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Use of microseisms in storm diagnosis

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सार–बंगाल की खाड़ी में आए झंझाओं से सूक्ष्म भूकम्पन उत्पन्न हुए । ये कम्पन विशाखापत्तनम और मद्रास में लगे स्परेन्नेथर सूक्ष्म भूकम्पन लेखी एवं पोर्ट ब्लेयर से मिलन-शा भूकम्पनलेखी पर अंकित हुए । यहां इनका अध्ययन किया गया है । जब झंझा की तीव्रता शिखर पर होती है तब सूक्ष्म कम्पनों के आयाम में प्रथमतः अधिकतम होता है और जब झंझा तट को पार करता है तब द्वितीयक अधिकतम सूक्ष्म कम्पनों आयाम A_M, A_V और A_P को क्रमशः मद्रास, विशाखापत्तनम और पोर्टब्लेयर पर 1961 से 1970 की अवधि में अभिलेखित किया गया । A_M/A_V और A_P/A_M के अनुपातों को दो अलग अलग मानचित्रों पर तत्संबंधित झंझा की स्थितियों पर आलेखित किया गया जैसा कि भारतीय दैनिक मौसम विवरण में दर्शाया गया है । इस प्रकार आयाम अनुपात की समय रेखाओं के दो समुच्चय मिले हैं । समरेखाओं ने इन दो समुच्चयों के सुस्पष्ट प्रतिच्छेद ने हमें इस योग्य बना दिया है कि यदि हमें आयाम अनुपात ज्ञात हो, तो हम झंझा की स्थिति ज्ञात कर सकत हैं । हमने 1971-1972 के दौरान इन आयाम अनुपात सचित्रों को झंझाओं का पता लगाने के लिए काम में लिया । इस विधि से ज्ञात की गई स्थिति भारतीय दैनिक मौसम विवरण में दिए गए तरीके से अक्षांश और देशान्तर में .5 अंश तक इधर उधर होती हुई मिलती जुलती है । जब मद्रास में चक्रवात अपने प्रचंड चरण में था, तब अयाम को अभिलेखित कर झंझा के केन्द्र में अभिरेखित किया गया तथा इन आयाम मानों से समरेखाएं (आयाम से चित्र) खींची गई । इससे यह पता चलता है कि झंझा की तीव्रता को ज्ञात करने के सचित्र को तैयार करने के लिए झंझा के अति सूक्ष्म विनिर्देश (जैसे अधिकतम पवन चाल) की आवश्यकता होती है ।

ABSTRACT. Microseisms generated by storms in the Bay of Bengal and recorded by Sprengnether micro-seismographs at Visakhapatnam and Madras and by Milne-Shaw seismograph at Port Blair have been studied. The amplitude of microseisms had a primary maximum when the storm is at peak intensity and a secondary maximum when the storm crosses the coast. Microseisms amplitudes A_M, A_V and A_P respectively recorded at Madras, Visakhapatnam and Port Blair during 1961 to 1970 were taken. The ratios A_M/A_V and A_P/A_M were plotted on two separate maps at the corresponding storm position as given in *IDWR* and thus two sets of amplitude ratio isolines were obtained. The clear-cut inter-sections of these two sets of isolines enabled us to locate the storm position when amplitude ratios are known. We applied these amplitude ratio charts for locating storm during 1971 and 1972. The location by this method was found to agree within 0.5 deg. in latitude or longitude as compared to the determination given in *Indian Daily Weather Report* (*IDWR*). Amplitude recorded at Madras when the storm was at severe cyclonic stage were plotted at storm centre and isolines (amplitude charts) were drawn through these amplitude values. It seems that preparation of such a chart for determining storm intensity requires more precise specification of storm (such as maximum wind speed).

1. Introduction

Records of sensitive seismographs show that there is always present a low level background movement of earth. These movements are called microseisms or earth noise. Regular microseisms have a range of period between 2 to 14 sec had along been known to be associated with large sea waves caused by various meteorological disturbances over the sea. Banerji (1930) had shown that microseisms were recorded on all seismographs whenever a cyclonic storm formed in the Bay of Bengal or in the Arabian Sea. The microseisms caused by a cyclonic storm had periods varying from 4 to 6 seconds and the amplitude displayed a characteristic variation suggesting superposition of waves of different period.

Two main theories had been proposed to account for the generation of microseisms. One presumed that microseims were generated in the area of the cyclonic storm, or high waves. The changes of pressure on the sea surface due to the propagation of free gravity waves were communicated to the sea bottom. This effective pressure field may be of first order in the form of a

TABLE 1

Station used in this investigation

Station	Location		Instrument	Compt.	Seis-mo-meter period (sec.)	Gal-vano-meter period (sec.)	Seism. damp-ing	Gal. damp-ing	Max. mag-nifi-cation
	Lat. (N)	Long. (E)							
Madras	13° 00′,	80° 11′	Sprengnether-microseismograph	E	7.5	7.5	—	1	5000
Visakhapatnam	17° 43′,	83° 18′	Sprengnether-microseismograph	E	7.6	7.6	—	1	5000
Port Blair	11° 40′,	92° 43′	Milne-Shaw	—	12.0	—	0.7	—	250

system of quasi-monochromatic waves and generates elastic modes of same frequency (Banerji 1930). According to this theory the sea waves and the microseismic waves should have the same periods.

The second theory attributes that there is also a second order pressure-effect shown to be analogous to piston like vertical motion of the water column produced by randomly distributed group of standing waves. This in turn communicates energy in the form of acoustic vibrations to the sea bed independent of the depth of the water layer and thus initiates microseisms with double the frequency of ocean swell (Longuet - Higgins 1950). The period of observed microseisms should therefore be nearly half the period of the observed sea waves. These two mechanisms sometime operate simulteneously as revealed by two distinct peaks in the amplitude spectra of microseims (Darbyshire and Okeke 1969). A spectral peak in the period 12-16 seconds band is attributed to primary frequency microseisms (corresponding to Banerji's theory) and the other peak in the period range 6-8 seconds band is called double frequency microseisms (corresponding to Longuet-Higgins theory).

Microseisms are transmitted as elastic waves through the surface of the earth. Detailed study of polarisation of microseismic waves shows that Rayleigh (LR) and Love (LQ) waves are the principal components of microseisms by sea storms and normally the contribution of Rayleigh waves is more than that of Love waves. The microseismic waves may sometimes have to cut across a geological discontinuity, in which case the amplitude may be sufficiently attenuated or the intervering discontinuity may cause change in the path due to refraction. Such discontinuity exists at continental margins where there are large geologic and bathymatric variations. Rayleigh wave as well as Love wave velocity decreases with an increase of low-velocity sediment and also water depth. Thus the tracks of microseismic wave paths are not generally straight line, but depend on the structure and elastic properties of media along the wave paths. Refraction diagrams have been drawn using the dispersion curves of LR and LQ for different parts of the world (Iyer 1958, Savarensky 1968, Krishna 1971). The propagation may further be complicated by mode conversion at the continental margin (Gregersen 1978).

There are various methods (Tandon and Bhattacharya 1969) of locating storm positions. Out of these methods in India, the tripartite method was tried by setting a tripartite station in Madras with central recording and each station having EW component of Sprengnether microseismograph. Locating storm by this method was not satisfactory presumably because of (*i*) mixing of Love and Rayleigh waves, each having normally different velocities (*ii*) curvature of propagation path of microseismic waves due to refraction in the earth's crust.

Gilmore (1951, 1953) introduced an empirical method for storm location, using amplitude ratio at a pair of stations. The technique is known as 'micro-ratio technique'. This method is based on the assumption that the amplitude ratio of microseisms at a pair of stations remains the same whenever any storm is located at a particular position irrespective of storm intensity or movement direction provided the instrumental constants remain the same. Iyer (1958) reported that Love wave to Rayleigh wave ratio is affected by storm intensity and bearing. In this study such an effect has been neglected and the Gilmore micro-ratio technique using two pairs of station has been tried for locating storm in Bay of Bengal.

2. Data

Records of microseisms obtained from Madras, Visakhapatnam and Port Blair have been used. The location and instrumental constants of the seismographs used at these stations are given in Table 1.

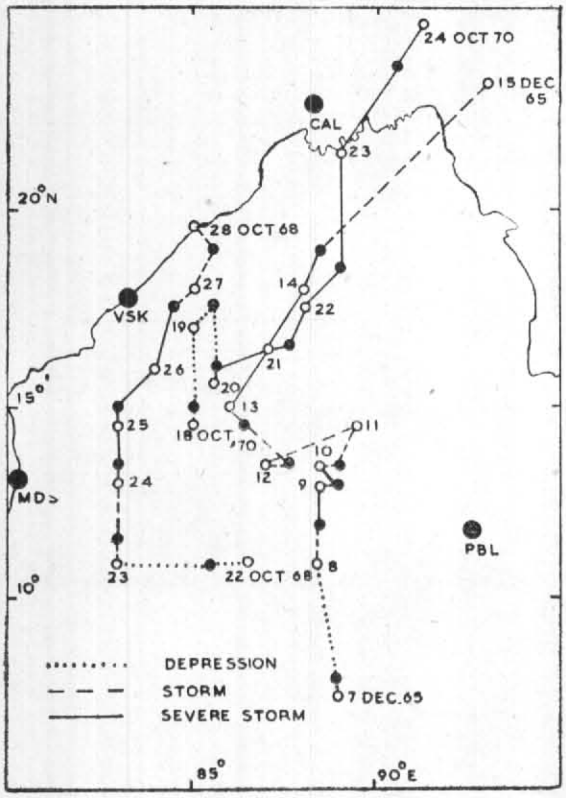

Fig. 1. Tracks of storms for which microseisms variations studied in Fig. 2. Open circles indicate the position at 0300 GMT and closed circles at 1200 GMT

The data used in the present investigation have been obtained from records of sprengnether micro-seismographs except in the case of Port Blair where records of Milne-Shaw seismograph have been used. The average amplitudes and periods have been measured from three good buildup of groups of microseisms within 5 minutes after the time of observation. The normal amplitude have been taken as the average microseismic amplitude on records during the months of January and February in the absence of any cyclone.

3. Amplitude and period variation of microseisms with the movement and intensification of storm

We have studied the amplitude and period variations of microseisms for three typical cases which have been shown in Fig. 2 for the storms of December 1965, October 1968 and October 1970 respectively. These storms intensified to severe cyclonic storms and their tracks are shown in Fig. 1.

The storm of December 1965 intensified to severe cyclonic storm from 8th evening to 10th morning when it started weakening, it again intensified to severe cyclonic storm from 13th morning to 14th evening and after that the storm weakened and moved fast to reach coast before the morning of 15th. The intensification of storm prior to 8th evening can be seen from the rise of amplitude of microseisms specially at Port Blair which was nearest to the storm position, the rise was almost simultaneous in all the three stations. The time of maxima of amplitude at these three stations did not differ significantly although maxima of amplitude was seen in Port Blair, Madras and Visakhapatnam in successions according to the closeness of the stations from the storm position. The second intensification of the storm is shown by the rise in amplitude at Madras and Visakhapatnam, while amplitude rise at Port Blair lags by a few hours as the storm intensified to severe cyclonic storm. The two amplitude maxima at each stations correspond to the intensity maxima of the storm. The period of microseisms was about 3 seconds in the beginning and increased to about 5.5 seconds corresponding to the time when storm reached shallow sea water area.

The storm of October 1968 intensified to severe cyclonic storm from 24th morning and weakened to storm on 26th evening. Intensification of the storm is seen with the rise of amplitude in all the three stations. Amplitude peaks at Madras and Port Blair almost coincided with the time of severe cyclonic stage of the storm. However, amplitude at Visakhapatnam started rising even after the cyclonic weakened to storm stage. The maxima seen on 27th morning was probably due to the proximity of storm position and also due to the effect of oceanic waves on continental shelf. The period changed only slightly and rose with increase in amplitude.

The storm of October 1970 intensified to a severe cyclonic storm in the evening of 20th and crossed coast on 23rd morning but continued as a severe cyclonic storm on land till 24th morning. Here also the intensification of storm can be visualized with the rise of amplitude in all the three stations. The max. of amplitude at Madras and Port Blair was seen on 22nd morning; this time corresponded nearly to the central position of severe cyclonic stage. However, the amplitude maximum at Visakhapatnam corresponded to the time of crossing of the coast by the storm. The period of microseisms in the record of Port Blair had a maximum on 21st when the storm intensified to severe cyclonic storm. However, the periods at Madras and Visakhapatnam were seen to rise with the movement of storm to shallow water area.

The above case studies along with the case studies by Tandon (1955) lead to the following inferences. The amplitude of microseisms are found to rise with the intensification of the storm and *vice-versa*. This is a phenomenon which has always been observed and can be taken as a forecasting aid. Microseisms amplitudes are

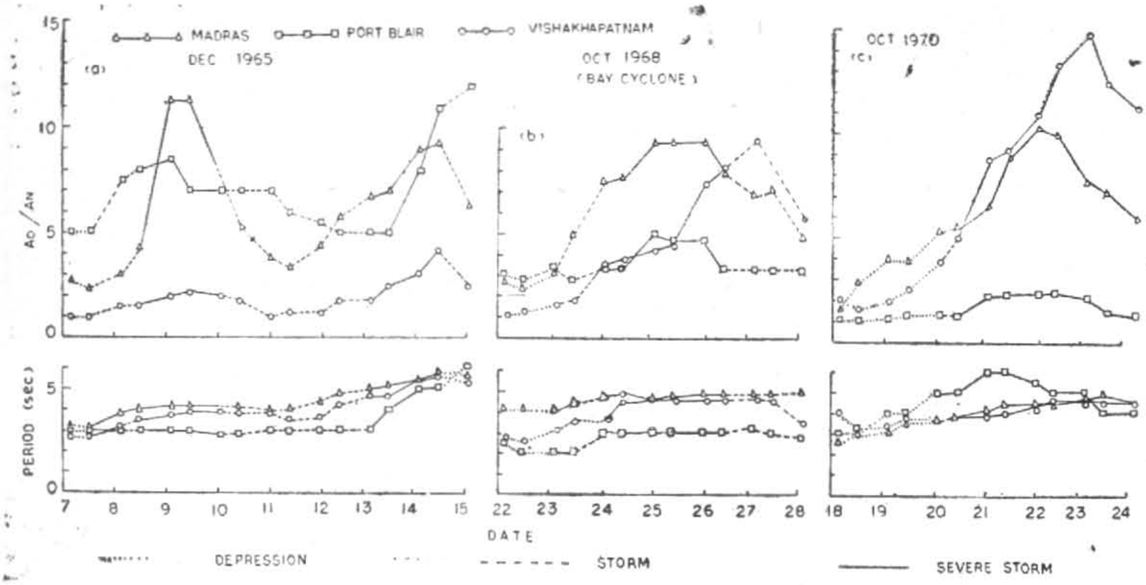

Fig. 2(a-c). Amplitude and period variations of microseisms with the movements of Bay cyclone of (a) December 1965, (b) Oct 1968 and (c) Oct 1970 respectively

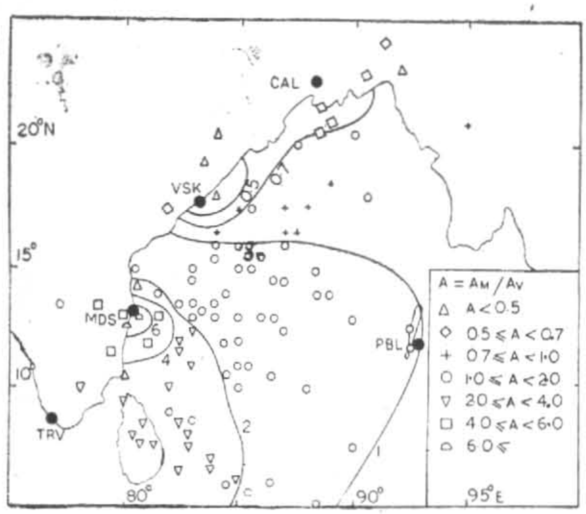

Fig. 3. Amplitude ratio chart for Madras amplitude: Visakhapatnam amplitude

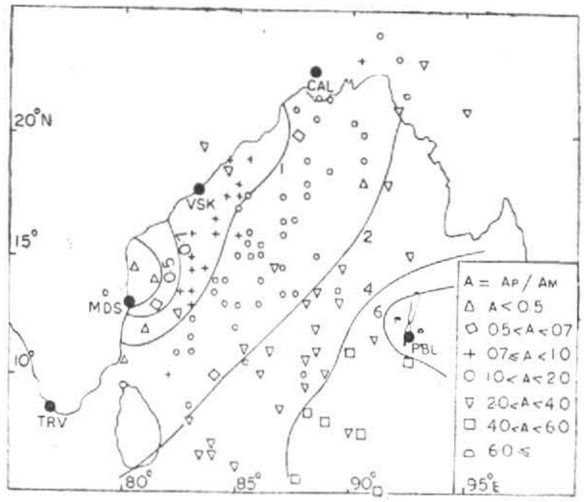

Fig. 4. Amplitude ratio chart for Port Blair amplitude: Madras amplitude

found to have two maxima. The primary maxima corresponds to intensification of storm and secondary maximum corresponds to the time of crossing the coast. The amplitude of microseisms is seen to decrease when the storm moves over land even if the storm does not weaken. Periods do not change significantly, primarily because the Sprengnether microseismograph at Visakhapatnam and Madras had peak magnification at about 3.8 sec and the magnification decreases sharply on both sides, *i.e.,* the ground vibrations of period at which seismograph has peak magnification are more magnified than vibrations at other periods. In the case of Milne-Shaw seismograph at Port Blair the magnification decreases after 4 sec period. However, there is a general tendency of the period to rise and fall with amplitude; there is also an apparent indication that the period increases with the arrival of storm over a shallow water area.

4. Use of micro-ratio technique and amplitude chart in storm diagnosis

4.1. *Preparation of amplitude-ratio isolines*

Microseisms generated by storms in the Bay of Bengal during the period 1961 to 1970 have been considered. Amplitudes of microseisms were measured when the storm intensity was at the deep depression stage or above. The ratio

TABLE 2

Verification chart

Date	Hours (GMT)	Mean amp. in mm MDS	Mean amp. in mm PBL	Mean amp. in mm VIS	Ratio of amp. MDS/VIS	Ratio of amp. PBL/MDS	Storm's centre by equal ratio lines (°N)	(°E)	Storms' centre & intensity as per *IDWR* (°N)	(°E)	
27 Sep 71	1200	0.8	1.3	1.0	0.8	1.6	18.5	90.0	18.5	89.5	Dep
28 Sep 71	0300	0.9	1.2	1.1	0.8	1.3	19.5	88.5	20.0	88.5	D. Dep.
	1200	0.9	1.2	1.5	0.6	1.3	21.0	88.5	20.5	88.5	CS
29 Sep 71	0300	1.2	1.5	2.0	0.6	1.3	21.5	88.0	21.5	88.5	SCS
14 Oct 71	0300	0.6	1.1	0.8	0.75	1.8	16.5	89.5	16.0	89.0	Dep.
	1200	0.8	1.0	1.0	0.8	1.25	17.0	87.5	16.5	87.0	D. Dep.
15 Oct 71	0300	1.0	0.8	2.1	0.5	0.8	18.0	85.0	18.0	85.0	SCS
	1200	1.1	0.9	DNA*	DNA*	0.8	—		18.0	83.0	SCS
16 Oct 71	0300	1.0	Earth-quake	DNA*	DNA*	DNA*	—		19.5	81.5	CS
27 Oct 71	0300	0.6	2.1	0.5	1.2	3.5	13.5	89.5	13.0	90.0	Dep.
	1200	0.6	DNA*	0.5	1.2	DNA*	—		14.6	90.0	D. Dep.
28 Oct 71	0300	1.0	DNA*	DNA*	DNA*	DNA*	—		16.0	90.0	CS
	1200	1.4	2.3	1.5	0.9	1.6	18.0	90.0	17.5	90.0	SCS
29 Oct 71	0300	1.5	1.8	2.2	0.72	1.2	19.5	88.0	19.0	88.0	SCS
	1200	1.6	1.6	3.2	0.5	1.0	Not intersecting		19.6	87.5	SCS
30 Oct 71	0300	2.1	1.8	3.7	0.6	0.8	20.5	86.0	20.6	86.5	SCS
	1200	2.5	P/F	2.5	1.0	DNA*	—		21.4	86.5	SCS
4 Nov 72	0300	0.4	1.65	0.3	1.3	4.1	12.0	90.2	12.0	91.0	Dep.
	1200	0.4	1.5	0.3	1.3	3.5	13.6	90.3	13.5	90.0	D. Dep.
5 Nov 72	0300	0.5	0.9	0.5	1.0	1.8	16.0	88.7	16.0	89.0	CS
	1200	0.6	0.9	0.8	0.75	1.5	19.0	89.0	18.5	89.0	SCS
6 Nov 72	0300	1.1	2.1	1.4	0.8	2.0	22.0	92.0	22.0	91.5	SCS
7 Apr 72	0300	0.2	DNA*	0.2	1.0	DNA*	—		9.0	91.0	Dep.
	1200	0.4	1.8	0.3	1.3	4.5	10.0	90.5	9.5	90.5	D. Dep.
8 Apr 72	0300	0.4	2.1	0.3	1.3	5.0	10.5	90.5	10.0	90.0	CS
	1200	0.6	2.4	0.4	1.5	4.0	11.6	89.7	11.5	90.0	SCS
9 Apr 72	0300	0.7	P/F	0.4	1.75	DNA*	—		13.0	90.5	SCS
	1200	0.7	2.6	0.4	1.75	3.7	14.0	90.7	14.0	91.0	SCS
10 Apr 72	0300	0.6	2.0	0.5	1.2	3.3	14.6	90.6	15.0	91.0	CS
	1200	0.5	E/Q	0.5	1.0	DNA*	—		16.0	91.0	CS
11 Apr 72	0300	0.3	1.6	0.4	1.75	5.3	Not intersecting		17.0	91.0	D. Dep.

DNA* : means data not available.

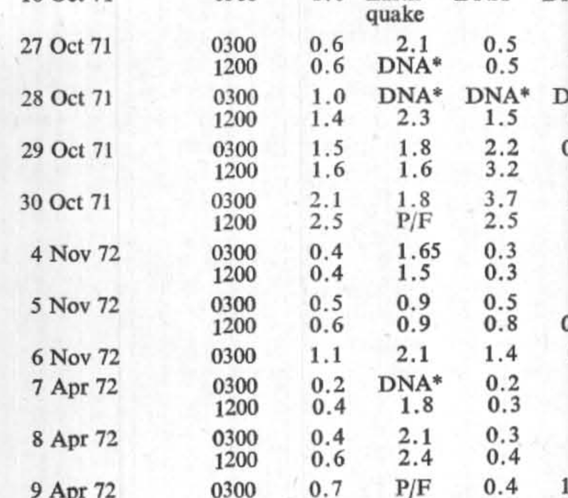

Fig. 5. Amplitude chart (mm) around Madras for various positions of severe cyclonic storm

A_M / A_V (Ratio of amplitudes of Madras and Visakhapatnam) and A_P / A_M (ratio of amplitudes Port Blair and Madras) were plotted at the corresponding storm location on two separate maps; storm locations were taken from *IDWR*. The plottings of these amplitude ratios are shown in Figs. 3 & 4. Amplitude ratio from a particular place is found to vary with the intensity of the storm. Carder and Eppley (1959) also noted such variations in amplitude ratio of two stations. This variations, observed here are, however, quite small and isolines could be drawn with these values as shown in Figs. 3 & 4. If the isolines of both A_M/A_V and A_P/A_M are drawn in a single map, it may be seen that the two sets of isolines make clear intersections; the position of the stations forms a triangle and this has caused a clear cut intersections. It may be noted that such clear cut intersection is necessary for unambiguous determination of storm position by amplitude-ratio isolines.

4.2 *Use of amplitude-ratio lines*

After the isolines have been prepared, it is possible to locate a storm position when amplitude ratio A_M/A_V and A_P/A_M are known. Using this technique a few storm centres have been located during the period 1971 and 1972 (Table 2). For locating storm centres 23 cases were tried. In two cases the storm centres could not be located as two isolines did not intersect in each of these cases. For each of the other 21 cases, storm centre was located at the intersection of the two isolines of observed amplitude ratio. When the storm centres so determined were compared with the storm locations given in *IDWR*, it was seen that the two locations differed by not more than 0.5 deg. either in latitude or in longitude.

4.3. *Preparation and use of amplitude chart*

Gilmore (1953) suggested the preparation of amplitude charts for finding intensity of the storm after its position was located. This was based on the fact that the recorded amplitude at a station would be the same for different storms with same intensity and position. He also suggested the preparation of amplitude charts for storms of different intensities (*e.g.,* 70, 80, 90, 100 knots) around a station. For the cases under study wind speeds were not available and only the degree of severeness of the storm was known (*e.g.,* deep depression, cyclonic sorm, severe cyclonic storm). An amplitude chart for only the severe cyclonic storm stage around Madras has been prepared. The amplitude as recorded at Madras for the period 1961-1970 is plotted on the chart at the centre of the severe cyclonic storm and iso-amplitude lines are drawn as shown in Fig. 5.

This amplitude chart is then used in finding the intensity of the storms of 1971-1972. However, the result is found to be unsatisfactory; it appears that this technique can be improved if a chart could be prepared with specified wind speed of storm (*e.g.,* 50, 70, 90 knots) instead of using only broad classification of intensity.

5. Conclusions

(1) Amplitude of microseisms generally increases with the intensification of storm (if it is over sea) and *vice versa.*

(2) Amplitude of microseisms has a primary maximum when the storm is at its peak intensity and a secondary maximum when it crosses the coast.

(3) Observed amplitude ratios of microseisms for pairs of station shows a systematic behaviour even with geological and bathymetric difference in the area and hence isolines of amplitude ratios can be drawn.

(4) Isolines A_M/A_V and A_P/A_M clearly intersect with one another and show that Madras, Visakhapatnam and Port Blair stations are suitable for the use of the amplitude ratio technique for storm location.

(5) Application of this method shows that the difference in location of the storm by this method differs by not more than either by 0.5 deg. in latitude or longitude as compared to the determination given in *IDWR.*

(6) It is noted that broad specification of storm into various stages is not sufficient for using recorded amplitudes of microseism to forecast the intensity of the storm. Specification of the storm by using maximum wind speed may prove to be more useful in preparing amplitude chart for finding the storm intensity.

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