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Thickness patterns and intensification of Bay storms

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ABSTRACT. A simple technique of utilising the thickness patterns to assess qualitatively the field of divergence or convergence by determining the tilt of the axis of the pressure system has been presented in this note. The utility of this technique has been discussed and illustrated by analysing one pre-monsoon storm, in the light of the above ideas.

1. Introduction

It is a well known fact that the prognosis of movement of storms or depressions can, though, to some extent, be made on the basis of normal tracks of different seasons and other guides, namely, previous history of the storm and the continuity principle, warm sector wind direction (Ramanathan and Iyer 1930 and Mull and Desai 1931) etc. The forecasting of intensification or weakening of a storm or depression becomes extremely difficult in view of pausity of data over sea areas. In this note an attempt has been made to prognosticate such developments on the basis of the tilt of the axis of the system as could be deduced from the thickness patterns.

2. The principle behind the tilt of the axis of a pressure system

According to Bjerknes quoted by Kidd and Reed (1946) "Incipient waves in a current with warm air-mass to the right (in the northern hemisphere) will develop thermal asymmetry and tilt in such sense that deepening of troughs and building up of wedges will result". The hydrostatic equation demands that the tilt of the axis be always towards the colder side and that its magnitude varies inversely with the temperature gradient. The cases of such tilt in the pressure axis have been studied in the Pacific areas by Krasner and London (1946), who following Bjerknes and Holmboe (1944) have shown from hydrodynamical principles and vorticity considerations that westward moving storms will deepen with east/southeastward tilt of the axis and will weaken with west/northwestward tilt.

The principles on which Krasner and London based their conclusions are given below—

Assuming balanced gradient flow as an approximation to streamline flow, the distribution of convergence and divergence in a sinusoidal streamline wave, disregarding the acceleration effects, are due primarily to two factors—the changing of curvature and latitude. With westward moving systems, say an easterly sinusoidal trough it is evident that both the effects of changing curvature and latitude act to produce divergence ahead and convergence in the rear. In a closed circulation also there will be divergence ahead, *i.e.*, in the western sector and convergence in the rear, *i.e.*, the eastern sector due to latitudinal effects only.

They have also shown from vorticity considerations the validity of the following conclusions—

"In the baroclinic state* there are two major cases: Case I—warm air originally to the south; east winds decreasing with height, often reversing to westerlies. Only shallow stable waves will result from such a distribution, with forward tilt and therefore a

*The thermal asymmetry of storms/depressions of the Bay of Bengal has been well established by various authors, Basu and Desai (1934), Malurkar and Pisharoty (1948), Mull and Desai (1931), Normand (1931), Ramanathan and Narayana Iyer (1930), Ramanathan (1931), Roy and Roy (1930), Sen and George (1952) and Sur (1935) tendency to fill almost as soon as formed. Case II—warmer air originally to the north, east wind increasing with height....the tilt of the axis is toward the east, or southeast: and troughs tend to deepen and move slowly westward. High-level divergence is present, intensified by the high velocities aloft—an effect which will continue even after a closed low has formed in the lower levels. This, then, is the ideal case for deepening of tropical cyclones.

3. Determination of the tilt

As the tilt of the axis is always towards the colder side, it can easily be determined if thermal wind over the surface centre is available. In view of complete lack of upper wind data near the depression centre, the authors have used the thickness pattern as could be drawn by calculating thermal winds for 700- and 500 mb levels (shear vector between 2000 and 10,000 ft and between 10,000 and 18,000/20,000 ft winds respectively). The thickness values reported by eleven radiosonde stations of India, have been used as an additional aid for the fixation of thermal patterns (use of 1500 GMT radiosonde thickness values for the determination of the run of the thickness lines though not strictly permissible had to be used in the absence of requisite data corresponding to 0900 GMT pilot balloon winds). According to the above ideas, the strengthening of a westward moving depression should generally be expected whenever the thermal winds are north/northeasterly over the surface centre of the depression and a weakening when they are southwesterly or southerly.

4. Analysis of cyclonic storm of May 1952

Short history: "A depression formed on the 19th evening near Lat. 13°N. It deepened rapidly and became a severe cyclonic storm by the 21st morning when it was centred about 120 miles eastnortheast of Madras. On the 22nd morning it was centred about 50 miles east of Ongole, but recurving thereafter, and weakening at the same time. it lay as a deep depression on the 23rd morning with its centre close to the coast near Masulipatam. It then weakened further, and a trough of low pressure extended over coastal Andhradesa and adjoining west central Bay of Bengal, which became unimportant by 26th".

Figs. 1 to 4 show the thickness patterns at 700 mb and 500 mb (partial thickness between 500 and 700-mb levels) for the period 19 to 22 May 1952.

In all these charts the centre of the storm or depression corresponding to 1200 GMT have been marked. In a few cases when the upper winds for 18,000/20,000 ft were extremely sparse, winds for 15,000 ft were used and shear vector between 10,000 and 15,000 ft were computed and plotted by broken lines in 500-mb thickness (partial) charts. Thickness values indicated in the figures are in metres.

19 May 1952

Indian Daily Weather Report of 19-5-52— Unsettled conditions in west central Bay have concentrated into a shallow depression within one degree of Lat. 11½°N Long. 83°E. likely weaken and move in a westerly direction.

Fig. 1(a)—700 mb: The thermal pattern shows the following broad characteristics. Whole of India is under the influence of vast thermal high with a well marked and extended ridge covering most of central and east central Bay. A thermal trough with a probable thermal pool is apparent over southwest Bay and adjoining west central Bay. Another thermal low is observed over north Deccan. The strong northerly thermal winds near Madras deserves special attention. The thermal wind over the surface centre is northeasterly showing a southeastward tilt of the axis of the pressure system.

Fig. 1(b)—500 mb: An extended ridge of the thermal high holds under its sway the most of the Bay region to the north of Lat. 10°N. A thermal trough lies over Malabar and south Kanara coast. Another thermal high is apparent over Madhya Pradesh. A thermal low is seen to be affecting the Punjab (I) and West Pakistan. A well-marked thermal trough

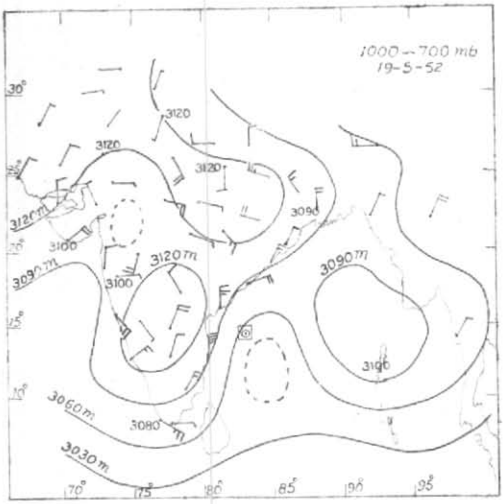

Fig. 1(a)

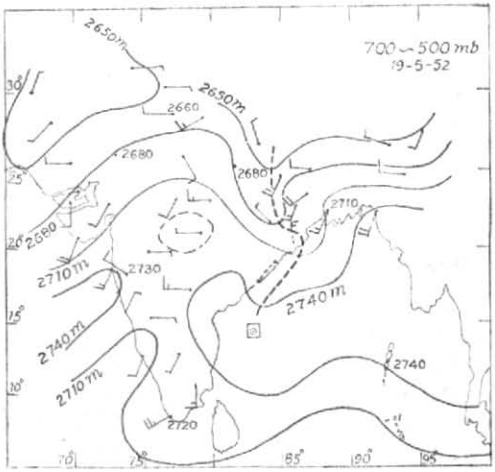

Fig. 1(b)

Fig. 2(a)

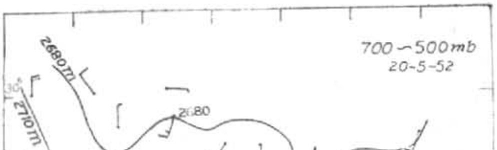

Fig. 2(b)

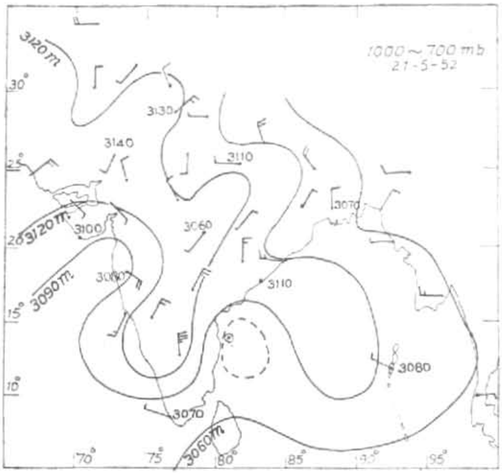

Fig. 3(a)

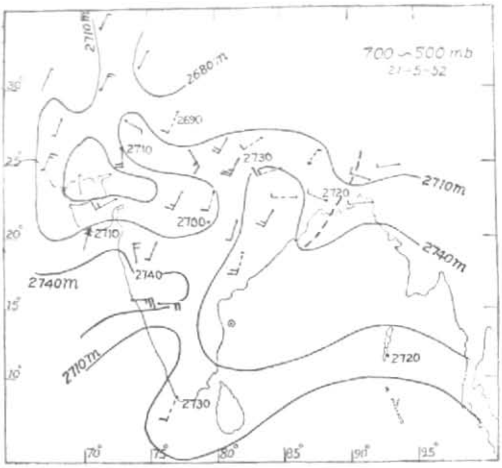

Fig. 3(b)

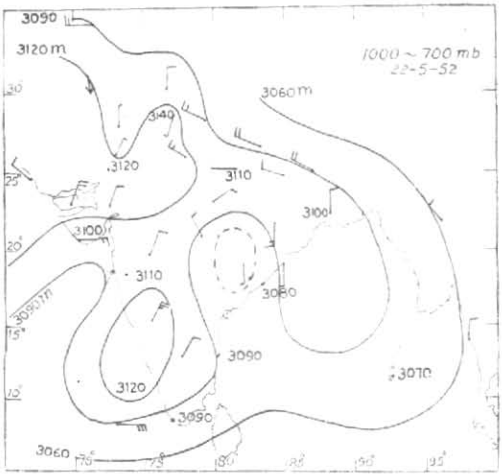

Fig. 4(a)

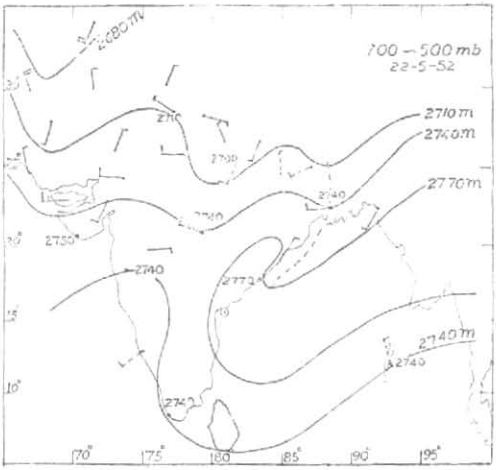

Fig. 4(b)

(with axis of trough shown in dashed lines) lies to the east of 83°E. Thermal wind over the surface centre is difficult to judge.

Though 500-mb chart is inconclusive, the 700-mb chart definitely suggests possibility of development of the system.

20 May 1952

The evening bulletin of 20-5-52 said—This morning's depression in west central Bay has intensified and is centred at 1200 GMT within a degree of Lat. 13°N and Long. 83½°E, likely move in westnorthwesterly direction.

Fig. 2(a)—700 mb: The thermal trough of 19th with cold pool in the southwest and adjoining west central Bay has moved slightly northwest and continues to be well marked. Thermal high over India with extended ridge over east central Bay persists. The thermal low over north Deccan has moved over Gulf of Cambay and adjoining region. Northeasterly thermal wind over the surface centre and southeastward tilt of the axis of the pressure system are apparent. Further intensification, therefore, should be expected on the basis of the above chart.

Fig. 2(b)—500 mb: The thermal ridge of 19th which was observed to protrude inland over south Hyderabad and Rayalaseema and the separate thermal high over Madhya Pradesh appear to have merged together, with consequent extension of the ridge inland over southeast Madhya Pradesh. Thermal low over south Kanara and Malabar coast has become unimportant. Thermal low over the Punjab (I) and West Pakistan has moved eastwards. Thermal trough over area east of 83°E persists. The thermal wind over the surface continues to be northeasterly showing a southeastward tilt.

Both the above charts show southeastward tilt of the axis and are, therefore, very favourable for further intensification of the depression. The depression, in fact, intensified into a cyclonic storm overnight.

21 May 1952

The evening bulletin said—This morning's severe cyclonic storm is centred at 1200 GMT about 60 miles northeast of Madras, likely cross coast tonight.

Fig. 3(a)—700 mb: Extended ridge at this level has shifted rapidly westsouthwestward from east central Bay to central Bay and neighbourhood. The thermal trough over southwest and adjoining west central Bay continues to be well marked. The thermal pool has apparently, moved northwestwards rather rapidly. Thermal wind over the surface centre continues to be northeasterly.

Fig. 3(b)—500 mb: A closed thermal low has appeared over Saurashtra, Gujarat and adjoining areas. Thermal high continues to persist over west central Bay, coastal Andhradesa, Orissa, Chota Nagpur and adjoining east Madhya Pradesh. The thermal wind over the surface has become southsouthwest, indicating a forward tilt of the axis. The well marked trough over area east of 83°E has moved eastwards and is less marked.*

The indication at 500-mb surface, which has become unfavourable for further intensification of the storm, suggests possibility of the weakening of the storm.

22 May 1952

The evening bulletin said—This morning's cyclonic storm remained stationary and is centred at 1200 GMT 50 miles east of Ongole, likely move north and cross coast near Masulipatam.

Fig. 4(a)—700 mb: A profound and a very remarkable change in pattern is noticed. Northerly 15 knots wind at Jagdalpur has changed to southerly 5 knots. Northerly wind at Jharsuguda has also changed to south. The thermal low of 21st near Madras has apparently moved northwards very

*Association of Polar troughs in the formation, deepening and movement of storms and depressions or its profound influence on the life cycle of tropical storms has been brought out by H. Riehl rapidly with consequent change in the tilt of the axis from southeast to northnortheast.

Fig. 4(b)—500 mb: The thermal wind over surface centre continues to be south-southwest.

Both the 700- and 500-mb charts show a forward tilt of the axis. The rapid changes, with remarkable shift of the tilt at 700-mb level, would suggest a rapid weakening of the system.

(This phase of formation of thermal low ahead of the depression or storm appears to be extremely significant not only in the prognosis of rapid weakening of the storm or depression but also in giving a probable indication of recurvature*). The severe cyclonic storm, in fact, recurved and weakened into a shallow low, with only one closed isobar, by the evening of 23 May 1952 (*vide* weather map of 1200 GMT, published in the *I.D.W.R.*)

*This point is being examined in further detail.

5. Conclusions

While the above results are in full conformity with the remark "We observed no young developing cyclones where upper winds taken within the cyclonic circulation indicated a forward tilt of the axis"—made by Kidd and Reed (1946) in regard to cyclones in Pacific areas, one should not expect this technique to be valid in all the cases. It may not be out of place to mention that we, as yet, do not know the exact mechanism of formation of depressions/storms and it is quite likely that the formation or intensification of all the storms/depressions cannot perhaps be fitted to a single model; consequently a single method, especially an approach of such a simple nature, should not be expected to fit in every case.

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