

Long term trends in the frequency of monsoonal cyclonic disturbances over the north Indian Ocean

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सार - इस शोध पत्र में वर्ष 1890 से 1999 तक के 110 वर्षों के आँकड़ों का उपयोग करते हुए दक्षिण पश्चिम मानसून ऋतु (जून-सितंबर) के दौरान बंगाल की खाड़ी और अरब सागर में बनने वाले चक्रवातीय विक्षोभों (अर्थात् अवदाबों और चक्रवाती तूफानों) तथा चक्रवाती तूफानों की दीर्घकालिक आवृत्तियों का अध्ययन किया गया है। दोनों की आवृत्तियों में उल्लेखनीय रूप से कमी की प्रवृत्ति पाई गई है किन्तु चक्रवातीय विक्षोभों की आवृत्ति में कमी तीव्र गति से आई है। इन प्रवृत्तियों का विश्लेषण करने से यह पता चला है कि मानसून ऋतु में चक्रवाती विक्षोभों की आवृत्तियों में प्रति सौ वर्ष से लगभग छः से सात तक विक्षोभों की दर से कमी आई है। मानसून ऋतु के चक्रवाती तूफानों की बारम्बारता में प्रति सौ वर्ष में एक से दो तक चक्रवातों की दर से कमी आई है।

ABSTRACT. Long term trends in the frequencies of cyclonic disturbances (*i.e.* depressions and cyclonic storms) and the cyclonic storms forming over the Bay of Bengal and the Arabian Sea during the southwest monsoon season (June-September) have been studied utilizing 110 years data from 1890-1999. There have been significant decreasing trends in both the frequencies but the frequency of cyclonic disturbances has diminished at a faster rate. The trend analysis shows that the frequency of cyclonic disturbances has decreased at the rate of about six to seven disturbances per hundred years in the monsoon season. The frequency of cyclonic storms of monsoon season has decreased at the rate of one to two cyclones per hundred years.

Key words - Cyclonic disturbance, Trend analysis, Variability, Cyclonic storm, Southwest monsoon, El Nino / Southern Oscillation (ENSO).

1. Introduction

The role of tropical cyclones and depressions in the climate of tropics can not be overemphasized (Riehl, 1979). The frequency of monsoon depressions forming over the north Indian Ocean especially over the Bay of Bengal is important for the summer rains over the central and northern parts of India. The main objective of the present study is to document long term trends in the frequencies of depressions and cyclonic storms forming over the Bay of Bengal and the Arabian Sea during the southwest monsoon season.

There have been some climatological studies on the storms and depressions in the Indian seas (Rai Sircar, 1958) but none of these have looked into the long term trends in the frequencies of cyclonic disturbances of the north Indian Ocean. Most of the studies on depressions and cyclones have dealt with the prediction of movement of these systems rather than prediction of their frequency (Sikka and Suryanarayana, 1968; Datta and Gupta, 1975; Neumann and Mandal, 1978).

The variabilities of different scales in the time-series of the frequencies of cyclonic disturbances may not be same in all the seasons. Similarly, the variabilities in the time-series of annual frequency may not reflect the inherent variabilities in different seasons. Therefore there is a need to examine the trends in the seasonal frequencies of cyclonic disturbances over the Bay of Bengal and the Arabian Sea. As monsoon depressions and cyclones are important weather systems of summer monsoon and there are large variations in their frequencies, an attempt has been made here to examine the long term modes in their frequencies.

2. Data and methodology

The frequencies of monsoon depressions and cyclonic storms that formed over the north Indian Ocean area from 5°N-35° N and 50° E-100° E (*i.e.* over the Bay of Bengal and the Arabian sea taken together) during the period 1890-1970 have been obtained from the IMD atlas (IMD, 1979). The frequencies during the period 1971-90 have been extracted from the addendum to the same

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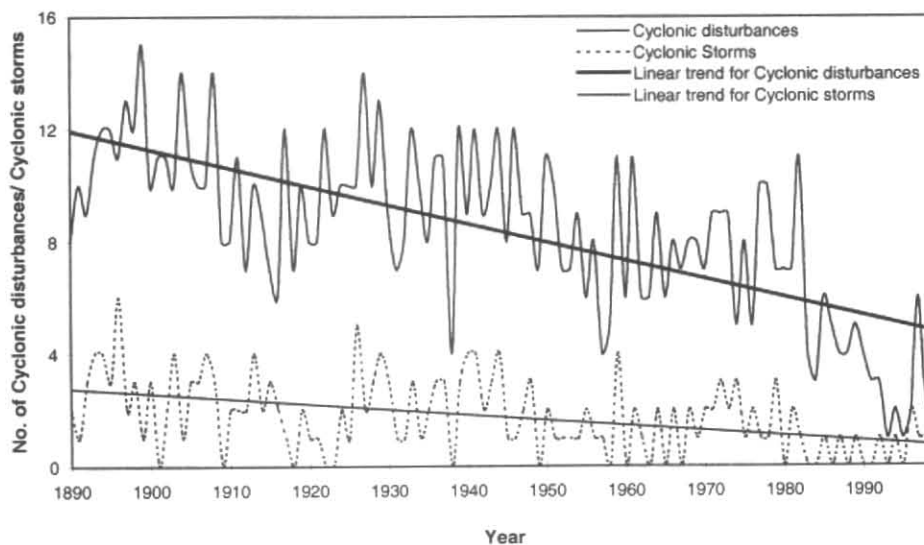


Fig. 1. Frequencies of monsoonal cyclonic disturbances and cyclonic storms (June-September) along with their trends over the north Indian Ocean during the period 1890-1999

atlas published by the IMD in 1996 and the frequencies for the recent period 1991-99 have been obtained from the quarterly Journal *Mausam* and IMD records.

The time-series of the frequencies of monsoonal cyclonic disturbances and the cyclonic storms have been subjected to the linear trend analysis using the method of least squares and the corresponding trend coefficients have been computed. The trends per hundred years presented in Table 1 have been obtained from the magnitude of trend coefficients, *i.e.* from the coefficient 'm' of the regression equation, $y = mx + c$. The significance of linear correlation coefficients has been tested using two-tailed *t*-test. As there were significant linear trends in the frequencies, the best fit lines in the least square sense have been computed and shown along with the time-series of the respective frequencies in Fig. 1.

3. Results and discussion

3.1. Trends in the frequency of total cyclonic disturbances over the north Indian Ocean during June to September

The time-series of the frequencies of total cyclonic disturbances *viz.* depressions and cyclonic storms and only cyclonic storms during the monsoon season from June to September for the period 1890 to 1999 have been presented in Fig. 1. There has been a significant decreasing trend in the frequency of monsoonal cyclonic disturbances in the north Indian Ocean. The linear trends in the

TABLE 1

The results of trend analysis

S. No.	Type of monsoon system	Trend (number per hundred years)
1.	Cyclonic disturbance	-6.6*
2.	Cyclonic storm	-1.9*

* Significant at 99% level

frequencies have been presented in Table 1. The frequency of monsoonal cyclonic disturbances in the north Indian Ocean has registered a decreasing trend of 6.6 disturbances per hundred years. The equation of the trend line for the frequency of cyclonic disturbances is

$$y = -0.066x + 12 \quad (1)$$

where *y* is the frequency of cyclonic disturbance and *x* is the year, *i.e.* 0, 1, ... etc., starting from the year 1890.

It is seen from Eqn.(1) that the trend correlation coefficient is -0.69 which is significant at 99% level. Highly significant negative CC shows the presence of decreasing trend in the frequency of monsoonal cyclonic disturbances in the north Indian Ocean. As revealed by Fig. 1 and Eqn.(1) there has been almost 50% reduction in the frequency of cyclonic disturbances during the monsoon season in recent years compared to the beginning of twentieth century. This is an interesting

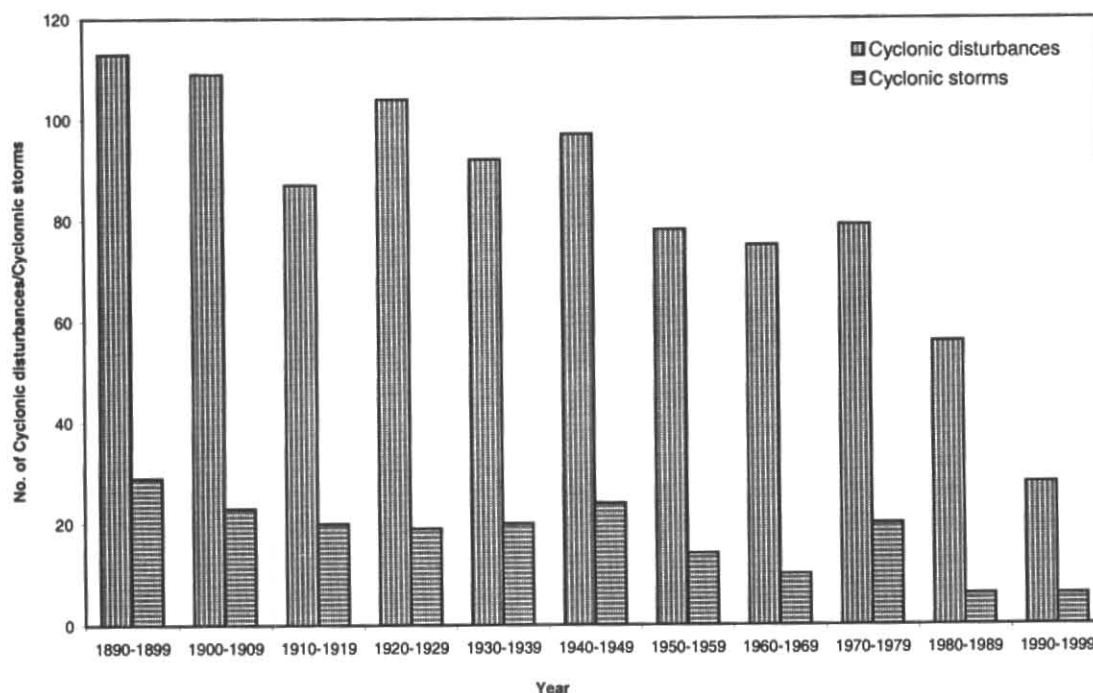


Fig. 2. Decadal frequencies of cyclonic disturbances and cyclonic storms (June-September) over the north Indian Ocean during the period 1890-1999

aspect for which the probable reasons need to be looked into. Some authors attribute the reduction in number of cyclonic disturbances to the advent of satellite era since 1960s and to a general falling trend (Ali and Chowdhury, 1997).

As shown by Fig.1 there is a definite falling trend in the frequency of cyclonic disturbances. The steepest trend is observed after 1980s but there is general falling trend since the beginning of twentieth century. The impact of satellite monitoring of cyclonic disturbances on the frequency seems to be very limited. In fact the frequency time-series does not reveal any abrupt discontinuity in the beginning of satellite era during 1960s.

3.2. Trends in the frequency of monsoon cyclones of the north Indian Ocean

As shown in Fig.1 the frequency of monsoon cyclones forming in the north Indian Ocean has registered a decreasing trend during last 110 year period. It could be seen from Table 1 that the trend is -1.9 per hundred years. The trend CC is -0.44 which is significant at 99% level, showing the existence of a decreasing trend in the time-

series of monsoon cyclone frequency. The equation of trend line is

$$y = -0.019x + 2.77 \quad (2)$$

where x is as defined in (1).

In the beginning of 20th century one to two monsoon cyclones used to form over the north Indian Ocean during the monsoon season every year. In recent decades the frequency has gone down to about one cyclone every alternate year. This amounts to more than fifty percent reduction in the frequency of monsoon cyclones of north Indian Ocean.

It is clearly seen from Fig.1 that there is a general falling trend in the cyclone frequency.

Thus to summarize, the main feature of long term trend in the frequency of total cyclonic disturbances in the north Indian Ocean during monsoon season has been a significant decreasing trend which does not seem to be the result of satellite era.

3.3. Decadal variabilities

The decadal frequencies of cyclonic disturbances and cyclonic storms during past eleven decades, *i.e.* 1890-1999 have been presented in Fig.2. Maximum number of cyclonic disturbances over the north Indian Ocean formed during the first decade of the period, *i.e.* 1890-99, the number being 112. Thus on an average about 11 depressions and cyclones formed every year over the Indian Seas in the monsoon season from June to September during the decade 1890-99. During the recent decade 1990-99, only 28 monsoon depressions and cyclones formed in the Indian Seas, the average seasonal frequency being only 2 to 3. However, there have been some decades when there was a spurt in the cyclogenesis as compared to the previous decades. For instance during 1920s more number of disturbances formed when compared with the corresponding number during 1910s. Similarly, during 1940s also the frequency was little higher as compared to 1930s. But after 1940s there is almost a continuous diminishing trend in the decadal frequency with the only exception during 1970s.

The decadal variability of cyclone frequency also shows more or less similar pattern. The maximum number of 29 monsoon cyclones occurred during the decade 1890-99. This number fell to 6 during the 1990s.

4. Conclusions

The following conclusions emerge.

(i) The frequency of monsoonal cyclonic disturbances in the north Indian Ocean has shown a significant decreasing trend during the twentieth century,

registering about fifty percent reduction from beginning to the end of the century.

(ii) The frequency of monsoon cyclones also has diminished considerably, the falling trend being more pronounced during recent decades.

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