AIR MASSES IN TROPICAL CYCLONIC STORMS FROM RADIO-SONDE DATA

S. L. MALURKAR AND P. R. PISHAROTY
Poona 5

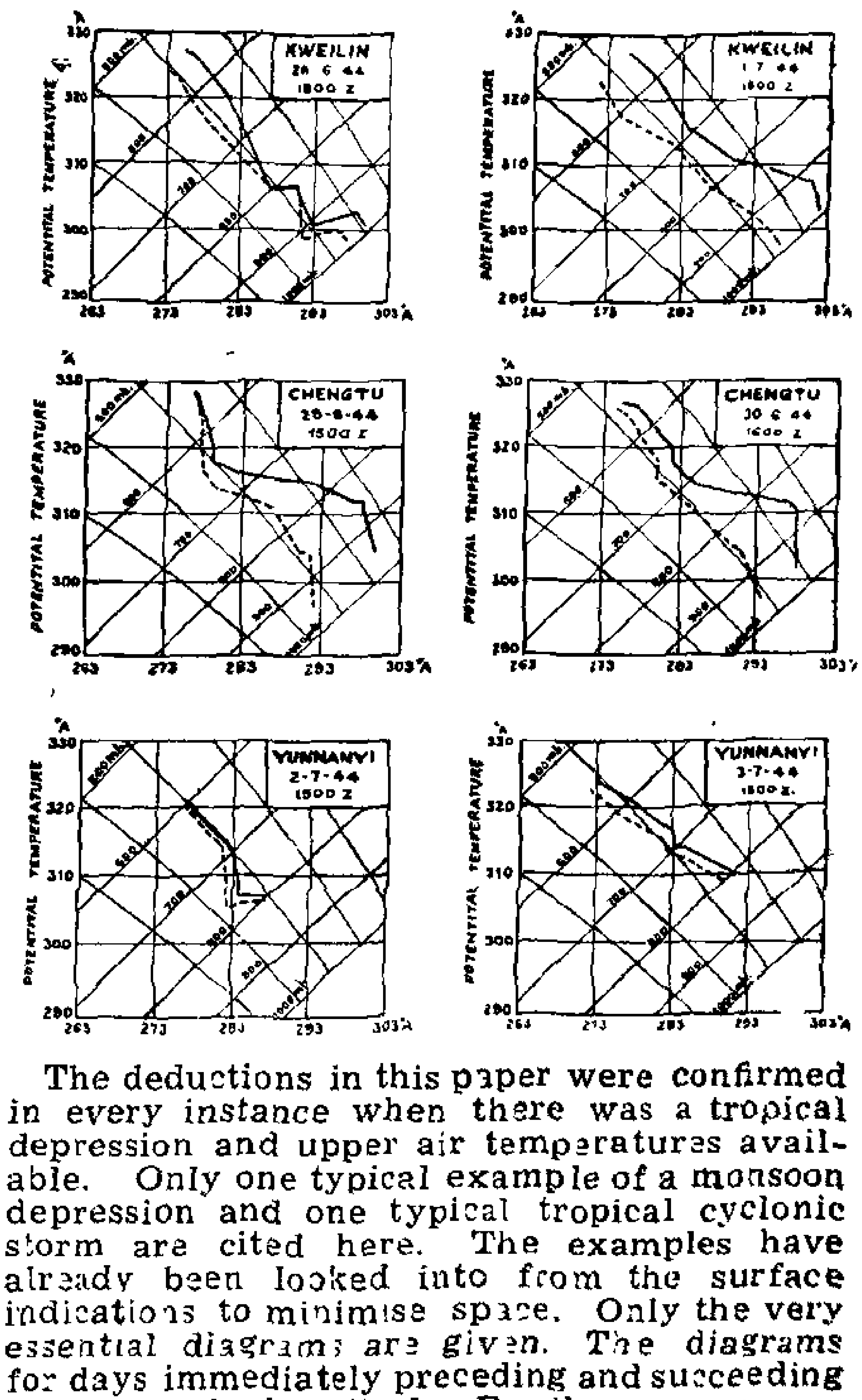
IN *an attempt to study the air masses*[1] in the Indian area associated with monsoon depressions or with the pre- and post-monsoon months, it was found that one has essentially to deal with three distinct air masses with separate regions of travel. The air masses entering into the structure, of all tropical cyclonic storms or depressions, could be considered as nearly the same. In the absence of *one of these air masses, usually, no westward* moving tropical depressions formed and only *a low pressure wave resulted.*

The air-masses are: (1) air from the S. hemisphere whose incursions across the equator occur at discrete intervals. The character of this air after crossing the equator remains sensibly the same (Fm); (2) air from the Far East ultimately the N. Pacific high which forms part of the 'N. E. Trades', its character is essentially stable but the temperature and humidity depend on the season and region of travel, and (3) dry continental air, with its large diurnal variation of temperature, from regions to the west of the depression. The properties of the air masses are described elsewhere.[2]

The tracing of the far eastern air as a distinct one was not easy. The observations, from regions east of India, were not available. Even *in pre-war days, the area from S. China to* Upper Burma was not meteorologically well represented. In the Pacific Ocean, the data were still less. Only, Deppermann[3] had tackled the question of air masses near the Philippines. The isobaric configuration in N. E. India, the weather sequence before the onset of a monsoon depression *and the nature of precipitation* showed that an air mass distinct from that of *fresh monsoon air and also from dry contin*ental air was involved. During the year 1944, radio-sonde ascents were made at a number of stations in India and the neighbouring countries like S. China.

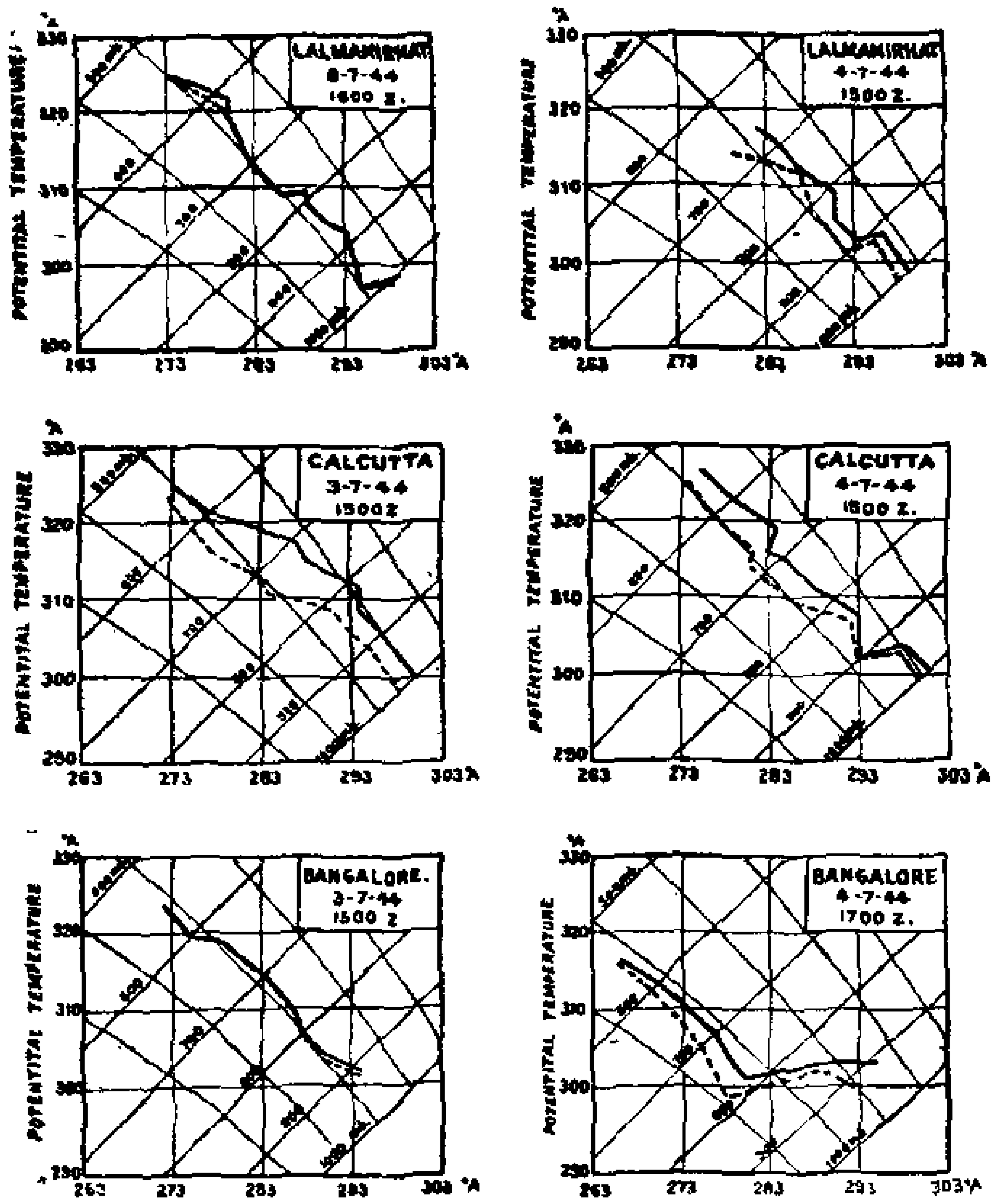
With the close of the war, the radio-sonde *stations, which were mostly maintained by the* army air force of the U. S. A. in places bordering to the east of India were closed down. The detection of the far eastern air, with only data from inside India, would again present difficulties, if the experience gathered during the war period was not utilised and recorded.

Technique—The radio-sonde data are recent *in and near India.*[4] In the temperate latitudes where the temperature and humidity change considerably with different air masses, the small instrumental defects can be ignored. But in the tropics, the temperature changes associated with different air masses near a depres*sion are small. One is apt to ignore altogether* the significance of small changes as being below the limit of instrumental errors. If one depended solely on the upper air temperature and humidity data, it may be the correct attitude. When the data are used along with synoptic charts, their utility cannot be challenged. The incursion of fresh air masses can be checked up alternately from surface and upper air data. When all the T - Ø grams are studied, *the shape of the curves indicates the incursion* of fresh air masses. The fall or rise in temperature at higher levels, if shown in a sequence at a number of stations far away from *one another or if shown simultaneously at* nearby stations can be relied upon and should *not be ignored.*



The deductions in this paper were confirmed in every *instance* when there was a tropical depression and upper air temperatures available. Only one typical example of a monsoon depression and one typical tropical cyclonic storm are cited here. The examples have already been looked into from the surface indications to minimise space. Only the very *essential diagrams are given. The diagrams* for days immediately preceding and succeeding days are only described. For the same reason, the question of tracing of the continental air, which can be done even on surface charts has not been stressed.

Observations : Based on the westward passage *of a shallow low pressure area south of* the equator and the rise of pressure at Mauritius *in the preceding 24 hrs.*, a forecast for a week-ahead was issued on July 3rd, 1944, that the monsoon may strengthen in the Indian area during the latter half of the week. It was expected that a 'pulse' of fresh monsoon air was about to cross the equator and form a depression at the head of the Bay of Bengal after three or four days. The Bay depression formed on 7th July 1944. Pisharoty[7] has cited the T - Ø grams of Bangalore for 4th and 5th July and shown that an 'unstable' or more accurately a less stable than usual air passed over the place; and that similar less stable air masses passed over Bangalore before the formation of other monsoon depressions, at the head of the Bay of Bengal. In the following θ_w is used as wet bulb potential temperature in the absolute scale of degrees, and only the numerals are put in.



Main features of the diagrams are only given.

Bangalore

3rd July 1944. Between 900 and 840 mbs. θ_w was greater than 296, while it was just 296 between 840 and 800 mbs. It was again greater than 296 between 800 and 630 mbs., and it was 295·5 between 600 and 525 mbs. The curve was almost dry adiabatic between 630 and 600 mbs.

4th July. The curve was super-adiabatic between 900 and 780 mbs. θ_w falling from nearly 298 at the surface to 290 at the higher level. θ_w was between 291·5 and 290 from 780 to 525 mbs.

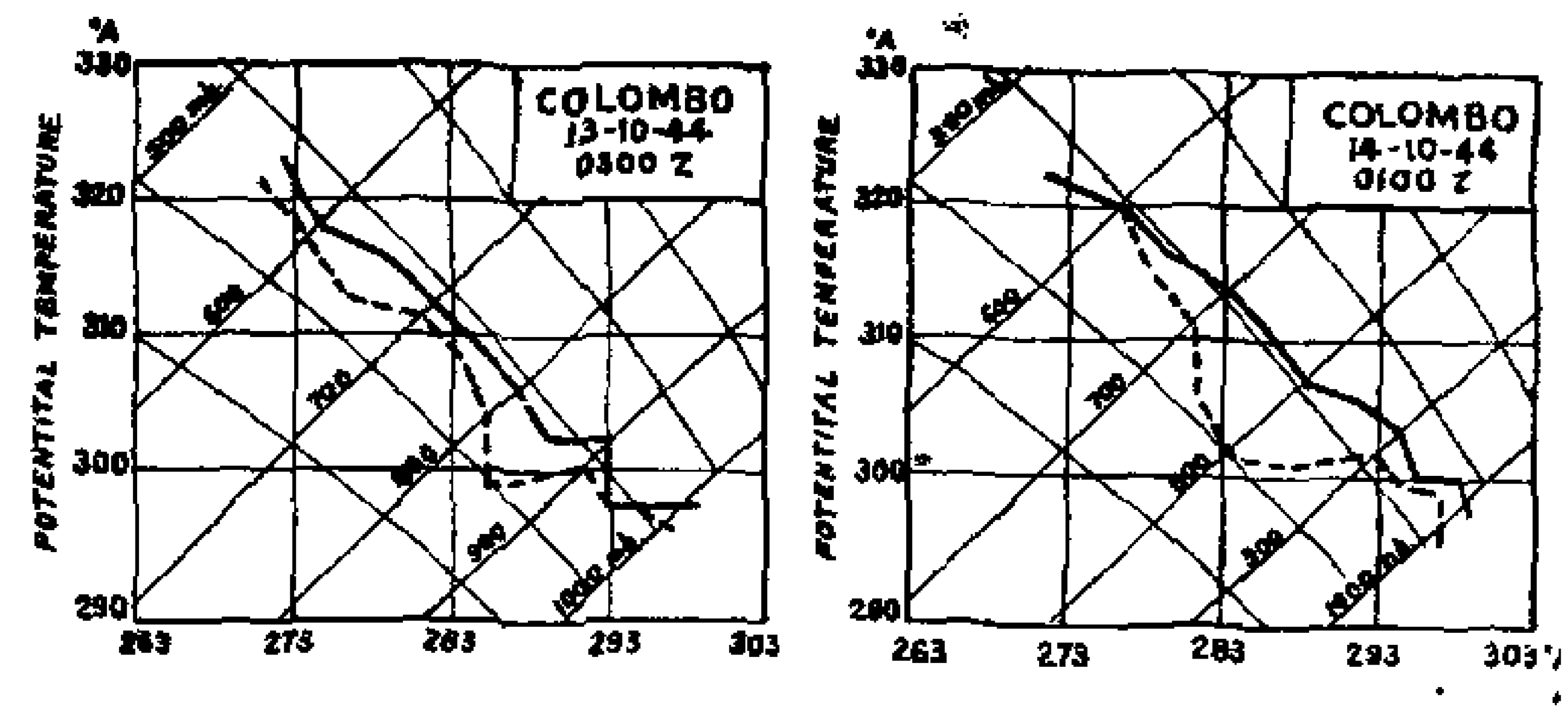
5th July. From 900 to 650 mbs., the curve is almost a straight line, θ_w being 297 and 291·5 at the extreme levels. At heights above 650 mbs. θ_w was greater than 291·5

6th July. No ascent.

7th July. θ_w was everywhere greater than 295 and often greater than 296.

The drop in the wet bulb potential temperature showed that there was an incursion of fresh air over Bangalore on 4th July 1944 (*cf.* Pisharoty, *loc. cit.*). The air was not quite stable. It could easily give rise to or maintain thunderstorms. The only source of colder air at the top could be from the southern hemisphere where it was winter.

The data for the Far Eastern Transitional or Mixed air (Tr) are derived from Kweilin (110° 10′ E, 25° 15′ N.), Chengtu (104° 02′ E, 30° 15′ N.), Yunannyi (100° 44′ E, 25° 25′ N), Lalmanirhat (Assam) and Calcutta.



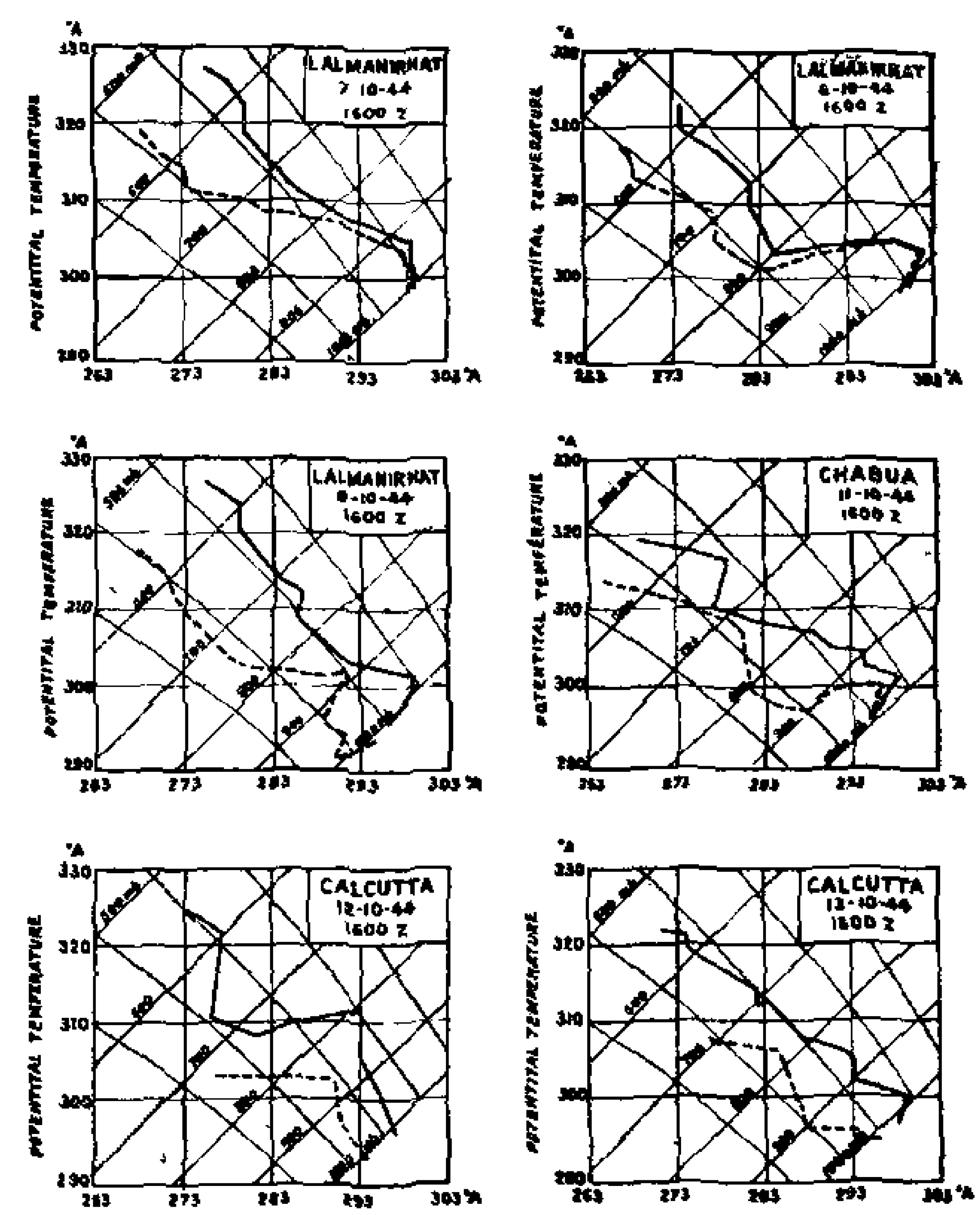
Kweilin:

28th June 1944. The curve is slightly superadiabatic from 950 to 920 mbs. and almost dry adiabatic from 840 to 800 mbs. θ_w was less than 298 at all heights above 930 mbs.

29th and 30th June. No ascents.

1st July. θ_w was above 298 upto about 780 mbs.

2nd July. Nothing special to report.



Chengtu

29th June 1944. Dry adiabatic between 850 and 650 mbs. showing a fresh incursion of air over the place.

30th June. The fresh incursion of air persisted.

Yunannyi

1st July 1944. "Normal curve." θ_w almost 297·5.

2nd July. Short flight; between 800 and 750 mbs.—dry adiabatic and higher up the temperatures had fallen since previous day and θ_w was there 296.

3rd July. Temperatures had increased upto 700 mbs. Lapse-rates were between dry and wet adiabatic values.

4th July. "Normal curve"—all temperatures had increased.

Lalmanirhat

3rd July 1944. Almost super-adiabatic lapse-rate from ground to 970 mbs. Nothing else of importance.

4th July. Temperatures had fallen from the previous day from 920 to 820 mbs. θ_w was 299 upto 910 mbs. and below 298 at heights above that level.

5th and 6th July. No ascents.

7th July. θ_w touched 302 at the height corresponding to 960 mbs. and was above 298 at all heights upto 580 mbs.

Calcutta

3rd July 1944. The curve nearly saturated upto 780 mbs. θ_w was 300.

4th July. From 940 to 840 mbs., a wedge of cold air had come in and above 840 mbs., θ_w did not exceed 298·5.

5th July. No ascent.

6th July. "Normal curve."

There is an unmistakable incursion of a fresh air mass from Kweilin on 28th June 1944 to Chengtu on the 29th, to Yunannyi on 2nd July and to Assam and Bengal on the 4th July. At Lalmanirhat and Calcutta, the thickness of the layer is almost the same and occurs at the same height intervals. *The air is not dry nor unstable.* By the time the air reaches Bengal, it is more moist and hotter than Em, as shown by a comparison of θ_w over Calcutta and Bangalore, being 300 and 290 respectively.

The surface charts, earlier than 7th July, show distinctly the incursion of fresh dry continental air into the Bay.

The Far Eastern air, that came over Calcutta and Lalmanirhat on the *same day* as Em over Bangalore, shows a definitely higher temperature and has to be treated as a distinct mass from the east and not as part of an 'old monsoon' stream. The Far Eastern Transitional air (Tr) passes over the neighbourhood of the thermal equator and over regions which are fully saturated due to swamps and forests in the track from Indo-China to Burma. The air is hotter and very much more oppressive than Em. Deppermann also noticed the hot air to the northeast of the Philippine typhoons, but did not follow it very much.

During the middle of October 1944, a tropical cyclonic storm formed in the Bay of Bengal. Between the 12th and 13th October 44 a 'pulse' of fresh monsoon air crossed to the north of the equator.[6] From the radio-sonde ascents, it is seen below that a fresh air mass passed over Colombo on the 13th.

Colombo

12th Oct. 1944. θ_w was more than 296 upto 640 mbs. The curve was dry adiabatic from 850 to 760 mbs.

13th Oct. From ground to 940 mbs.; the lapse-rate was dry adiabatic and also again from 900 to 850 mbs. Above 850 mbs. θ_w was 295.

14th Oct. Temperature curve almost normal. θ_w was greater than 296 upto 670 mbs.

The radio-sonde ascent of 6th Oct. shows a distinct colder wedge of air between 700 and 550 mbs. In the next available ascent on 10th, there is no such wedge.

Lalmanirhat

7th Oct. 1944. Curve normal.

8th Oct. From 940 to 800 mbs.—slight superadiabatic lapserate. All temperatures less than on the previous day.

9th Oct. Colder wedge from 900 to 600 mbs. can still be seen; though the shape of temperature curve has recovered.

10th and 11th Oct. Fresh incursions of air.

After that date for a few days, the curves were normal.

Calcutta

12th Oct. 1944. A remarkable wedge of cold air between 800 and 600 mbs. The air is not moist though not very dry.

13th Oct. The temperature curve had recovered.

The fresh air mass that was over Chengtu about the 6th of Oct. 1944 passed over Calcutta on the 12th to feed the Bay depression; while the fresh 'pulse' passed over Colombo on the 13th. The fresh air mass from the east is not very moist in this season. Data from an earlier epoch than the depression have to be examined as Tr may have to travel longer in case of tropical cyclonic storms.

The data of Chittagong and Chabua (Assam) generally support the incursion of fresh air mass for the above cyclonic storm. Chabua shows layers of subsidence from 675 to 640 mbs. and again from 550 to 515 mbs. on the 11th. This disappeared on the next day.

The dry continental air gave a sharp wedge on 5th Oct. 44 extending from Russian Turkestan to Mekran and brought in unusually low temperatures over N. W. India. The low temperatures gradually extended throughout N. India during the course of the succeeding week and descended down the latitudes to feed the depression in the Bay of Bengal.[7]

It follows that the upper air temperatures confirm the conclusion that three distinct air masses are involved in the tropical cyclonic storms and in the monsoon depressions. Elsewhere,[8] it has been pointed out that the easterly upper wind stream should not be looked for just north of the place where ultimately a depression forms but should be noticed very much further north, just as in the case of the extra-tropical cyclones.

---

1. Malurkar, "Forecasting Weather in and near India," 1945 (limited ed.), p. 42, and p. 87 2. Malurkar, *Curr. Sci.*, 1948, **17**, 112. 3. Deppermann, 'Outlines of Philippine Frontology,' 'Are there Warm Sectors in Philippine Typhoons,' 1937. Weather Bureau, Manila. 4. Data printed in Indian Daily Weather Reports. 5. Pisharoty, "Combined Role of Fresh Monsoon 'pulses' and Easterly Waves in the Formation of Monsoon Storms", *Symp. Nat. Inst. Sci (India)*, Aug. Sept., 1946. 6. Malurkar, "Forecasting Weather, etc.," *loc. cit.* 7. *Ibid.*, 8. Malurkar, 'Role of three air masses in Tropical Cyclonic Storms' at present MSS.

Note.—The cost of printing this article has been met from a generous grant from the National Institute of Sciences, India.