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Extreme value analysis and the return period of tropical cyclone parameters over maritime States of India

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सार --1890-1984 की अवधि की वार्षिक चक्रवात श्रृंखलाओं का प्रयोग करते हुए, समुद्रवर्ती राज्यों, तमिलनाडु, आन्ध्र प्रदेश, उड़ीसा, पश्चिमी बंगाल, महाराष्ट्र और गुजरात से सम्बन्धित विभिन्न प्रत्यावर्तन अवधियों के झंझा प्राचल $\triangle P$ के लिए चरममान विश्लेषण किया गया है। भारतीय तटों के लिए उपयुक्त मानक आनुभविक सम्बन्धों का प्रयोग करते हुए उन्ही प्रत्यावर्तन अवधियों से सम्बन्धित अन्य प्राचलों के लिए चरममान जैसे V_{max} तथा उच्चत्तम महोर्मि (तरंग) का अनुमान लगाया गया है।

ABSTRACT. Using annual cyclone series for the period 1890-1984, the extreme value analysis is carried out for the storm parameter $\triangle P$ for various return periods for the maritime States Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, Maharashtra and Gujarat. Using standard empirical relationships suitable for Indian coasts the extremes for other parameters, *viz.*, V_{max} and peak surge height are also estimated for the same return periods.

1. Introduction

With increasing economic activity, industrial growth and growing population on the Indian coastal belts, the penalty for not taking adequate precautions against the tropical cyclone, perhaps the nature's worst manifestation, needs no elaboration. The most important overall impact of a cyclone is from the wind stresses imposed on the water surface as well as on the habitation layer near the coastal areas affecting structures, buildings, human habitation, agriculture etc. Therefore, it is necessary to assess the local impact of these cyclones, especially while planning coastal developmental programmes and in this regard the study of return period analysis of the essential storm parameters is extremely important.

With this in view, a study is undertaken to find out the expected maximum value of the cyclone parameters for cyclones affecting the maritime States.

Such studies have been undertaken in India for some of the coastal projects (India Met. Dep. 1980, 1981), which are but restricted only to specified stretches of the coast. Ghosh (1985) has worked out the probable maximum storm surge on the coasts of India, where he has assumed the maximum expected value of $\triangle P$ to be 100 mb throughout the coast. Recently, Abrol (1986) based on 1925-1983 data has worked out $\triangle P$ values using method of least square fit for various return periods for the east coast of India taken as a whole.

In the present case the extreme value analysis is carried out for each maritime State separately since each State has its own peculiarity ranging from varying orography to bathymetry and combining all of them into a single series may be over-estimating the extremes for certain areas which may escalate the cost of planning activities over that particular coastal belt. Therefore, the analysis is carried out for each maritime State separately.

Though the most vital cyclone parameters are V_{max} (the maximum wind velocity in association with cyclones) and the peak surge height, in the present study the extreme value analysis is carried out only for the parameter, $\triangle P$, *viz.*, the pressure drop at the centre of the cyclone, since unfortunately, in most of the cyclonic storms the main handicap is the non-availability of actual record of maximum wind velocity in association with them. This is mainly because only a very small percentage of wind recording instruments survive the exposure to the wrath of cyclones. Same is the case with non-availability of peak surge height values. Nevertheless, it is comparatively easier to obtain or estimate $\triangle P$ values which is related to both V_{max} and peak surge. Several available empirical relationships suitable to Indian coasts are available inter-relating $\triangle P$, V_{max} and peak surge which can be made use of to obtain the parameters, V_{max} and peak surge from $\triangle P$ value.

TABLE 1

Extreme values of tropical cyclone parameters for different return periods over select maritime States

Maritime States	Parameters	Return period (yr) Probability given within brackets				
		10 (.90)	25 (.96)	50 (.98)	100 (.99)	200-yr (.995)
(1) Tamilnadu	$\triangle P$ (mb)	36	45	52	58	65
	V_{max} (kt)	85	95	102	108	115
	Peak surge (m)					
	North of 10°N	2.2	2.7	3.0	3.4	3.7
	South of 10°N	4.8	5.9	6.6	7.5	8.1
(2) Andhra Pradesh	$\triangle P$ (mb)	54	64	70	76	83
	V_{max} (kt)	104	113	119	125	129
	Peak surge (m)	3.8	4.2	4.8	5.2	5.6
(3) Orissa	$\triangle P$ (mb)	39	54	63	73	84
	V_{max} (kt)	89	104	113	121	130
	Peak surge (m)					
	South of 20.5°N	2.0	2.7	3.2	3.8	4.4
	North of 20.5°N	5.1	6.4	6.9	8.8	10.4
(4) West Bengal	$\triangle P$ (mb)	40	55	67	78	90
	V_{max} (kt)	90	105	116	125	135
	Peak surge (m)	4.5	6.3	7.8	9.2	10.9
(5) Maharashtra	$\triangle P$ (mb)	26	32	36	40	44
	V_{max} (kt)	72	80	85	90	94
	Peak surge (m)	1.1	1.4	1.6	1.8	2.0
(6) Gujarat	$\triangle P$ (mb)	38	45	50	55	61
	V_{max} (kt)	88	95	100	105	111
	Peak surge (m)	1.9	2.2	2.4	2.6	2.9

2. Data used

Since we have a hundred-year old well-documented history of all the cyclonic disturbances from depression stage onwards, the above analysis is carried out separately for all the cyclonic disturbances affecting each of the maritime States during a 95-year period, from 1890 to 1984, *viz.*, Tamilnadu, Andhra Pradesh, Orissa, West Bengal, Maharashtra and Gujarat coasts.

3. Method of approach

The return period analysis is done for the annual series of $\triangle P$ (in mb) for the period 1890-1984. For each year the extreme $\triangle P$ value recorded is considered for each maritime State which forms the basic data sequence for the extreme value analysis. Using the Fisher Tippet Type I distribution function given by $P(x) = \exp\left[-\exp-\left(\frac{x-\alpha}{\beta}\right)\right]$ the extreme value analysis is carried out for $x = \triangle P$, where $P(x)$ is the probability function. The constants α and β are determined using Lieblein's fitting procedure (WMO 1966), maintaining the original time order of the climatological series. The series (of 95 years data) is again divided into 19 sub-groups of 5 each and appropriate weights are used to determine α and β.

Having thus determined the constants, the expected $\triangle P$ values are computed for various return periods (T) using the relationship :

$$T = \frac{1}{1-P(x)}$$

Using Mishra and Gupta's formula (1976) relating V_{max} and $\triangle P$, by the relation V_{max} (in kt) $= 14.2\sqrt{\triangle P}$ the corresponding extreme V_{max} is also worked out for various return periods.

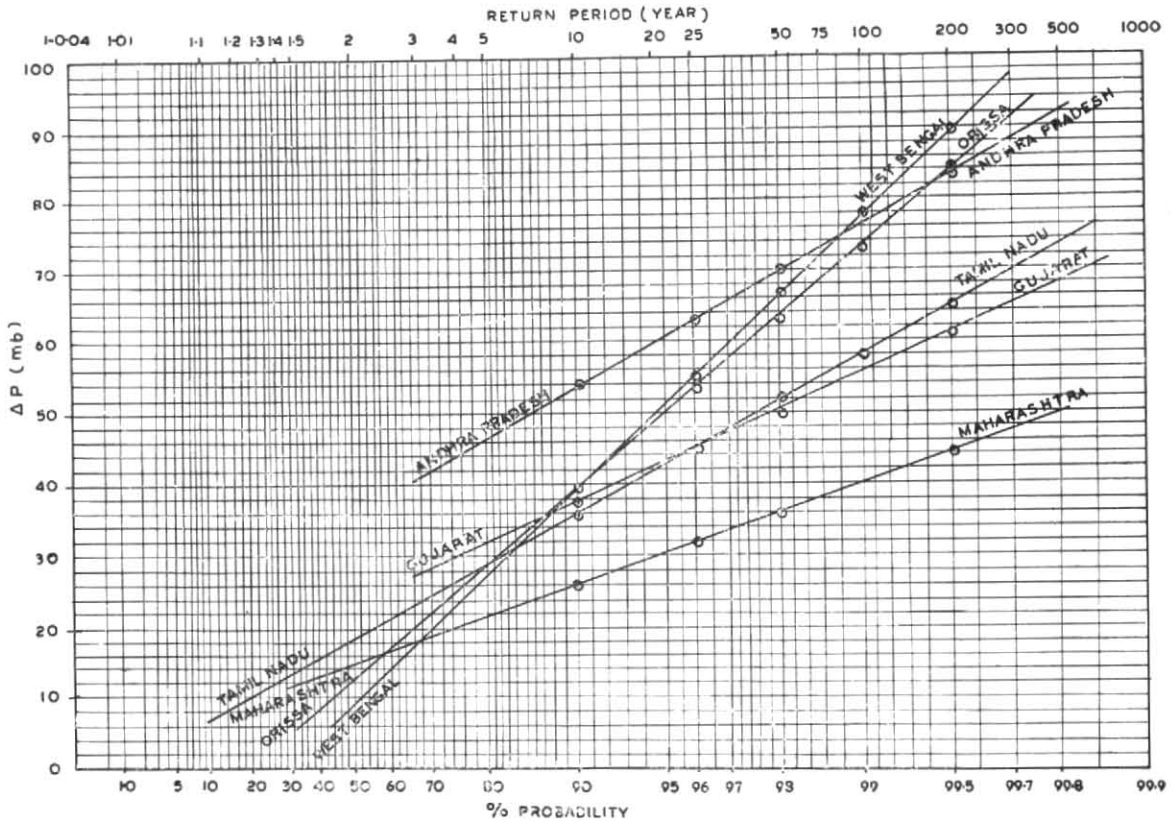

Fig. 1. Return period curves of $\triangle P$ (in mb) for maritime States of India

The estimates of the storm surge parameter are also presented using Ghosh's (1977) nomograms for east coast of India. For west coast of India the factors were taken from Ghosh's (1985) data. Also while estimating the peak surge, the angle of crossing is always taken as perpendicular to the coast. Also for radius of maximum wind, bathymetry factor, speed of movement etc the highest values of the correction factors given by Ghosh (1977, 1985) are considered. In the case of the maritime States Tamilnadu and Orissa, due to abrupt bathymetry differences, the peak surges are calculated separately for south of 10°N and north of 10°N and south of 20.5°N and north of 20.5°N respectively.

Table 1 gives the expected extreme values of the three storm parameters $\triangle P$, V_{max} and peak surge for the three maritime States. The fitted double exponential curves which assume the form of straight lines when plotted on a double logarithmic paper (extreme probability paper) are also given in Fig. 1. This will enable one to obtain the probable extreme value for any return period (or probability level) and *vice versa*.

4. Discussion of the results

Comparison of the extreme value curves for the maritime States indicates that for a given return period, west coast is likely to experience cyclones of lesser magnitude when compared to the east coast. In the east coast, Tamilnadu is likely to be affected by storms of lesser magnitude for a given return period when compared to other States. Also for the return periods upto about 75 years, Andhra Pradesh is prone to experience more intense storms than the other States while for return periods greater than 50 years the coastal West Bengal is likely to experience storms of higher intensity.

Further, as per the fitted extreme curves, the severe cyclonic storm of the magnitude which affected Andhra Pradesh in 1927, *viz.*, the Nellore cyclone of 1927 (where 919 mb was the lowest pressure recorded) is likely to have a return period of more than 500 years.

Similarly, the magnitude similar to the False Point cyclone of 1885 (where observed $\triangle P$ is 91 mb) is likely

to have a return period of more than 300 years. Likewise the Bakerganj cyclone of 1876 which recorded a storm tide of 40′ and the lowest pressure of 930 mb is likely to have a return period of more than 100 years.

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