ON COLD POOLS AND THEIR ROLE IN THE DEVELOPMENT OF NOR'WESTERS OVER WEST BENGAL AND EASTERN PAKISTAN

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DURING the pre-monsoon period, March to May, West Bengal and Eastern Pakistan and the adjoining areas are visited by thunderstorms of a severe type which are popularly known as nor'westers and which sometimes reach tornadic violence, causing heavy destruction of life and property. The mechanism of these thunderstorms has been investigated by a large number of meteorologists,[1-11] but it is yet very imperfectly understood. Consequently, even to-day, the forecasting of nor'westers continues to be one of the most baffling problems in Indian Meteorology and the forecaster has often to fall back upon empirical methods for issuing timely warning against these thunderstorms.

It is clear from a perusal of the literature so far published on this subject that emphasis has been laid by most of the workers on the sea-level conditions and in the layers of the atmosphere below 10,000', especially between 3,000' and 5,000' where there is a marked inversion caused by the dry northwesterly winds (Tc) over-running the relatively colder and moist southerly winds (Tm) from the Bay of Bengal. As early as in 1937, however, Ramanathan and Ramakrishnan[11] pointed out that, in addition to the breaking down of the inversion, which is a fairly regular feature in the afternoons even on days of no nor'westers, the replacement of the normally warmer air over Bengal at 20,000' and aloft by colder air, would be necessary for the development of these thunderstorms. Their remarks were, however, of a general nature based on *average monthly temperatures* and *not on a study of individual cases*. This aspect of the problem subsequently received little attention by the later workers in this field, presumably because of the lack of sufficient upper air temperature data to confirm or contradict the views expressed by Ramanathan and Ramkrishnan.

The present authors have pursued this aspect of the problem by a study of the thickness patterns at the 700 and 500 mb. levels over north-east India and Eastern Pakistan during the nor'wester season. Seven spells of extensive nor'wester activity have been studied by this method.* Six of these spells related to the nor'wester season of 1952 and one related to 7-3-49. The last-mentioned case was specially chosen because it was responsible for a record squall of 76 m.p.h. at the Calcutta Airport although there were very few indications in the charts for sea-level or upper levels below 10,000' to suggest the development of a nor'wester of this severity. Among the six spells in 1952, the one on 14-4-52 was also specially selected because it caused a severe squall at Calcutta in the afternoon from the east—a very unusual direction—for as long a period as one hour and blew away the revolving beacon from the terrace of the Control Building at the Calcutta Airport. In this case also, practically none of the conditions usually associated with nor'westers existed either at sea-level or anywhere below 10,000' a.s.l.

The thickness patterns at 700 mb. (1,000 — 700 mb.) and at 500 mb. (700 — 500 mb.) were drawn on the basis of the thermal winds and thickness values at these levels. The thermal winds were computed from the Pilot Balloon winds for 09 G.M.T. available for a large number of stations in India, Eastern Pakistan and Burma. The thicknesses were obtained from the Radiosonde data of 15 G.M.T. of the Radiosonde stations in India and Western Pakistan (total 12 in number).

A study of the seven cases† referred to above has revealed the following:

(*a*) In every one of the seven cases, 18-24 hours before the outbreak of the nor'westers, there was either a cold pool (*i.e.*, an area where there was at least one closed thickness line curving cyclonically) or a well-marked cold trough (*i.e.* an area in which the thickness lines were symmetrical and curved cyclonically) at the 500 mb. level in the area where the nor'westers developed. This time-difference between the first appearance of the cold pool (or cold trough) and the later development of nor'westers is of special importance in view of its usefulness in forecasting.

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* Mr. C. K. M. Douglas[15] and others have studied the significance of thickness patterns in the development of thunderstorms in middle latitudes. As far as the present authors are aware, a similar study has so far not been made with regard to thunderstorm-situations in India and Pakistan.

† These conclusions have been confirmed by one more case of extensive and severe nor'westers, *viz.*, on 18-4-1944.

(*b*) The nor'westers tended to be a maximum in the sector of the cold pool or the cold trough where the thermal winds were between SSE and WSW.

(*c*) In six out of the seven cases, in the region where the thermal winds were between SSE and WSW, the actual winds had an appreciably greater westerly component than the thermal winds suggesting the possibility of further advection of colder air over that region.

(*d*) So long as there is a cold pool or cold trough at the 500 mb. level, one should always keep in mind the possibility of thunderstorms even if the charts for the sea-level and the lower levels in the upper air do not give clear indications of such a possibility. The case of 14-4-52 is a definite pointer in this direction The streamlines on the constant level upper wind charts at 2,000′ and 5,000′ a.s.l. at 02 G.M.T. on 14-4-52 are shown in Figs 1 and 2 and the

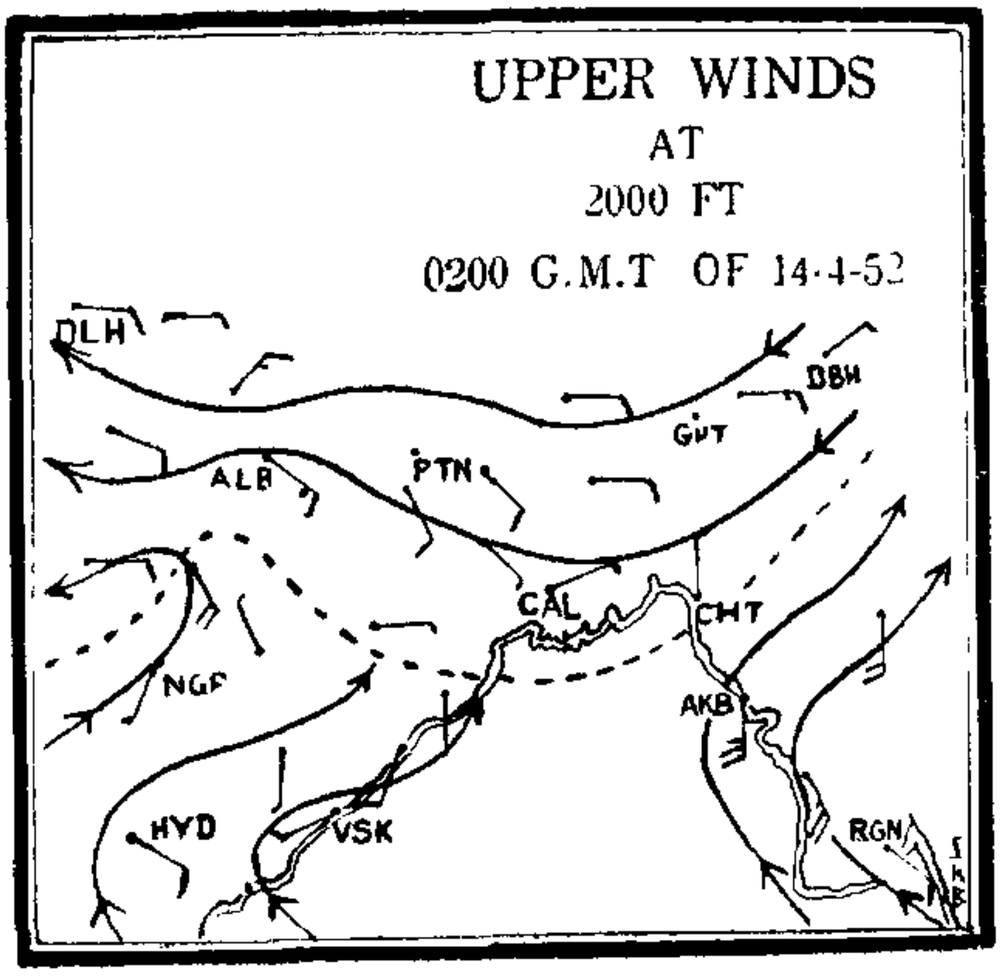

FIG. 1.

thermal winds and thickness patterns at the 500 mb. level on the evening of 13-4-52 are shown in Fig. 3. The thunderstorms which developed between the afternoon of 14-4-52 and morning of 15-4-52 are superposed on the thickness patterns in Fig. 3. It is of special interest to note here that the weather travelled most unusually from Gangetic West Bengal to Chotanagpur on this afternoon and that the nor'westers over Gangetic West Bengal were not associated with any earlier development in Eastern Pakistan or Lower Assam. The thunderstorms over Aijal and Chittagong shown in Fig. 3 were an independent development and occurred in the early hours of 15-4-52.

In addition to the above seven cases, the authors have also made a general study of situations which nor'westers did *not* develop over West Bengal although the sea-level and the upper air conditions *below* 10,000′ were

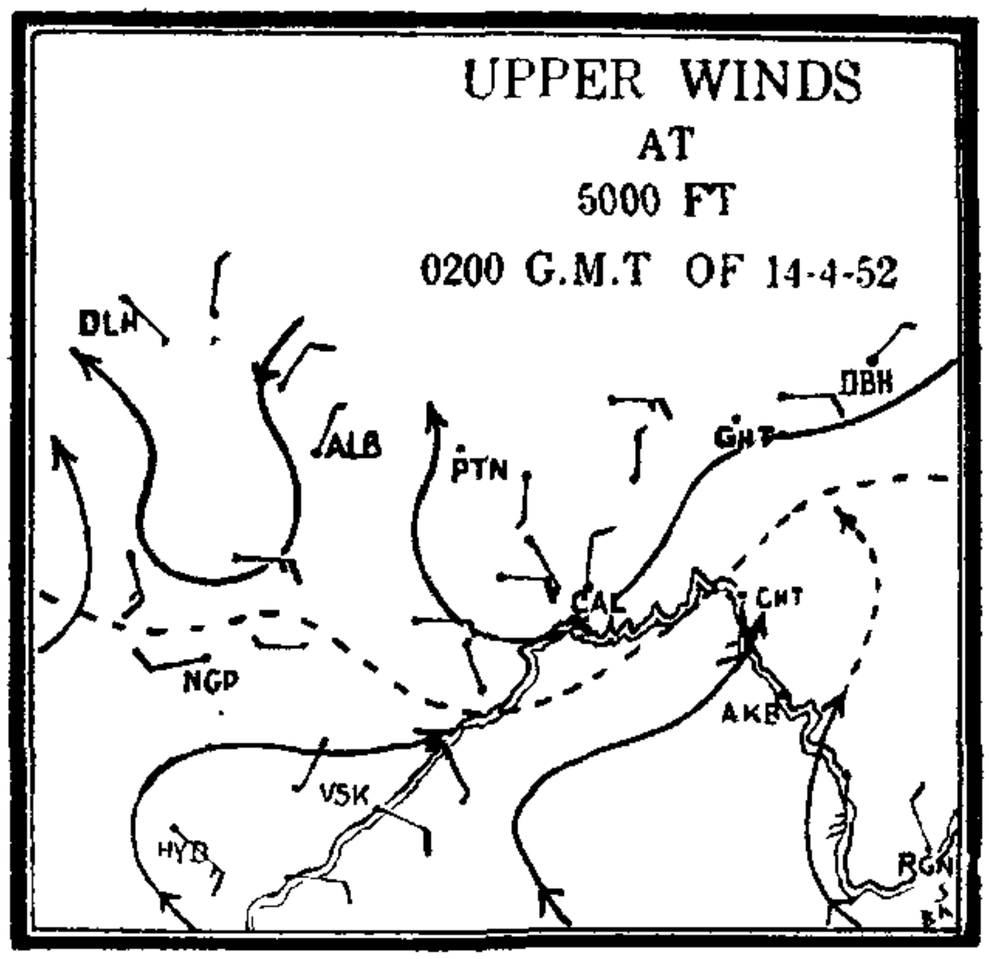

FIG. 2.

favourable according to the present accepted ideas. On such occasions, it has been found that there was no cold pool or even a weak cold

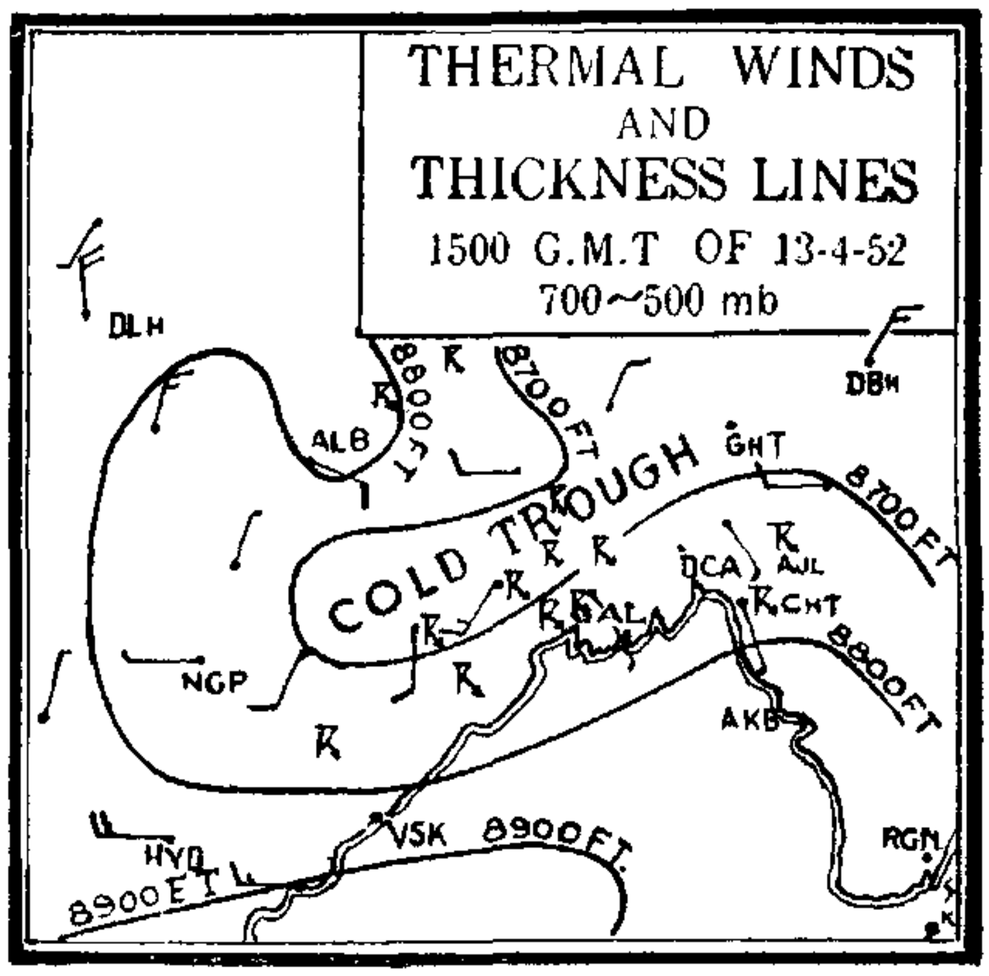

FIG. 3.

trough at the 500 mb. level in or near the region where nor'westers could be expected from other evidence. The situations on 2nd and 11th March and 2nd April ‡ 1953, are instances in support of this staement.

The authors would have liked to study in detail the thickness patterns at the 300 mb. level

‡ Added at proof stage.

(500 — 300 mb.) also but the paucity of thermal wind data for this level discouraged them from undertaking the study at this stage. They would, however, like to mention that in the cases of nor'wester activity on 5-6-52 and 6-6-52 for which adequate amount of thermal wind and thickness data were available, there were very well-marked cold troughs at the 300 mb. level also, 18-24 hours before nor'westers developed. The thermal winds (500 — 300 mb.) in these cases were SSE/SW over the entire region where the nor'westers developed while the actual winds in the same region were SW/W.

From the above, the authors are tempted to conclude that the advection of colder air between 10,000′ and 20,000′ and possibly also between 20,000′ and 30,000′ appears to be the *final determining factor* in the outbreak of nor'westers, at least when they are widespread.

In conclusion, it may be pointed out that the technique adopted by the authors in this investigation is a simple one, not open to any theoretical objection from the point of view of validity of the geostrophic assumption, as the phenomena of nor'westers occur in regions to the north of latitude 20° N. and during a period of the year when the westerlies are predominant over north-east India and Eastern Pakistan in the upper air. Further, there is usually a fairly adequate amount of Pilot Balloon wind data at the 500 mb. level over India except on very cloudy days and the accuracy of these data is quite well known. Consequently, it is possible to identify the existence of cold pools or cold troughs qualitatively even from the thermal wind circulation patterns on days on which Radiosonde data are not available or are not reliable on account of instrumental errors.

Full details of the seven cases referred to above, together with diagrams showing the thermal winds and thickness patterns at the 500 mb. level and the thunderstorms superposed upon these patterns for purposes of comparison are being sent for publication in the *Indian Journal of Meteorology and Geophysics.*

1. Blanford, *Indian Meteorologist's Vade Mecum*, Part II, 135. 2. Elliot, *Indian Met. Memoirs*, **1**, 119. 3. Normand, C. W. B., *Ibid.*, **23**, Part 1, 21. 4. Roy and Chatterjee, *Nature*, 1929, **124**, 481 5. Sohoni, V. V., *India Met. Deptt. Sc. Notes*, **4**, No. 33. 6. Sen, S N, *Nature*, 1931, **127**, 128. 7. Das, A. K. Gerland Beitr, *Geophysics*, 1933, **39**, 144. 8. Desai and Mull, *Ibid.*, 1938, **53**, 285–304. 9. Sur and Chatterjee, *India Met. Memoirs*, **26**, Part 9. 10. Pramanik, S. K., *Proc. Nat. Inst. Sci., India*, **5**, No. 1, 93-9. 11. Ramanathan, K. R. and Ramkrishnan, K. P., *India Met. Deptt. Memoirs*, **26**, Pt. X. 12. *India Met. Deptt. Tech. Notes*, No. 10. Norwesters of Bengal, 1945. 13. Roy, A. K., *Proc. Nat. Inst. Sci. India*, 1949, **15**, No. 7, 289-300. 14. Sengupta, P. K., *Proc. Ind. Acad. Sci.*, 1952, **35**, No. 6, 303. 15. Douglas, C. K. M., *Met. Magazine*, 1947.

MENDELIAN ANOMALIES

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THOUGH over fifty years have elapsed since Mendel's Law of Segregation was rediscovered by three different investigators, De Vries, Correns and von Tschermak in 1900, no attempt apparently seems to have been made to collect systematically Mendelian anomalies, occasionally observed in experimental data and scattered in the genetic literature. Not without exception every population has a classical Mendelian ratio of 3 : 1, etc. Thus in the course of intensive genetic research during the past fifty years, it has not been a rare observation that abnormal segregations in families, arising from various crosses, have been recorded by different authors, who have also expressed doubts in regard to offering an explanation on ordinary Mendelian lines. For example, Luther Smith[8] in his review on genetics and cytology of barley has rightly remarked, "Workers who have studied many genetic characters have noted that not all F_2 segregations are exactly 3 : 1, although only one gene pair is involved. There are a number of possible reasons for this discrepancy between theoretical and observed ratios. However, not many workers have taken the time and trouble to determine which of the possibilities actually obtain".

Yule[14] reporting on the data afforded by the experiment initiated by Derbyshire, remarked, "No explanation is offered of the remarkable divergences from the expectation based on simple Mendelian theory ; they remain a puzzle. But it seems clear that the theory is inadequate completely to explain all the facts. The mechanism at work appears to be more complex than is commonly postulated". Also Bateson's[1] remarks in this connection that "even as regards the outline of genetical principles, finality has not been attained," may not be out of place to record.

Again, Pease[10] working on the inheritance of