

AN OBSERVATIONAL STUDY OF TROPICS MID-LATITUDE INTERACTIONS DURING
DIFFERENT SEASONS

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ABSTRACT

Over Indian region when the tropical easterly troughs and the extratropical westerly troughs come closer longitudinally, they interact and amplify each other, while maintaining their distinct identities. This level of interaction varies with season, and goes up in height from 350 hPa during winter to 500 hPa during monsoon. During interaction, in winter, pre- and post-monsoon seasons, the tropical easterlies extend considerably into northern latitudes in lower tropospheric levels. The extratropical westerlies extend considerably equatorward in upper tropospheric levels. In monsoon this interaction is responsible for the northward propagation of monsoon pulses from the equatorial region to the foot hills of the Himalayas. The tropics-mid-latitude interactions provide the necessary dynamics for the development and steering of the rain-giving systems in all seasons.

1. Introduction

The passage of an upper level westerly trough has been linked with the downstream convective activity and formation of cyclonic disturbances over Indian region and adjoining areas (Srinivasan, et. al., 1973). In turn it has also been shown that tropical convection modifies the upper level circulation - such that a new westerly trough with an embedded jet core is generated over region to its north and an easterly trough with embedded jet core forms over region to its south (Ranjit Singh, 1984, 1985, 1987). An attempt is made to present a three dimensional picture of these interactions between the tropical and mid-latitude systems over Indian region through a number of case studies for different seasons in 1985.

2. Case study of 1 - 2 January, 1985 (Winter season)

A low pressure area over Southeast Bay moved in a westerly direction. Its position as a cyclonic circulation embedded in an easterly wave at 850 hPa on 31 December 1984, 1 and 2 January 1985 is depicted in Fig.1(a). Two western disturbances (WD) moved across north Pakistan, Punjab and western Himalayas between 27 December 1984 and 2 January 1985. Under their influence an induced cyclonic circulation

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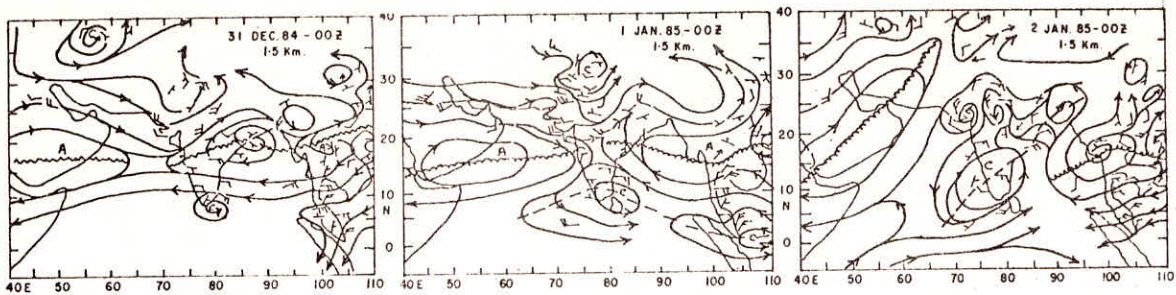


FIG. 1(a) - INTERACTION BETWEEN TROPICS AND MID LATITUDES DASHED LINE - TROUGH, WAVY LINE - RIDGE.

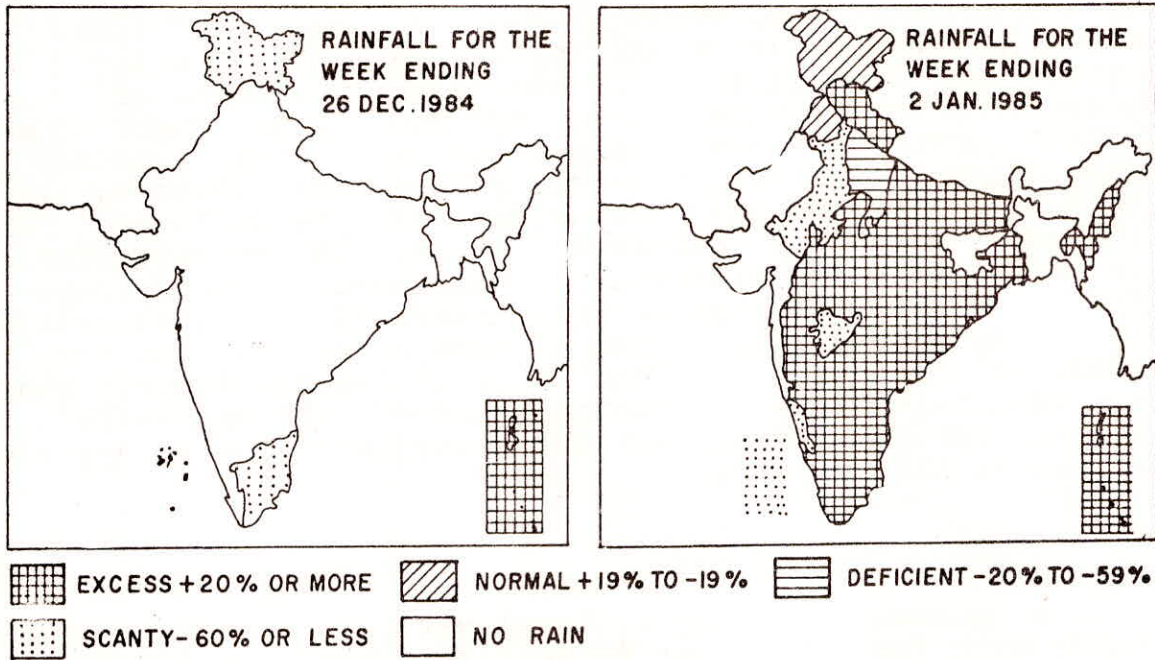


FIG-1.b

formed and lay over northeast Rajasthan and adjoining west Uttar Pradesh and Haryana on 1 January. An interaction between a mid latitude westerly trough and the tropical easterly trough is strongly marked when we explain the changes that have taken place between 31 Dec. 84 and 2 Jan. 85. at 850 hPa level. The two waves are seen to amplify between 31 Dec.84 and 1 Jan.85. On 2 Jan.85, the tropical easterly wave extends upto 30°N. The rainfall charts (Fig.1b) for the weeks ending on 26 December 1984 and 2 Jan.85 are suggestive of the weather that has occurred under the interaction of the trough in the tropical easterlies with the trough in the mid-latitude westerlies.

3. Case study of 29 March - 3 April 1985 (Premonsoon season)

The rainfall charts for the weeks ending on 27 March 1985 and 3 April 1985 (Fig.2a) throw an interesting light on the interaction between tropical and extratropical systems

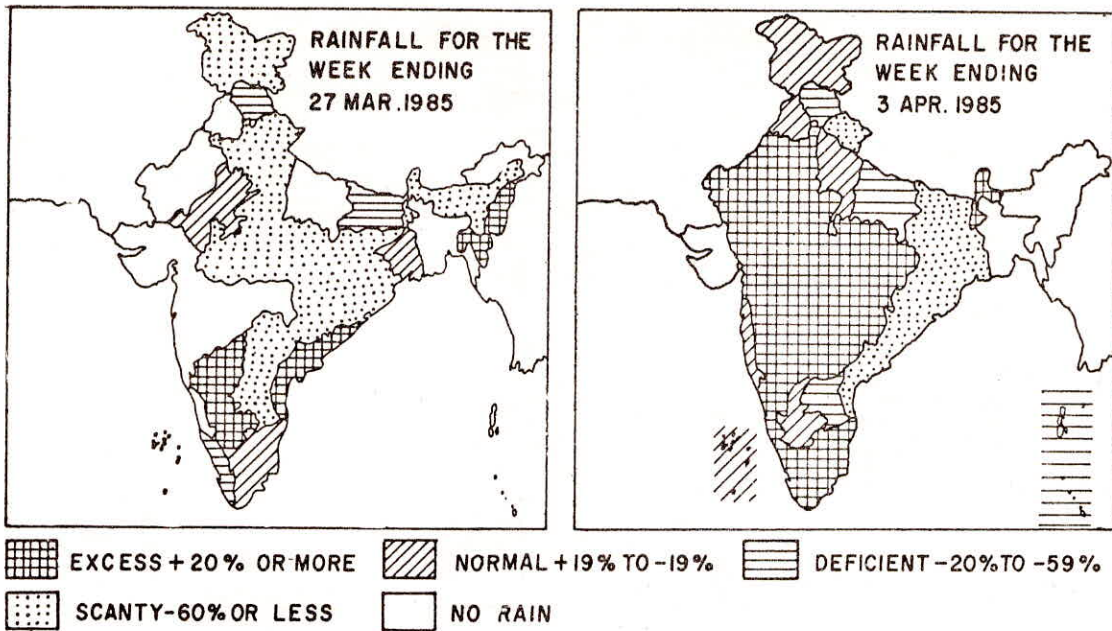
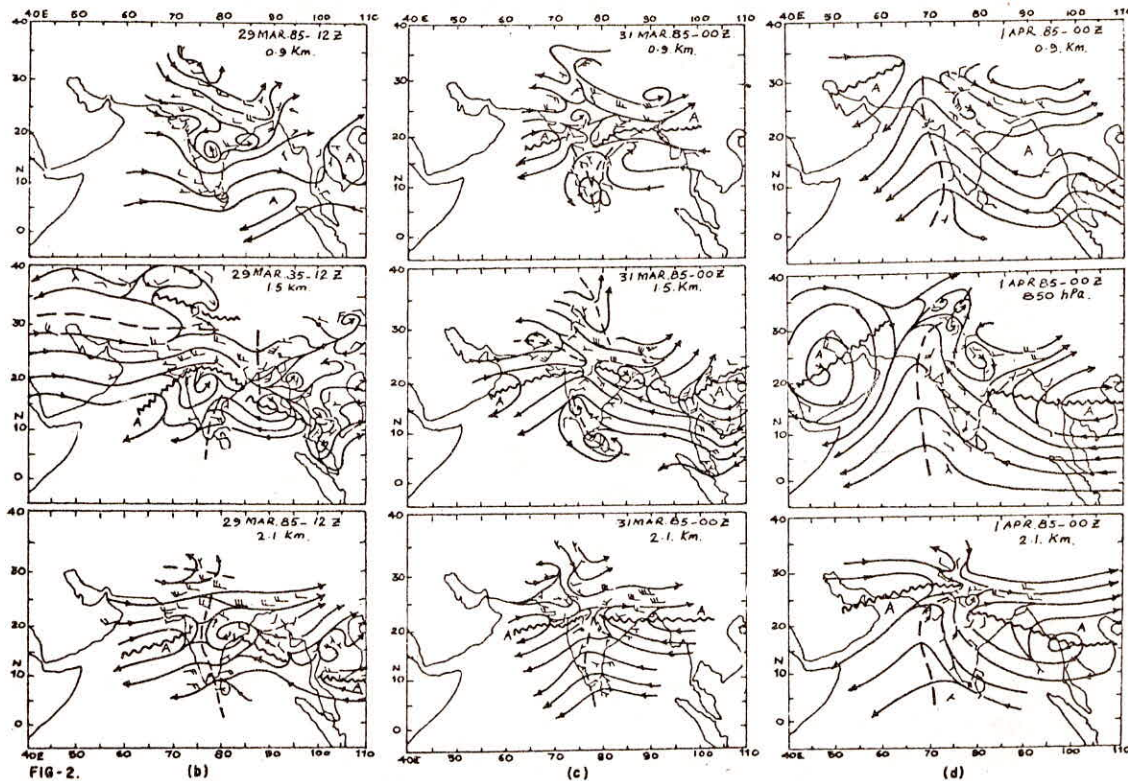


FIG-2.a



INTERACTION BETWEEN TROPICS AND MIDLATITUDES. DASHED LINE - TROUGH, WAVY LINE - RIDGE

in the pre-monsoon season. In Fig.2(b) an easterly wave is identified south of the subtropical ridge at 1.5 Km and 2.1 Km asl at 12 GMT of 29 March. At 0.9 Km and 1.5 Km asl the extratropical westerlies penetrate deep into Peninsular India, and in situ development of cyclonic circulation occurs in these westerlies. At 00Z of 31 March a tropical easterly

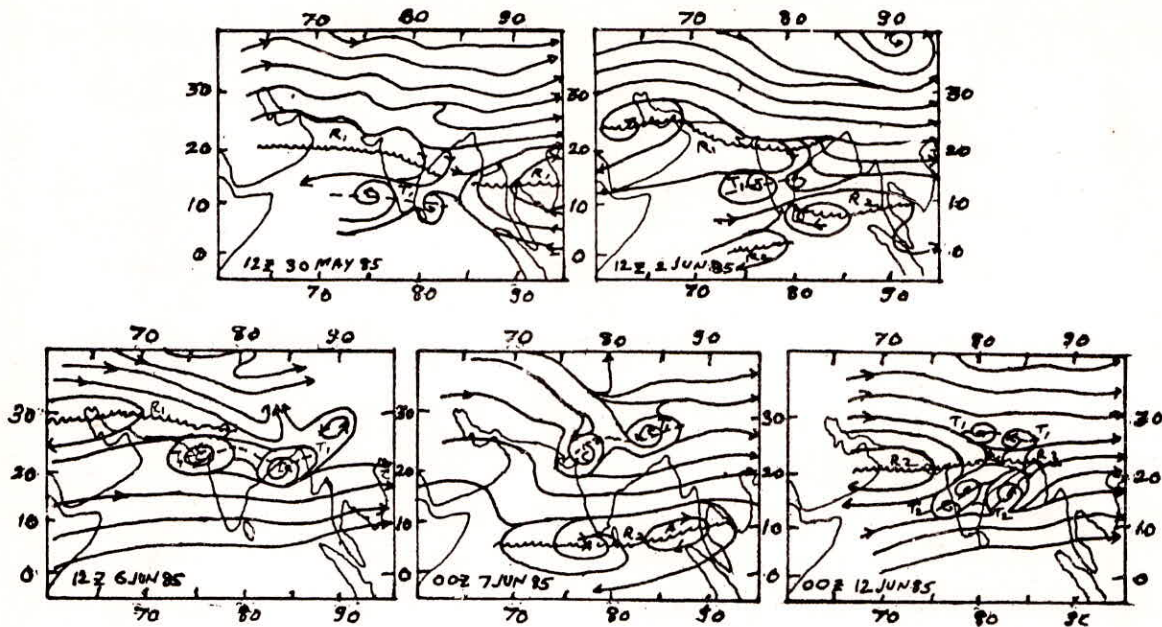


FIG 3 (a) ADVANCE OF THE FIRST PULSE OF MONSOON
 DASHED LINE - TROUGH. WAVY LINE - RIDGE

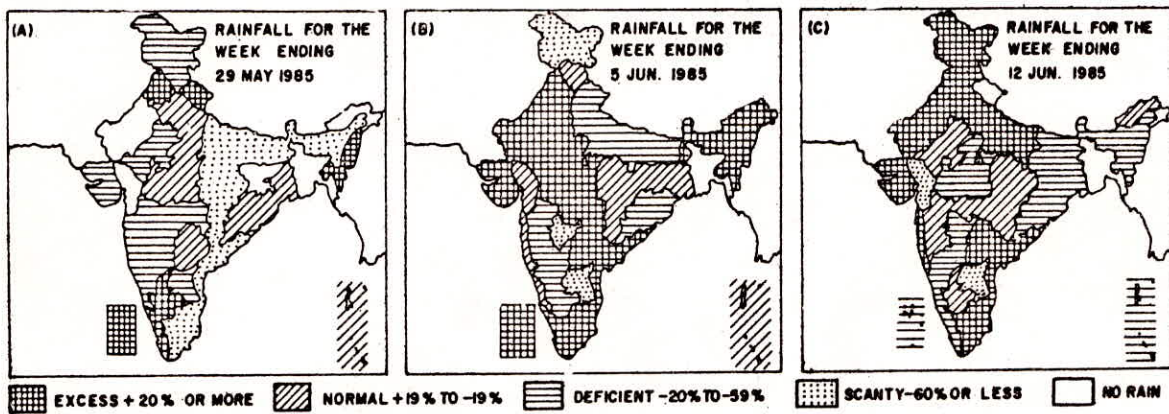


FIG-3.1

trough and cyclonic circulations embedded in it appear to form at 1.5 Km and 0.9 Km asl Fig.2(c). The mid-latitude westerly trough is observed to intensify at 1.5 Km asl over North-west India at this instant suggestive of the interaction between the tropical and middle latitude systems. On 1 April the easterly trough has moved westward over sea and in its wake the southeasterlies have penetrated deep into northern latitudes upto 20°N.(Fig.2d). These southeasterlies feed moisture into the mid-latitude westerly trough which develops a cyclonic circulation within and appear to merge with the easterly trough. This interaction between the tropical and extratropical troughs was responsible for rainfall over Most of the Peninsular and northwest India.

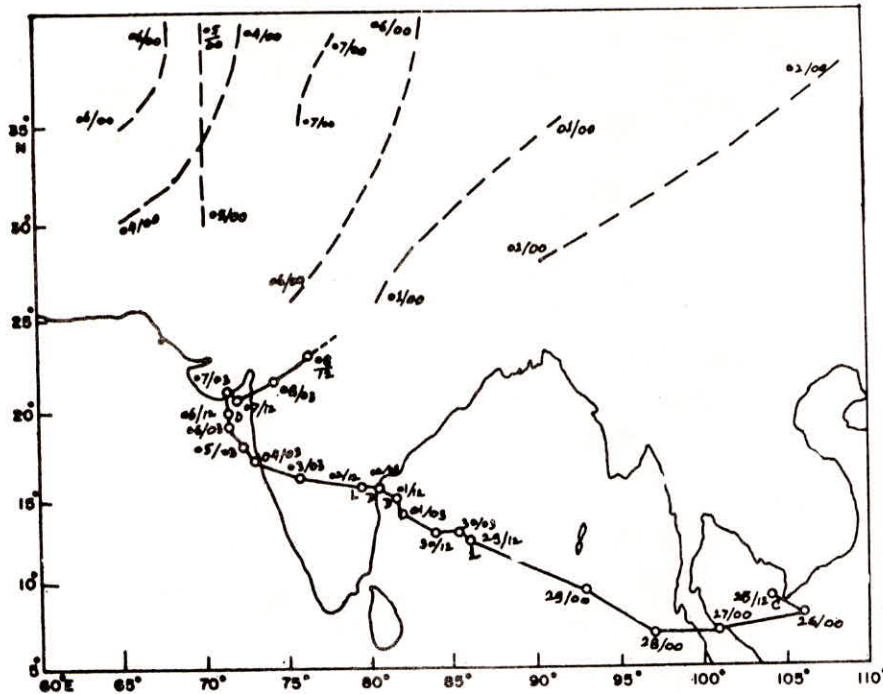


FIG. 4(a) TRACK OF OCT.'85 DEPRESSION. DASH LINE-WESTERLY TROUGH. C-CYCLONIC. CIRCULATION. L-LOW. D-DEPRESSION.

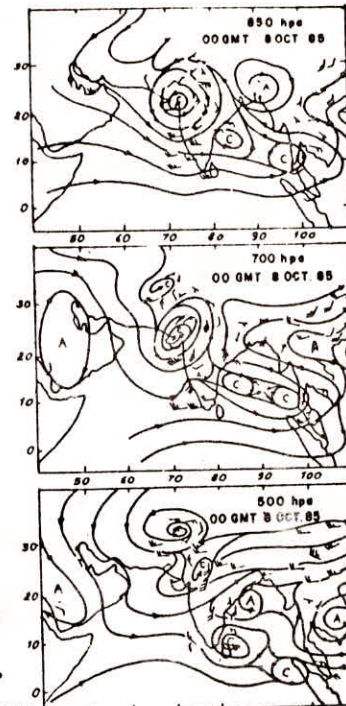


FIG. 4(b) INTERACTION BETWEEN TROPICS AND MIDLATITUDES.

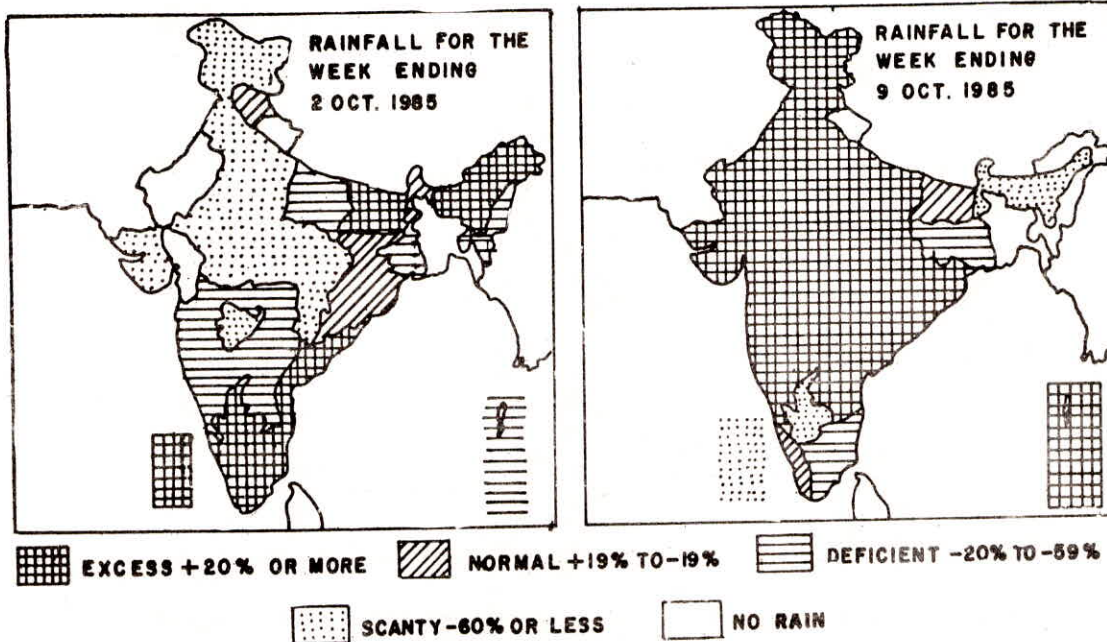
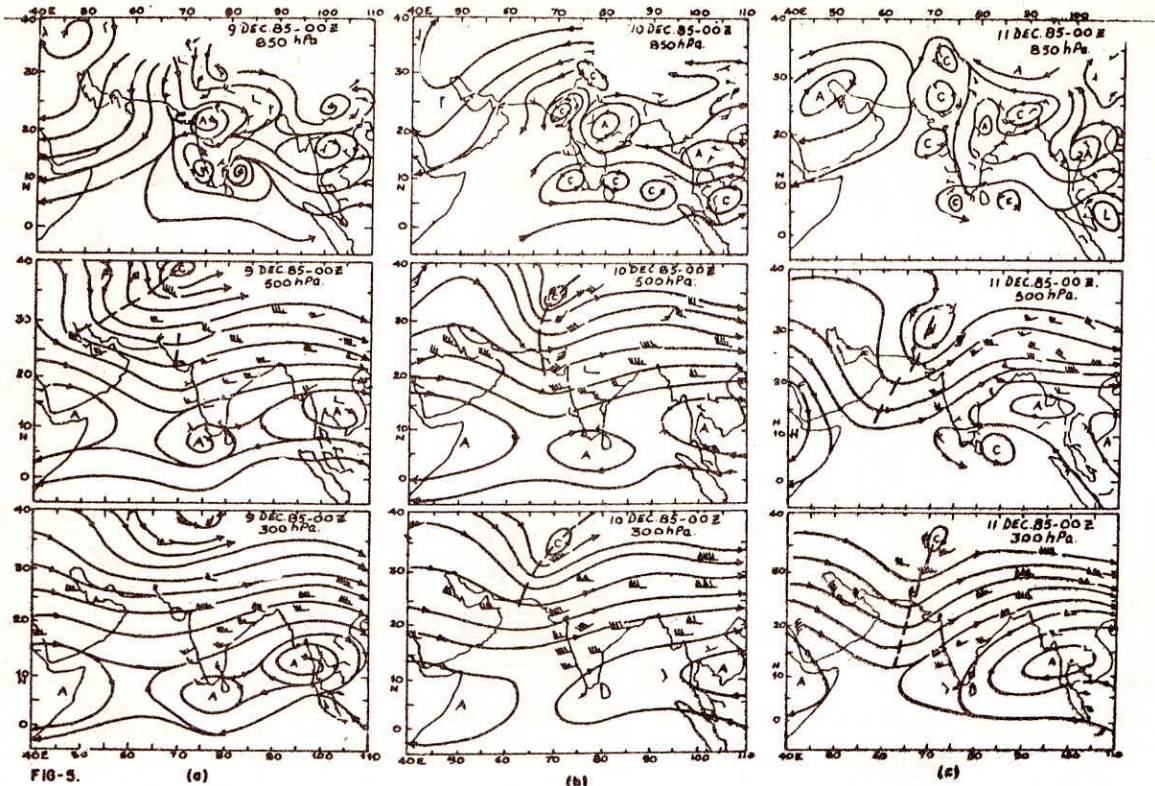


FIG : 4 .C

4. Case of 28 May - 12 June 1985 (monsoon season)

During monsoon season, the interaction between a mid-latitude westerly trough and the east-west monsoon trough is most evident at 500 hPa level. The activation of the east-west trough and its northward propagation from an equatorial position along 10°N, to an active phase position along 21°N



INTERACTION BETWEEN TROPICS AND MIDLATITUDES.

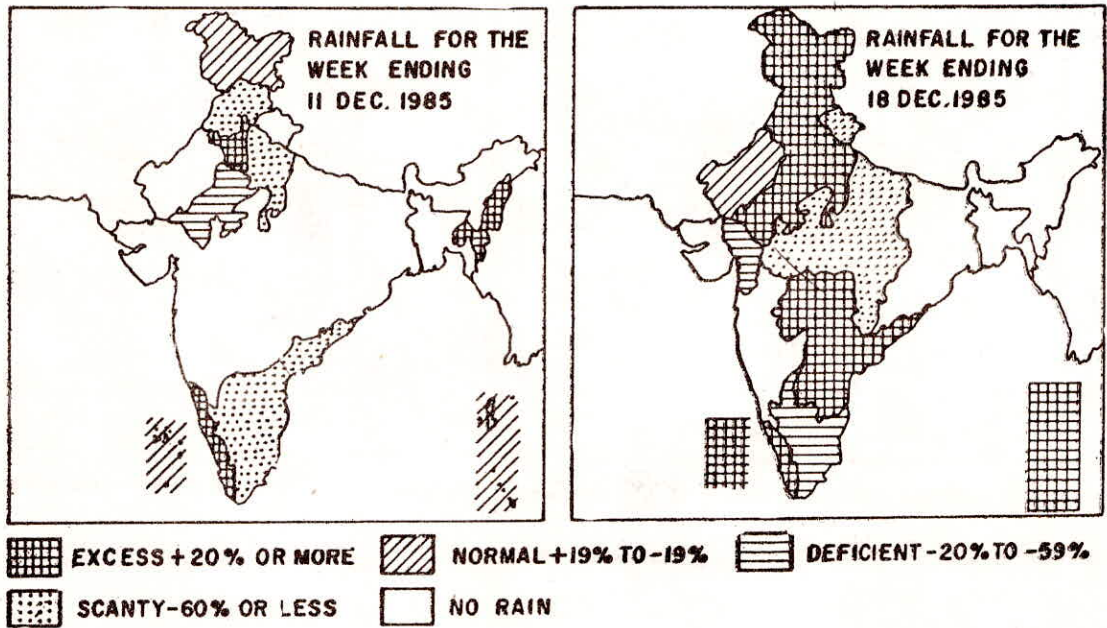


FIG-5.d

and then to its break monsoon position along foot hills of Himalayas is determined to a large extent by this interaction. The sequence of these northward propagating east-west troughs is said to comprise the monsoon pulses. An example of such interaction is shown in the present case study.

In Fig.3a an east-west trough T_1 is located south of the subtropical ridge (STR) R_1 on 30 May. This forms the first monsoon pulse. On the surface chart at 03 GMT of 28 May a depression was centred near 15°N , 67.0°E in the Arabian Sea and a well marked low pressure area lay in the Bay of Bengal. The Arabian Sea branch of monsoon started advancing northward from this day and covered the Maharashtra coast by 8 June. Thereafter this monsoon pulse had weakened. However, between 6 and 12 June, an interaction takes place between the east-west equatorial trough T_1 and the mid-latitude westerly trough, and this suggests the mechanism which is responsible for the northward progress of monsoon. On 6 June, the tropical east-west trough and the mid-latitude westerly trough are separated by the subtropical anticyclone (STA). On 7 June the mid-latitude trough amplifies. The circulations in the east-west trough T_1 , now appear embedded in the mid-latitude westerly trough. A new tropical ridge R_2 is aligned along 10°N south of trough T_1 . On 12 June, the trough T_1 and circulations embedded in it are driven north-east ward to the foot hills of Himalayas (break monsoon position). Another east-west equatorial trough T_2 has organized itself along 15°N south of the ridge R_2 in its new position along 21°N . This explains the occurrence of monsoon rainfall over India in pulses. The rainfall distribution for the weeks ending on 29 May 85, 5 Jun.85 and 12 Jun.85 (Fig.3b) indicates the northward progress of the first pulse of monsoon on the weekly rainfall charts prepared in the weather section of the office of the Deputy Director General of Meteorology, (Weather Forecasting), Pune.

5. Case study of 1-9 October 1985 (Post-monsoon season)

During post-monsoon season also, the interaction between a tropical circulation and the mid-latitude westerly trough manifests more clearly at some mid-tropospheric level as brought out in the following case.

The position of westerly troughs on 1 and 2 October when a tropical system became a depression in the Bay of Bengal and again on 4, 5, and 7 October when the same system emerged into the Arabian Sea and reintensified into a depression are marked in Fig.4a. They lie $10-15^\circ$ north of the tropical system and to its west. When the longitudinal separation between the tropical and mid-latitude systems starts decreasing, the tropical system intensifies. In turn the upper air westerly trough deepens. The interaction as noticed at 00 GMT of 8 October on 850, 700 and 500 hPa levels and which led to widespread rainfall over northwest India is discussed here (Fig.4b). At 500 hPa, the tropical circulation due to the depression and mid-latitude circulation to its north have distinct identities. At 700 and 850 hPa, the southerlies in the eastern sector of the circulation extend northward enlarging the extent of tropical circulation, whereas the mid-latitude circulation has diminished in size and has become less important. Fig.4c shows

the rainfall distribution for the week ending on 2 October and 9 October. Many subdivisions of northwest and Peninsular India which had remained deficient during the SW monsoon period got good rainfall in the wake of this depression.

6. Case study of 9-11 December 1985 (Winter season)

At 00 GMT of 9 December two cyclonic circulations, one off south Tamil Nadu coast, and the other off Kerala coast were embedded in an east-west trough south of the subtropical anticyclone (STA) at 850 hPa. A westerly trough of mid-latitudes lies over N-W India. At 500 hPa a mid-latitude cyclonic circulation is centred at 38°N , 75°E , which opens up into a trough at 200 hPa. In Fig.5, 300 hPa chart is presented in place of 200 hPa in order to maintain a continuity between middle and upper tropospheric levels. On 00 GMT of 10 December the westerly trough at 850 hPa splits up into two cyclonic circulations, one in the mid-latitudes westerlies lying over Himachal Pradesh and neighbourhood and the second over Gujarat and adjoining area of west Rajasthan. The STA cell at this level is displaced eastward and the second circulation appears to be embedded in the easterlies. The westerly trough at 500 hPa and 200 hPa deepens and extends southward upto 20°N (Fig.5b). This seems to have happened by the modification of circulation at these levels in response to the interaction between tropical and mid-latitude systems in lower tropospheric levels and also due to an eastward movement of an up-wind westerly trough. At 00 GMT on 11 December, the STA at 850 hPa is displaced further eastward. The southerly flow extend upto 35°N forming a trough in the tropical easterlies with embedded cyclonic circulations lying over Punjab, Rajasthan, Off Maharashtra and off Kerala coasts. The westerly trough at 500 hPa and 200 hPa. retrogress westward and extend further south upto 10°N . The embedded cyclonic circulation at 500 hPa is also displaced south (Fig.5c).

The southerlies in the present easterly trough at 850 hPa level are of land origin. So they have not given much weather over northern India except over Haryana and neighbourhood. Here the flow in the middle and upper tropospheric levels appears to be coupled with the circulation in the lower tropospheric levels during changes occurring in response to the interaction between tropical and mid-latitude systems. This has occurred without much of convection over the region. As a result of the deepening of westerly trough at 500 & 200 hPa, the low over SW Bay off Tamil Nadu coast intensified into a depression on 11th evening and lay centred near 8.5°N , 87.5°E at 0830 hrs IST, on 12 December. It rapidly intensified into a cyclonic storm in the evening of 12th and lay centred at 0830 hrs IST of 13th near 11.5°N , 82.5°E . The cyclonic storm crossed South Andhra Coast on the night of 13th, and alongwith the western disturbances over northwest India gave good rainfall. The rainfall distribution for the week ending on 18 December, as compared to

week ending on 11 December is shown in Fig.5d which together depict the net effect of this interaction.

7. Discussion and concluding remarks

A number of studies on mid-latitude-tropical interactions have been made for east Asia and Malaya - Indonesian region (Liebmann and Hartmann, 1984; Pan & Zhou'85, Chang, Lau and Lim'85, Arkin and Webster'85) following techniques of spectral analysis, analysis of velocity potential and stream functions etc. In this paper the author has discussed interactions between the tropical easterly troughs and the extratropical westerly trough when they come in longitudinal close up over Indian region following synoptic treatment. This has been done through case studies from different seasons in 1985. During monsoon season this interaction takes place between the equatorial east-west troughs and the extratropical westerly troughs. These levels where the tropical and extratropical waves are distinctly noticeable are identified as the level of interaction.

During December and January (Representative months of winter season), such interaction is noticeable at 850 hPa. The level of interaction rises to 2.1 Km asl during March & April (premonsoon season). In monsoon season this goes up to 500 hPa. It is maintained at 500 hPa in the early part of postmonsoon season and descends to 850 hPa during December. The circulation below and above this level undergoes considerable modification. In the lower tropospheric levels tropical easterlies extend deep poleward. In the upper tropospheric levels the extratropical westerlies extend deep equatorward. During monsoon season the equatorial east-west trough at the mid-tropospheric level of 500 hPa moves northward under this interaction.

The northward extension of the tropical easterlies carries the warm humid air to northerly latitudes in the lower tropospheric levels. The southward extension of the upper air westerlies draw the dry cold air equatorward. This results in the build up of conditional instability and also upper air divergence leading to widespread weather activity over Indian region. During monsoon the interaction between the mid-latitude westerly troughs and the equatorial east-west trough leads to the northward propagation of the monsoon pulses.

This is a preliminary study by the author on the interactions between tropics and mid-latitudes. The results are tentative. More such studies are contemplated for further elucidation.

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