Mausam, (1988), **39**, 1, 57-64

551.513 : 551.583.13

Study of certain sudden weather developments over central India in winter

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(*Received 21 August 1985*)

सार — मध्य भारत में शीतऋतु में होने वाली अधिकांश वर्षाएं पश्चिमी विक्षोभों द्वारा उत्पन्न प्रणालियों से सम्बन्धित हैं और ये कभी-कभी देश के सुदूर दक्षिण में गतिमान चक्रवाती प्रणालियों से भी प्रभावित होती हैं । परन्तु ऐसे भी उदाहरण मिलते हैं जब ऐसी प्रणाली के अभाव में भी देश के मध्य भागों में शीत ऋतु में आकस्मिक बौछारें पड़ी हैं । यह अध्ययन दर्शाता है कि, मध्य भारत में कुछ आकस्मिक व्यापक वर्षाएं वास्तव में अत्यन्त प्रवर्धित निम्न क्षोभमण्डलीय बंगाल की खाडी से उठने वाली पूर्वीय तरंगों से सम्बद्ध हैं जो प्रायद्वीपीय भारत के पार बढ़ती हैं और मध्य भारत के शुष्क प्रदेशों में अत्यन्त आर्द्र हवा लाती हैं जिनके कारण वहां पर मौसम प्रबल हो जाता है । मध्य भारत के आस-पास आर्द्र वायु के आरोहण का पता लगाने व उसके ऊर्ध्व वेग को निर्धारित करने के लिए आइसन्ट्रापिक विधि का प्रयोग किया गया है । यह दिखाया गया है कि इस ऊर्ध्व उठाव के प्रत्येक मामले के क्षेत्र में स्थित ऊपरी क्षोभमण्डलीय जेट प्रवाह की अनुकूल स्थिति द्वारा वृद्धि होती है जिसके कारण प्रबल संवहनी क्रिया होती है ।

ABSTRACT. Most of the winter rains in central India are associated with systems induced by western disturbances and, sometimes, as an effect from the moving cyclonic systems in the extreme south of the country. But, there are instances of sudden winter wet spells localised in the central parts of the country in the absence of any such system. This study shows that, some of the sudden widespread rains in central India are actually associated with highly amplified lower tropospheric easterly waves from the Bay of Bengal progressing across the Peninsular India and bringing in considerable moist air into the dry regions of the central India to cause vigorous weather there. Isentropic method has been used to locate the ascending moist air around central India and determine its vertical velocity. It has been shown that this vertical lift is further augmented by the favourable position of an upper tropospheric jet stream located in the area in each case, thus causing vigorous convective activity.

1. Introduction

1.1. Three typical cases of winter rains are discussed, when, the entire central India comprising of Vidarbha, Madhya Pradesh and the adjoining areas of neighbouring States were caught by sudden wet spell, lasting only for a day or so.

1.2. The cases studied are of : (1) 6/7 February 1979, (2) 25/26 December 1983 and (3) 31 December 1983 to 2 January 1984—when, the rainfall was not only sudden and widespread, but in most of the cases was unusually heavy for the season, attended with severe thunder and hail.

1.3. The natural calamity was also high for the season, severely damaging the crops and other agricultural interests, besides claiming human lives also, as happened in the case of February 1979.

1.4. Though the subject of winter rains in the Indian subcontinent, including the central parts of the country, has been widely discussed by many Indian authors from time to time, the present study brings out identifiable features peculiar only to these typical situations. An objective method of their determination has also been devised.

2. Qualitative survey

2.1. *Significant features in the field*— In all the cases of 1979, 1983 and 1984 it was seen that there was no western disturbance or its induced systems in the vicinity of central India to cause rains in the region. In the south, in some cases, there were cyclonic systems moving across extreme south Peninsula but they were not extending to the north nor causing rainfall towards north. In all cases of rainfall over central India of the type shown by the three cases noted above, the only significant feature was the propagation of highly amplified easterly waves in the lower troposphere bringing about a marked partition of very dry and moist air in the Peninsula. In the upper troposphere there was present a very strong upper westerly jet stream across the central Peninsula in each case (Figs. 2, 3, 6 & 7).

2.2. *The case of 6/7 February 1979* — On 5th a lower tropospheric easterly wave progressing across southwest Bay of Bengal amplified to the northwest Bay of Bengal with a partition of very dry and moist air running from Orissa coast to north Tamilnadu. In the upper troposphere a westerly jet stream was passing through south Rajasthan to Uttar Pradesh hills. On 6th, at the representative level of 850 mb (Fig. 2), the easterly wave moving through Sri Lanka

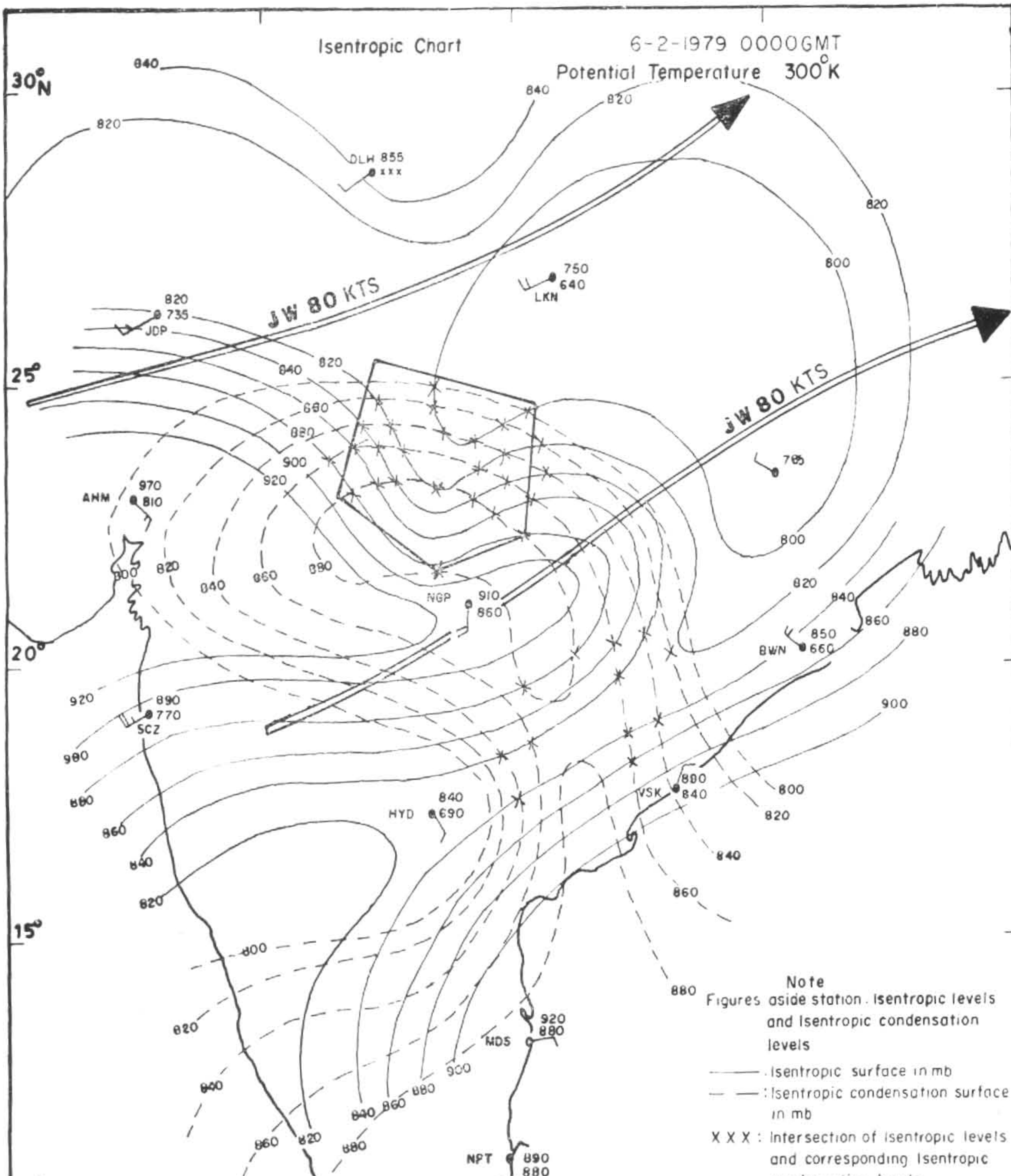

Fig. 1. Isentropic chart, 6 February 1979, 0000 GMT, potential temperature 300 °K

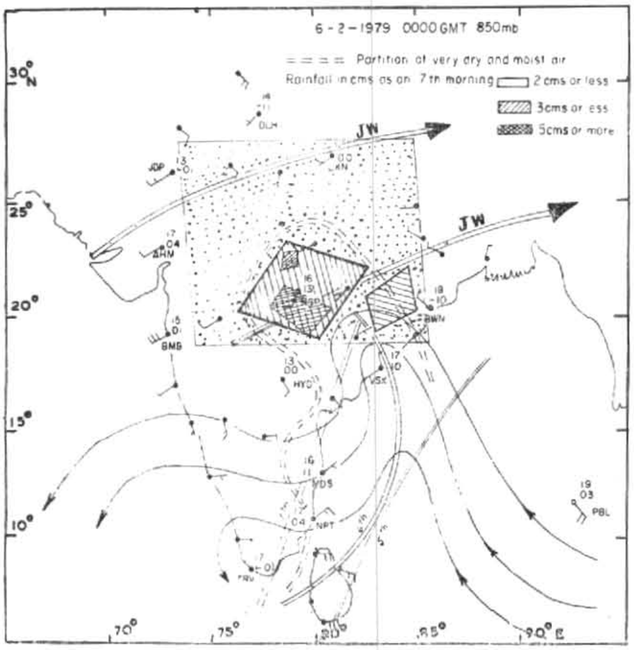

Fig. 2. 6 February 1979, 0000 GMT, 850 mb

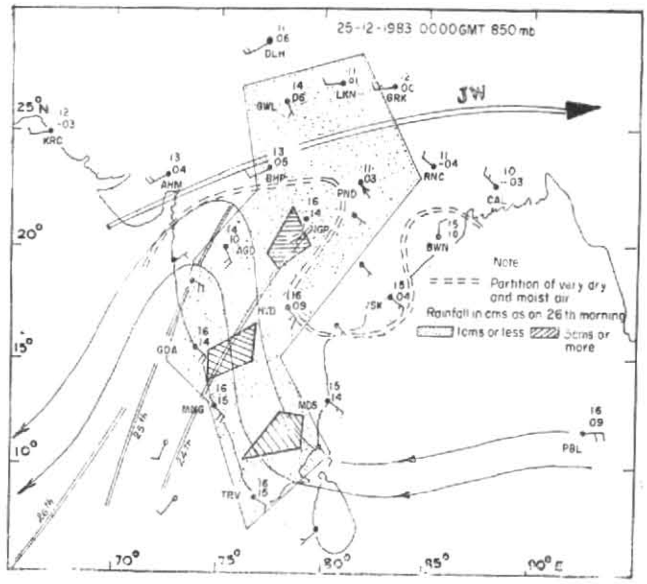

Fig. 3. 25 December 1983, 0000 GMT, 850 mb

extended to southeast Madhya Pradesh with partition of very dry and moist air passing through Telengana-Marathwada-central Madhya Pradesh-Orissa. In the upper troposphere, at 300 mb level, a second westerly jet stream of maximum wind speed 80 kt passed through Marathwada to West Bengal while the westerly jet stream of the previous day still passed through Gujarat to eastern Himalayas. On 7th, the easterly wave, though considerably damped, was still moving across southwest Peninsula with the partition of dry and moist air extending meridionally from west Madhya Pradesh to Telengana. The southern jet stream passed through Andhra coast to Assam. Regarding rainfall, on 6th morning there was no rainfall in central India except for a few falls in Telengana and adjoining Marathwada. However, it was widespread in central India on the morning of 7th with several rather heavy to heavy falls in Vidarbha. On 8th it ended abruptly in the central India and was confined to the northeast India and around.

2.3. *The case of* 25/26 *December* 1983 — On 24th an easterly wave was propagating across central Peninsula embedded in which was a low pressure area over Laccadives. Partition of very dry and moist air passed through south Orissa-northeast Madhya Pradesh-Telengana, when, in the upper troposphere a westerly jet stream was passing through Rajasthan to north Bihar. On 25th, at 850 mb (Fig. 3), the easterly wave moved west and amplified to north Maharashtra, still embedding the low over southeast Arabian Sea. Partition of very dry and moist air passed through south Gujarat to West Bengal. In the upper troposphere the westerly jet stream of 100 kt now passed through Gujarat to south Uttar Pradesh. On 26th the easterly wave damped considerably, progressed to southeast Arabian Sea still embedding the low in the south. The partition of dry and moist air passed through Gujarat-central Madhya Pradesh-Uttar Pradesh and the upper westerly jet stream retreated to north across Uttar Pradesh. Regarding rainfall, on 25th there was practically no rain in the central Peninsula but widespread rains with few heavy falls occurred in the south Peninsula. On the morning of 26th, rainfall became widespread in central India with many moderate falls in Vidarbha. Rains in the south continued but diminished in intensity. By the morning of 27th rainfall in central India decreased abruptly and was seen only in the south Peninsula and northeast India.

2.4. *The case* 31 *December* 1983 *to* 2 *January* 1984 — On 30th a low pressure area was lying off the coast of Kerala embedded in an easterly wave which extended upto Konkan coast. At the same time another lower tropospheric easterly wave was advancing across Sri Lanka extending upto west central Bay. The resultant partition of very dry and moist air passed from south coastal Andhra Pradesh to north Maharashtra coast. In the upper troposphere, a westerly jet stream passed through north Gujarat to north Bihar. On 31st, at 850 mb the easterly wave to the west moved further and amplified to south Gujarat coast. At the same time the easterly wave to the east moved west and associated trough amplified to south Orissa coast with the resultant partition of very dry and moist air passing through southeast Madhya Pradesh-Vidarbha-south Gujarat. In the upper troposphere, at 300 mb, a second westerly jet stream of 100 kt passed through Marathwada to Bihar, the westerly jet stream to the north still passing through south Rajasthan to Uttar Pradesh hills. On 1st morning, both the easterly troughs progressed, the former amplified to Madhya Maharashtra and the latter to southeast Madhya Pradesh, with the resultant partition of very dry and moist air passing through north Gujarat-central Madhya Pradesh-Orissa. In the upper

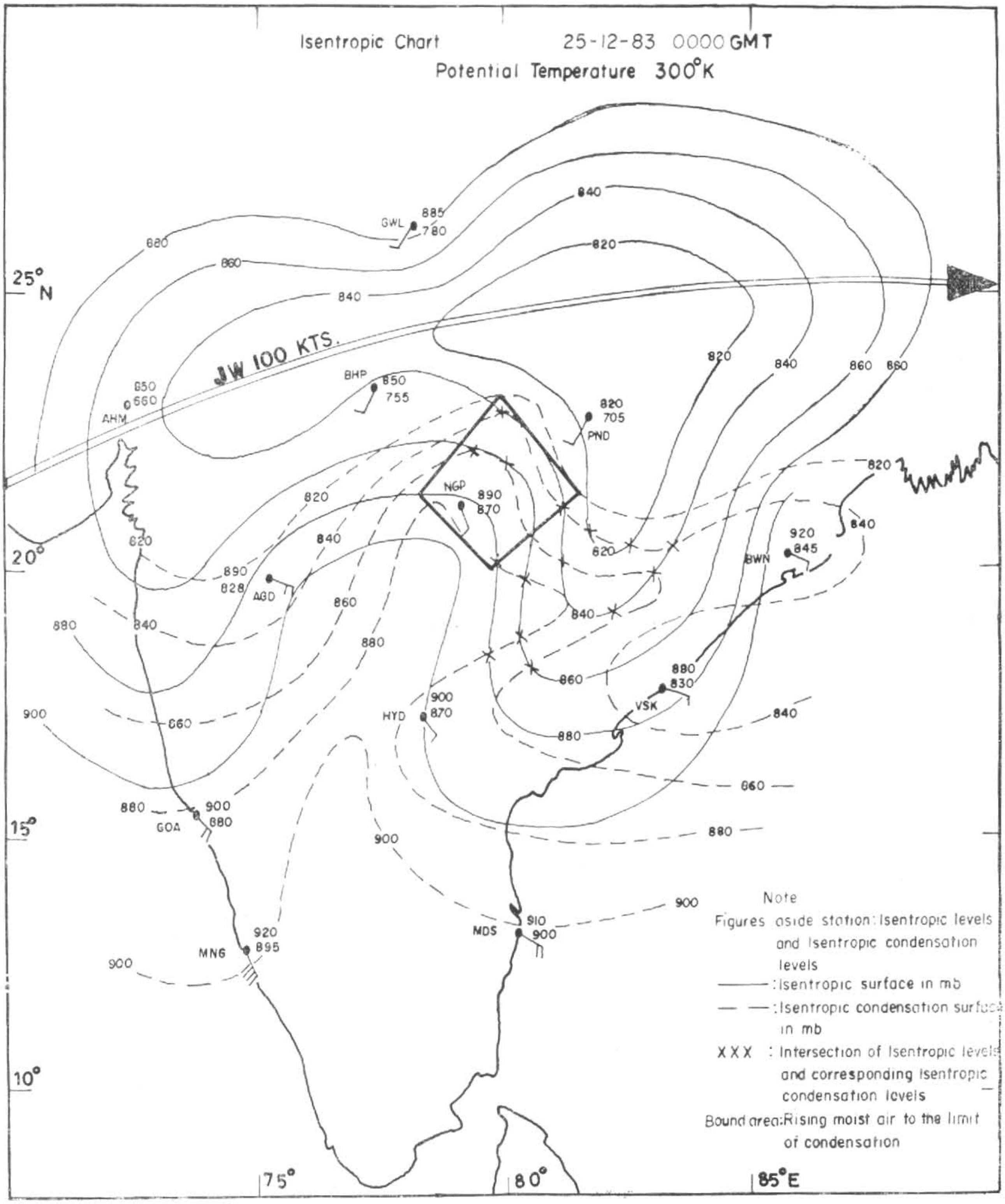

Fig. 4. Isentropic chart, 25 December 1983, 0000 GMT, potential temperature 300° K

troposphere, the second westerly jet stream continued to pass through Madhya Maharashtra to West Bengal, the other jet stream retreating to further north. On the morning of 31st there was no rain in the subcontinent except of the extreme south. On the morning of 1st light to very light rains were widespread in central India with only isolated light rains in the south (Fig. 6). On 2nd morning rainfall became widespread in central India with several moderate falls around Vidarbha (Fig. 7). On 3rd morning rainfall decreased abruptly in the central Peninsula except a few in the eastern-half. It is also to be noted that all these events of rainfall activity in the central parts of the country were accompanied with severe thunder and hail.

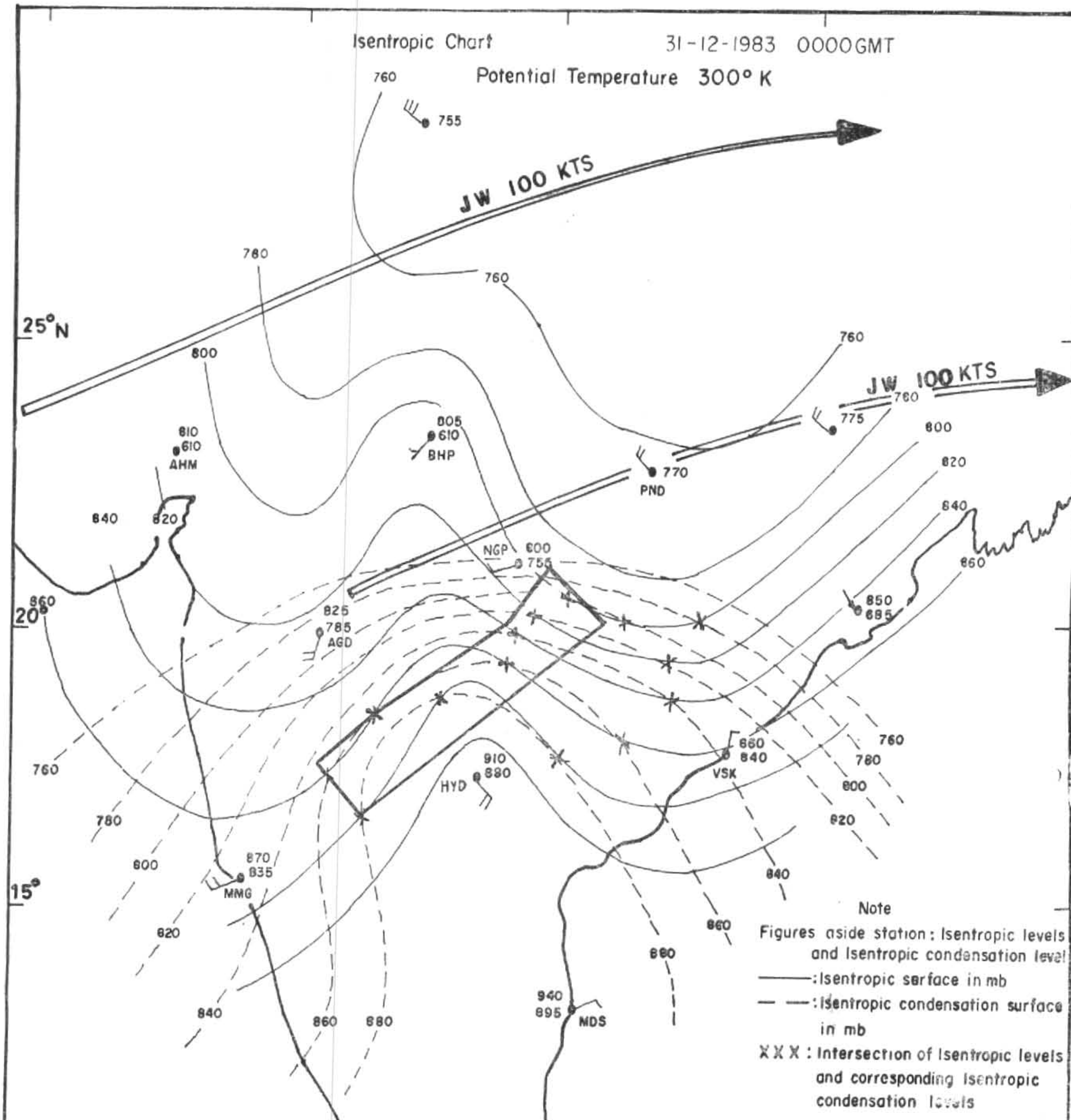

Fig. 5. Isentropic chart, 31 December 1983, 0000 GMT, potential temperature 300° K

3. Discussion

3.1. *Results of the qualitative survey* — A careful study of the qualitative survey brings to light that in all the three cases discussed, the developments in central India were sharp and sudden. Subject of winter rains in central India has been widely discussed by Indian authors, attributing to western disturbances (Pisharoty and Desai 1956) and their induced systems (Rao and Srinivasan 1969) when rainfall can be traced to move from west and, to intense cyclonic systems in

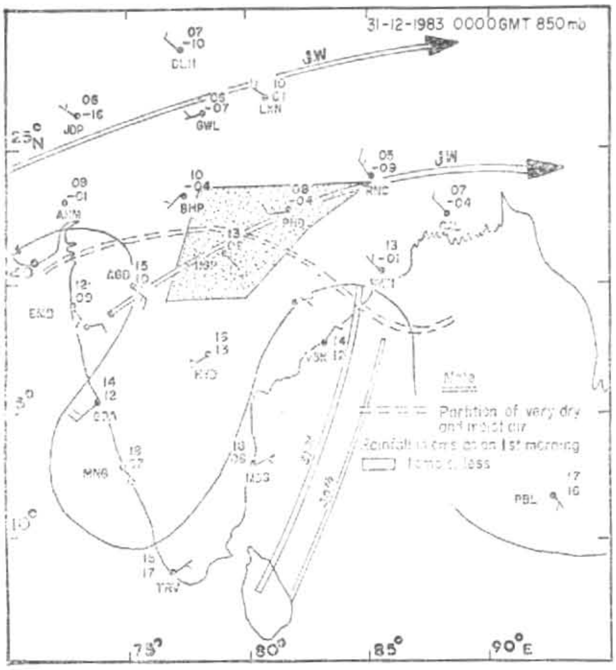

Fig. 6. 31 December 1983, 0000 GMT, 850 mb

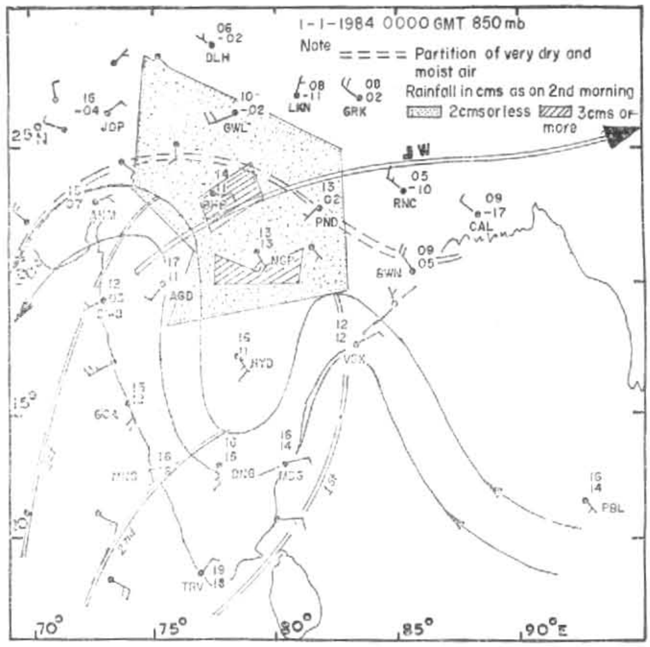

Fig. 7. 1 January 1984, 0000 GMT, 850 mb

the south undergoing interactions with systems in the north (Ranganathan and Soundarajan 1965, Sharma and Subramanian 1985) when rainfall can be traced approaching from south. In the present cases there was no western disturbance or its induced system in the vicinity and rainfall in central India did not progress from west or south. There had been, however, cyclonic systems in the south for all the cases, sometimes embedded in easterly waves. The only significant feature in all the cases present here is the propagation of highly amplified lower tropospheric eastery waves across the Peninsula, bringing in considerable moist air (Reihl 1954) into the pre-existing field of very dry air of the Peninsula causing a marked partition of very dry and moist air (Srinivasan and Ramamurthy 1973) in or around the central India. In the upper troposphere the only significant feature is the passage of a westerly jet stream of strong core across the central India which are known for triggering intense weather development when favourable conditions exist in the lower troposphere (Reiter 1963). The sudden developments in central India in the form of widespread rain, moderate to heavy falls, severe thunder and hail are seen to occur only when the above said boundary region of very dry and moist air is superposed by this strong upper westerly jet stream (Figs. 2, 3, 6 & 7).

3.2. A qualitative appraisal of the role of contrast air-masses in lower tropospheric levels in causing intense weather activity when overlain by a jet stream in the upper troposphere is given below.

4. Quantitative survey

4.1. *Choice of quantitative method* — Isentropic analysis has been found suitable for study of contrast airmass and has been mostly utilised for thermal fronts prevalent in the extratropics. Although it is rather difficult to conceive a clear thermal front in the tropics Hill (1969), while dealing with the unusually heavy rains of New Zealand, contended that, even if clear thermal fronts are not seen, a distinct humidity regime can also be taken as one of the participants of a front. In view of the existence of a distinct moisture regime in all the present cases the isentropic method is chosen for the quantitative study of the thermodynamics of this development.

4.2. *Isentropic method* — The object of the isentropic analysis is, first of all, to find out an area where air is rising and then to locate the ascending moist air in it. Isentropic charts of such a potential temperature are chosen where the surfaces corresponding to the lower tropospheric values transit towards an upgradient around the partition of air. If the wind is normal to the upgradient of the isentropic surfaces, the air rises on the windward side with a vertical velocity (Petterssen 1940) that can be calculated directly from the chart. If v is the normal wind component in kt, $\triangle p$, the interval of the isentropic surfaces in mb and $\triangle x$, the normal distance in nautical miles between two isentropic surfaces in the upgradient, then, the air takes $(\triangle x/v)\times 60\times 60$ seconds to cross the distance and same time gain a height equivalent to $\triangle p$. Considering 1 mb change in height in the free atmosphere equivalent to 30 ft, the air, during the time of crossing these two isentropic surfaces of interval $\triangle p$, rises to a height of $\triangle p\times 30\times 12\times 2.54$ cm. The vertical velocity of the rising air can then be calculated in cm/sec. Hill (1969) has also used this method for estimating vertical motion. The next problem is to see whether in the area of rising air on the isentropic chart, the corresponding isentropic condensation levels penetrate to mark a moist area of condensation (Byers 1974, Petterssen 1940). It helps in selecting the exact area of ascending moist air which will be the area of development.

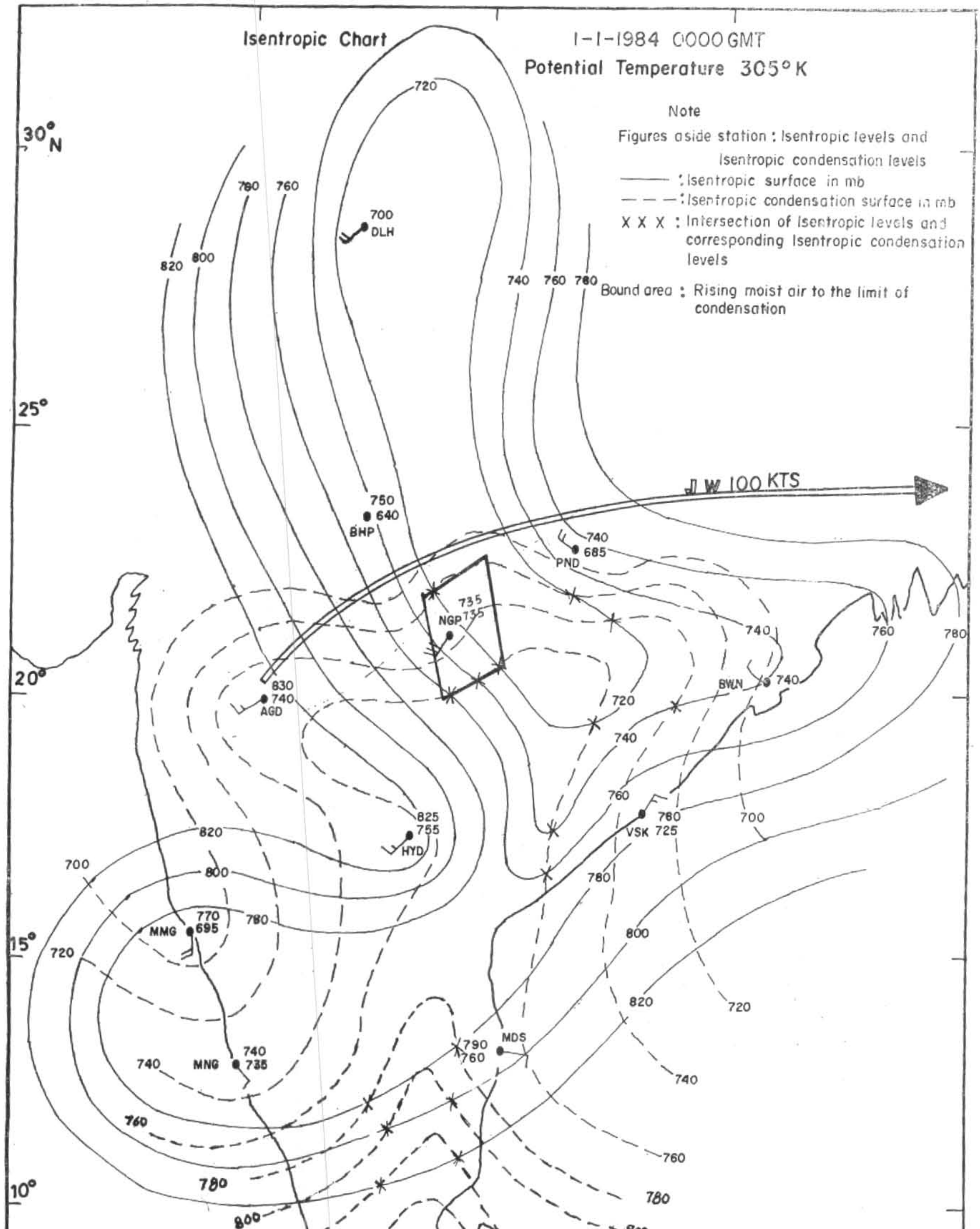

Fig. 8. Isentropic chart, 1 January 1984, 0000 GMT, potential temperature 305° K

4.3. *Development* — For determining the development, the vertical velocity in the lower troposphere, especially in the demarcated ascending moist air, is calculated from the isentropic chart. Panofsky (1946) has mentioned, that, in such a field of uniform motion, the vertical velocities generally are of the order of a few cm/sec capable of forming weather. Gordon (1962) mentions that vertical velocities of the order of 2 to 4 cm/sec generally found in such a field of uniform motion can cause medium clouds with moderate rain. In the present cases the developments were not only in the form of severe thunderstorm and hail, but occurred with the suddenness and the intensity of precipitation was much more than moderate. The stimulation of the intense development will, therefore, need additional triggering agency. This has been provided by the upper jet streams as mentioned by Reiter (1963). Determination of the intense development, is, therefore, done by examining the relative position of the the ascending moist air to the upper jet stream. It is noted, that, the right entrance and left exit of an upper tropospheric jet stream are favourable areas for the low level development.

4.4. *Accentuation* — For the case of 6 Feb 1979, the isentropic chart of the morning for potential temperature 300° K is referred (Fig. 1). It shows rising air for the entire central India with vertical velocity of about 3 cm/sec, marked by the bound area around Vidarbha and adjoining areas. This area is located in the middle of the two upper jet streams, particularly in the right entrance of the northern jet. Rainfall was widespread in central India with localised considerably heavy falls in and around Vidarbha (Fig.2). For the case of 25 Dec 1983, the isentropic chart of the morning for the potential temperature 300°K is chosen (Fig. 4). It shows rising air in the entire Peninsula with a vertical velocity of about 1 cm/sec, marked by the bound area in Fig. 4. This area can be seen to be located at about the right entrance of the upper jet stream of very strong core. Rainfall was widespread in central India with considerably heavy falls in Vidarbha (Fig. 3). For the events of the case starting 31 Dec 1983 the isentropic charts of the morning of 31st and 1st for potential temperatures 300°K and 305°K respectively are referred. For 31st it shows rising in the western-half of the central Peninsula with vertical velocity of about 1.5 cm/sec, marked by the bound area of moist concentration in the southern fringe, placed in the right entrance of the upper jet stream (Fig. 5). On this day only light to very light widespread rains occurred over central India (Fig. 6). For 1st, it shows rising air in almost the entire central India of vertical velocity about 3.5 cm/sec, marked by the bound area of ascending moist air around Vidarbha (Fig. 8), placed in the right entrance of the upper jet stream. Rainfall was widespread in central India with considerably heavy falls in and around Vidarbha (Fig. 7). The study on the four events of the three cases also conforms with the contention of Panofsky (1946) that superposed on the field of uniform vertical motion of air there can be vertical velocities of higher order bringing in intense developments. In these cases the upper jet streams provide the mechanism causing severe thunder and hail and also stimulating developments in the cases where vertical velocities were only of the order of 1 cm/sec or so (Hill 1969) and localising the considerably heavy falls around the area of ascending moist air.

5. Conclusion

It is, therefore, concluded that if in the absence of any western disturbance in the vicinity or any interaction from cyclonic systems in the south, there are sudden localised winter wet spells over central India, they are attributable to a combination of amplified lower tropospheric easterly waves progressing across the Peninsula and suitably placed upper westerly jet streams aloft. The influx of considerable moisture brought by the amplified part of the propagating easterly wave over central India forms a contrast airmass of very dry and moist air over the region. The isentropic method has been used to locate the ascending moist air and determine the vertical velocity in such a situation and it has been shown that the vertical ascent when further aided by a favourably placed jet stream aloft can cause sudden widespread rains in central India with localised heavy falls.

Acknowledgement

The authors are extremely grateful to Dr. S. N. Chatterjee, Meteorologist, Met. Office, Pune for supplying very useful data for the work.

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