Chapter - 6

Quasi – Biennial Oscillation fetches persistence in Tropical Cyclone

6.1 Preamble

The QBO (quasi-biennial oscillation) is a quasi-periodic oscillation of the equatorial zonal wind between easterlies and westerlies in the tropical stratosphere with a mean period of 28 to 29 months (Holton, and Lindzen, 1972). The amplitude of oscillation is maximum and nearly symmetric with respect to the equator. It has some peculiar characteristics. The alternating wind regimes develop at the top of the lower stratosphere and propagate downwards at about 1 km per month until they are dissipated at the tropical tropopause. Downward motion of the easterlies is usually more irregular than that of the westerlies (Takens, 1981). The amplitude of the easterly phase is about twice as strong as that of the westerly phase.

The purpose of this chapter is to view the nature of the cyclonic disturbances, tropical cyclones and severe tropical cyclones in the presence of upper air quasi - biennial oscillation (QBO). The cyclonic disturbances in the coastal regions of India are considered in this study. Statistical techniques are adopted to attain the objective. The results reveal that the tropical storms are more persistent during the presence of easterly waves of quasi biennial oscillation than the westerly phase of the wave.

Chaudhuri S and De Sarkar A, (2009), “Quasi – Biennial Oscillation fetches persistence in Tropical Cyclones” (communicated for publication)
6.2 Methodology and Implementation Procedure

Several statistical techniques are adopted to study the behaviour of cyclonic disturbances, tropical cyclones and severe tropical cyclones along the Indian coasts during the period of quasi-biennial oscillation. The annual frequencies of occurrence of cyclonic disturbances, tropical cyclones and severe tropical cyclones during the westerly and easterly phases of QBO are considered from the period of 1951 to 1986 (Mandal, 1991).

The different methods which are espoused for carrying out this study are;

i. Method of probability.

ii. Computations of auto-correlation

iii. Calculation of Shannon’s entropy.

6.2.1 Method of probability

It is generally preferable to express uncertainty quantitatively, and this is done using numbers called probabilities. In a limited sense, probability is not more than an abstract mathematical system that can be developed logically from three premises called the axioms of probability (Elsner, et.al., 1999).

The probability of an event is the ratio between the number of points in the sample space favorable to the event to the total number of points in the given sample space;
Pr(E) = (Number of points in the sample space favorable to the event E / total no of sample points)

The probability of an event follows some axioms. These are,

i. The probability of any event is non-negative.

ii. The probability of the compound event S is 1.

iii. The probability of one or the other of two mutually exclusive events is the sum of their individual probabilities.

The probabilities of turning of cyclonic disturbances (CD) into tropical cyclones (TC) are computed. The computation of the probability is made for both westerly as well as easterly movement of the quasi biennial oscillation (QBO). It is observed that the turning of cyclonic disturbances into tropical cyclones is more consistent during the easterly phases of quasi biennial oscillation than the westerly phase of the oscillation.

Further, the probabilities of turning of tropical cyclones (TC) into severe tropical cyclones (STC) in two different phases of quasi-biennial oscillation are also computed. It is observed that the turning of tropical cyclone into severe tropical cyclones during the easterly phase is also more persistent than that of the westerly phase (Frisch and Parisi, 1985).
6.2.2 Auto correlation coefficient

Equi-spaced data points constitute a time series. A correlation coefficient measures the degree of association between two time series. Auto-correlation function can be used for the following two purposes:

i. To detect randomness in dataset.

ii. To identify an appropriate time series model if the data are not random.

Auto-correlation is a correlation coefficient. However instead of correlation between two different variables, the correlation is between two values of the same variable at time \(x_i\) and \(x_{i+k}\). When auto-correlation is used to detect non-randomness, it is usually only the first auto-correlation (lag 1) that is of interest. When the auto-correlation is used to identify the time series model, the auto-correlations are usually plotted for many lags (Chaudhuri and De Sarkar, 2009).

However, in meteorology some time series appear very frequently that are persistent in nature. Persistence means the dependence of a variable on its own past values. The persistence is measured by the Auto Correlation Coefficient (ACC). This ACC is calculated by shifting the data series a few lags. For a data series with entries \(x_1, x_2, \ldots, x_n\), the ACC is calculated as:

\[
ACC = \frac{\sum_{i=1}^{n-1} (x_i - \bar{x})(x_{i+1} - \bar{x})}{\left( \sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=2}^{n} (x_i - \bar{x})^2 \right)^{1/2}} \tag{6.1}
\]
The existence of autocorrelation in meteorological and climatological data has important implications regarding the applicability of some standard statistical methods to atmospheric data. In particular, uncritical application of classical methods requiring independence of data within a sample will often give badly misleading results. In some cases it is possible to successfully modify these techniques, by accounting for the temporal correlation using sample autocorrelations.

The autocorrelation coefficient is computed among the cyclonic disturbances during easterly wave as well as the westerly wave of oscillation. The result reveals the existence of regular peaks at $2^{nd}$, $5^{th}$, $7^{th}$, $9^{th}$ lags in case of easterly waves of quasi biennial oscillation. The long time coherence depicts some degree of deterministic pattern within the data series. No such regular peaks are available in case of westerly phase of quasi biennial oscillation. In the similar fashion the autocorrelation coefficient for the occurrence series of tropical cyclones for both the phases of quasi biennial oscillation is computed. The result shows no particular pattern for the occurrence of tropical cyclones. The same methods are applied to the occurrence of severe tropical cyclones in the easterly as well as the westerly phases of oscillation. Significant pattern is not observed in such cases as well.
6.2.3 Shannon’s Entropy

The concept of Shannon’s entropy plays the central role for the information theory, sometimes referred to as measure of uncertainty. The entropy of a random variable is defined in terms of its probability distribution and can be shown to be a good measure of randomness or uncertainty.

Let \( X \) be a random variable and \( P \) the space of all finite probability distributions;

\[
P = \{ f / f : \text{dom}(X) \mapsto [0,1], x \in \text{dom}(X) = \{ s_1, ..., s_n \}, n = 1,2, ... \}
\]

The entropy associated with this probability distribution is defined as;

\[
H(X) = H(f(x) / x \in \text{dom}(X)) := - \sum_{x \in \text{dom}(X)} f(x) \log_2 f(x) \text{ bits}
\]

Where \( \text{dom}(X) \) is the value-set of variable \( X, x \in X \) a specific value and \( f \) the probability distribution of \( X \).

The Shannon’s entropy of turning of cyclonic disturbances into tropical cyclones and turning of tropical cyclones into severe tropical cyclones are computed for the different phases of quasi biennial oscillation.

6.3 Results and Discussions

The occurrences of cyclonic disturbances, tropical cyclones and severe tropical cyclones during westerly and easterly phases of QBO oscillation are considered during the period from 1951 to 1986 over different coastal region of India. The variations of turning of cyclonic disturbances into tropical cyclones in the westerly and easterly phases of QBO oscillation is computed (fig 6.1). It is
apparent from the figure that the oscillation in the easterly phase is more dominating over the westerly phase. The oscillation in the easterly phase shows peaks at higher values than that of the westerly phase. The variations of turning of tropical cyclones into severe tropical cyclones during the QBO phases of easterly and westerly waves are considered (fig 6.2). It is observed that the peaks appear in a regular interval in case of easterly waves. The peaks appear after a larger time intervals for westerly waves. The auto - correlation coefficients of cyclonic disturbances in easterly as well as westerly phase of QBO oscillation are computed (fig 6.3). The result reveals that there is a definite pattern for easterly wave that shows a regular coherence of peaks at 2\textsuperscript{nd}, 5\textsuperscript{th}, 7\textsuperscript{th}, 9\textsuperscript{th} lags of the data series. No such deterministic pattern is apparent in case of westerly phase of QBO.

The auto - correlation coefficients of tropical cyclones in both the phases are computed (fig 6.4). No such regular pattern is observed in this case. The autocorrelation coefficients of severe tropical cyclones also depict no definite pattern for long time forecasting potential (fig 6.5). The variations of Shannon’s entropy for turning of cyclonic disturbances into tropical cyclones for both the phases of QBO shows that the easterly phase is more persistence (fig 6.6). It is thus, clear that the turning of cyclonic disturbances into tropical cyclones is uncertain in the presence of westerly phase of QBO oscillation. The turning of cyclonic disturbances into tropical cyclones is more predictable. The variations of
Shannon’s entropy for turning of tropical cyclones into severe tropical cyclones represents higher possibility in case of westerly phase of QBO oscillation than easterly phase (fig 6.7). The figure also depicts that in case of easterly phase the turning of tropical cyclones into severe tropical cyclones are more predictable.

6.4 Conclusions

The results of the present study lead to conclude that the easterly phase of quasi biennial oscillation plays commendable role in case of cyclonic disturbances over Indian coasts. Thus it can be concluded that the occurrence of tropical storms over Indian coast are more predictable in case of easterly phase of quasi biennial oscillation than the westerly phase.
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Turning of cyclonic disturbances to tropical cyclones during the easterly and westerly wave

Fig 6.1 The Variations of Turning of Cyclonic Disturbances into Tropical Cyclones in Easterly and Westerly Phase of QBO Oscillation
Fig 6.2 The Variations of Turning of Tropical Cyclones into Severe Tropical Cyclones in Presence of Westerly and Easterly Phase of Oscillation

Turning of tropical cyclone into severe tropical cyclone during Westerly Waves and Easterly Waves

Values of Probabilities

-0.2 0 0.2 0.4 0.6 0.8 1

1 2 3 4 5 6 7 8 9 10 11 12 13 14

tc to stc (w)
tc to stc (E)
Fig 6.3 The Variations of Occurrence of Cyclonic Disturbances in The Westerly and Easterly Phase of Quasi Biennial Oscillation

Autocorrelation coefficient

Lags

lag-1 lag-2 lag-3 lag-4 lag-5 lag-6 lag-7 lag-8 lag-9

cd (w) cd (e)
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Autocorrelation coefficients versus lags

Lags

0 0.2 0.4 0.6
-0.2 -0.4 -0.6 -0.8 -1

sct (W) sct (E)
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