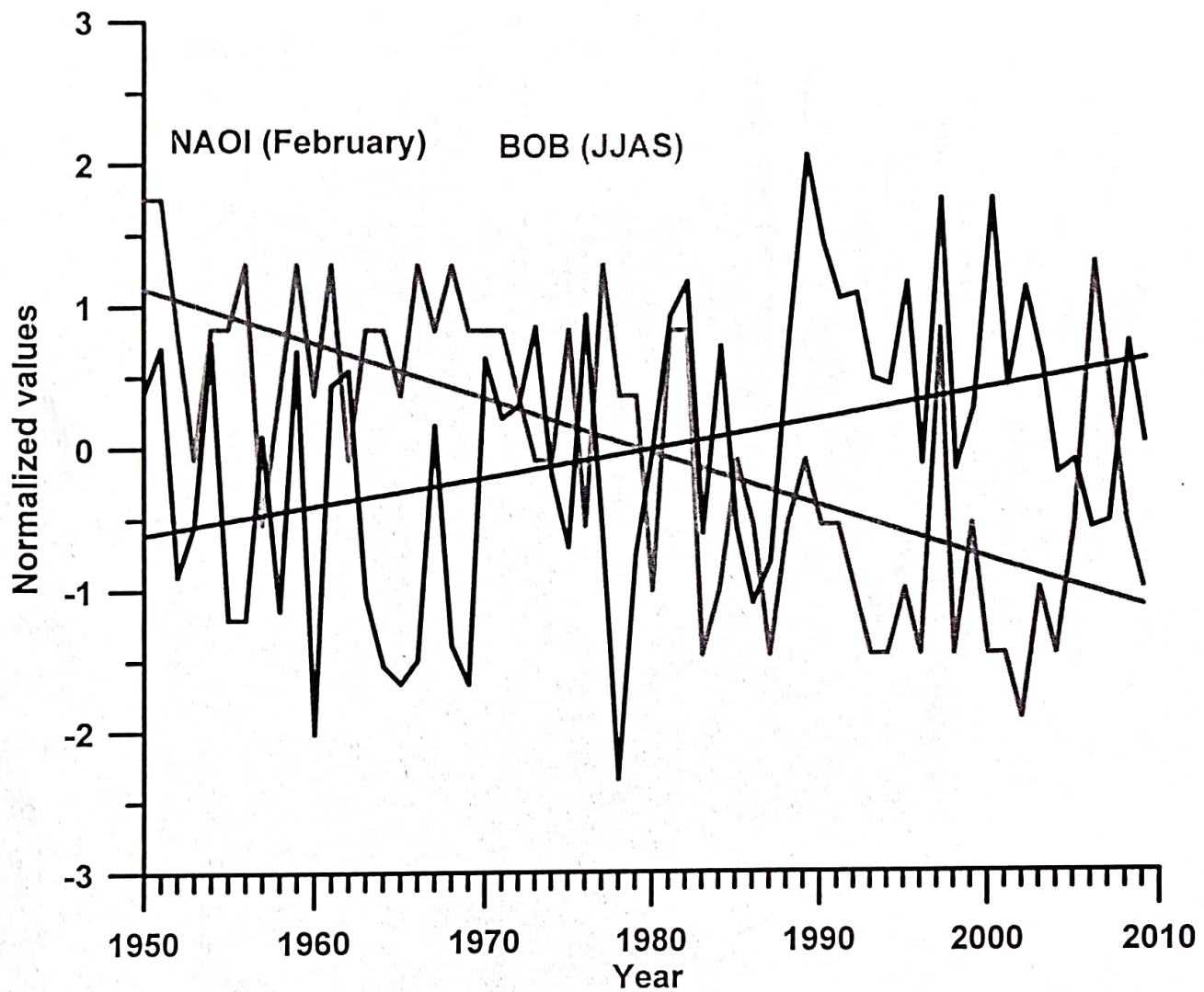


Figure 8: The time series of the normalised values of the frequencies of cyclonic storm over BOB in summer monsoon season and the NAOI in February

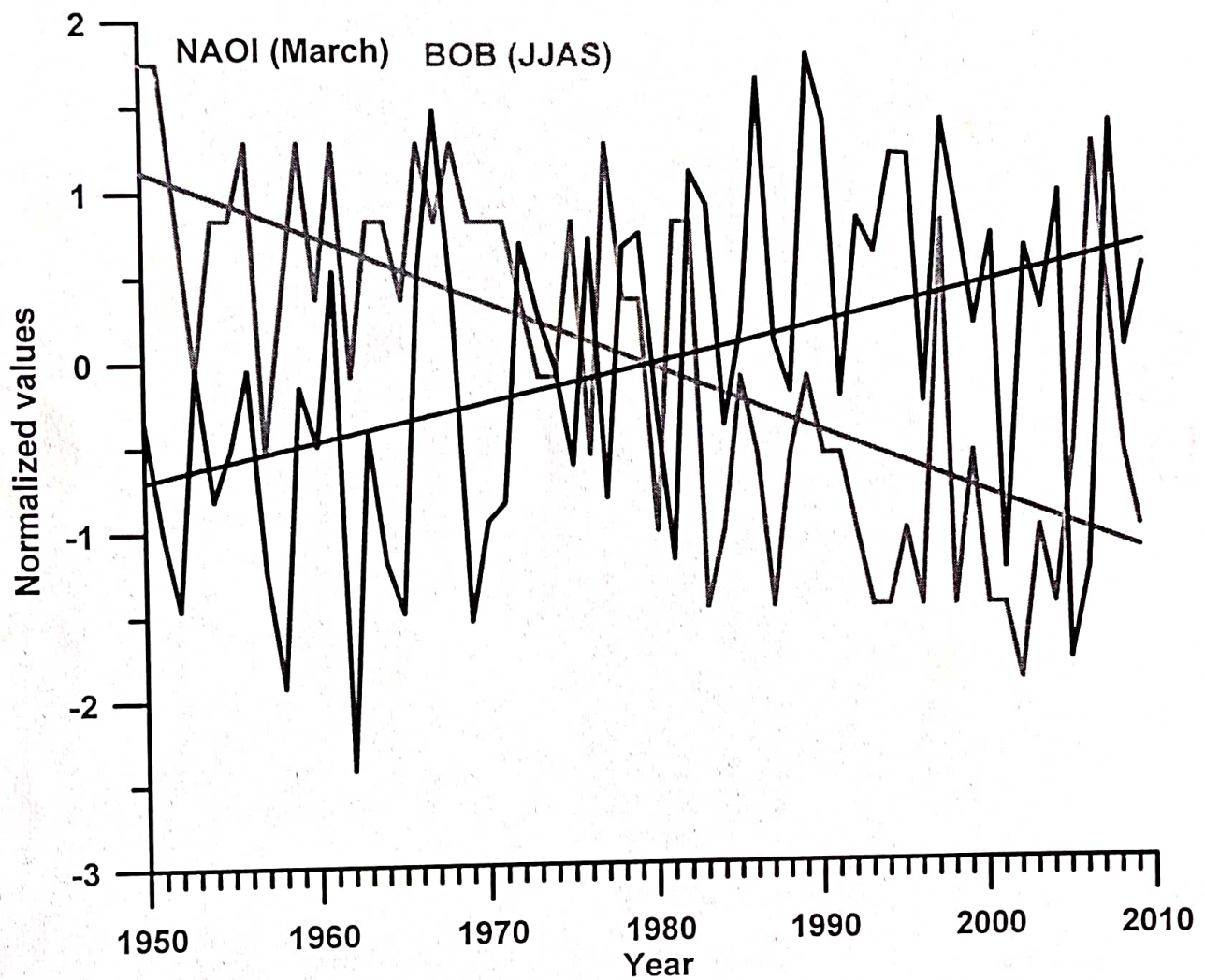


Figure 9: The time series of the normalised values of the frequencies of cyclonic storm over BOB in summer monsoon season and the NAOI in March

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