

## Withdrawal of southwest monsoon 1985 — Diagnostic study of cyclonic storms and onset of northeast monsoon

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सार — इस शोध-पत्र में अक्टूबर 1985 के प्रथम पखवाड़े में भारतीय समुद्रों में उत्पन्न चार चक्रवातीय विक्षोभों का अध्ययन किया गया है। वे देशान्तर जहाँ ये विक्षोभ प्रतिवर्तित हुए उत्तरोत्तर  $75^{\circ}$  पू० से  $90^{\circ}$  पू० तक थे।  $70^{\circ}$  से  $90^{\circ}$  पू० तक ऊपरी वायुमण्डल में किसी अर्द्ध-स्थायी पश्चिमी द्रोणिका के विस्थापन के कारण है जिसके फलस्वरूप दक्षिण-पश्चिम मानसून की वापसी और उत्तर-पूर्वी मानसून का प्रारंभ हुआ। यह सम्पूर्ण विकास प्रक्रिया और इन विक्षोभों का संचालन मध्य-अक्षांश की पश्चिमीय द्रोणियों के साथ उनकी अंतःक्रिया के कारण हुआ।

ABSTRACT. In this paper a study has been made of the four cyclonic disturbances that formed in the first fortnight of October 1985 in the Indian seas. The longitude, where these disturbances recurved, progressively advanced from  $75^{\circ}$  E to  $90^{\circ}$  E. This is due to the displacement of a quasi-stationary westerly trough in the upper atmosphere from  $70^{\circ}$  E to  $90^{\circ}$  E, which further led to the withdrawal of SW monsoon and onset of NE monsoon. The entire development process and steering of these disturbances took place because of their interaction with the westerly troughs of middle latitude.

### 1. Introduction

In the first fortnight of October 1985 three cyclonic disturbances, first noticed as cyclonic circulations in the lower and middle troposphere over Gulf of Siam and neighbourhood, moved westward and emerged in the south Bay of Bengal. The first of these developed into depression in the Bay of Bengal, moved northwestward, crossed the south Andhra coast, weakened into a low over land and again emerged into Arabian Sea, where it concentrated into a depression. Moving northward it crossed Gujarat coast and then moved northeastwards. Maintaining its intensity as a depression it reached west Madhya Pradesh. Then it weakened into a low, moved northnorthwestward, bringing moisture and rain to Rajasthan, Haryana, Punjab and J. & K. State.

The other two cyclonic disturbances developed into severe cyclonic storms (the 3rd with a core of hurricane winds) in the Bay of Bengal and crossed the coast of north Andhra Pradesh and north Orissa respectively. They maintained their intensity over land first as cyclonic storms and then as depressions over long tracks and finally weakened into lows and dissipated. The life history and tracks of these disturbances together with the axes of mid-latitude westerly troughs at 500 hPa, which influenced their development and movement are shown in Fig. 1. It will be shown in the sections to follow that these cyclonic disturbances intensified in the Bay of Bengal and the Arabian Sea under interaction with the mid-latitude troughs and the embedded disturbances, which also provided them the steering current.

The pattern of the tracks further suggests that the quasi-stationary westerly trough along  $70^{\circ}$ E during SW monsoon has steadily moved eastward up to  $90^{\circ}$ E and this is responsible for the rapid withdrawal of SW monsoon from India and subsequent onset of the NE monsoon over Tamil Nadu.

### 2. The interaction between tropical and extra-tropical systems

In this section, events on particular days when the interactions between the tropical and extra-tropical systems have been very pronounced so as to draw definite conclusions are presented separately.

#### 2.1. Depression of 1-9 October 1985

The positions of westerly troughs on 1 and 2 October when the first system became a depression in the Bay of Bengal and again on 4-7 October when the system emerged in the Arabian Sea and intensified into a depression are marked in Fig. 1. They lie  $10^{\circ}$ - $15^{\circ}$  north of the tropical system and to its west. As the two come closer longitudinally, tropical system intensifies, in turn the upper air westerly trough deepens. The obvious interaction is noticeable at 00 GMT of 8 October at 850, 700 & 500 hPa levels (Fig. 2). At 500 hPa, the tropical circulation due to the depression and extra-tropical 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 size of the tropical circulation, whereas the extra-tropical circulation has diminished in size and has become less important. At 00 GMT of 9 October, the mid-latitude

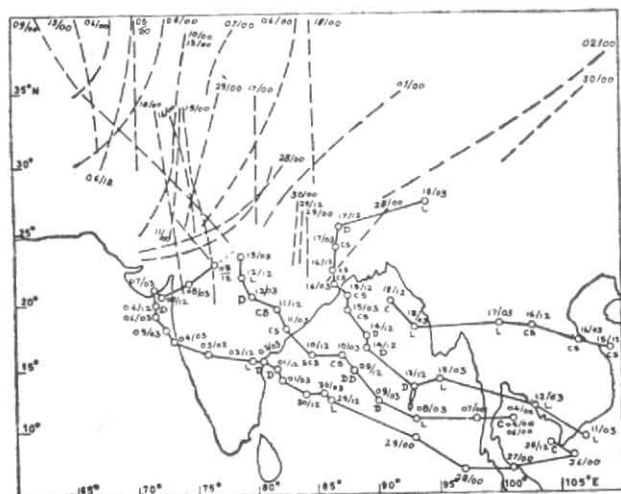


Fig. 1. The life history and tracks of the four October 1985 cyclonic disturbances and the axes of mid-latitude westerly troughs at 500 hPa

circulation at 500 hPa changes into a westerly trough. At 700 hPa, the southerlies extend further north with an embedded cyclonic circulation lying over J.&K. State. Many sub-divisions of northwest and Peninsular India, which have remained deficient during SW monsoon period get good rainfall in the wake of this depression.

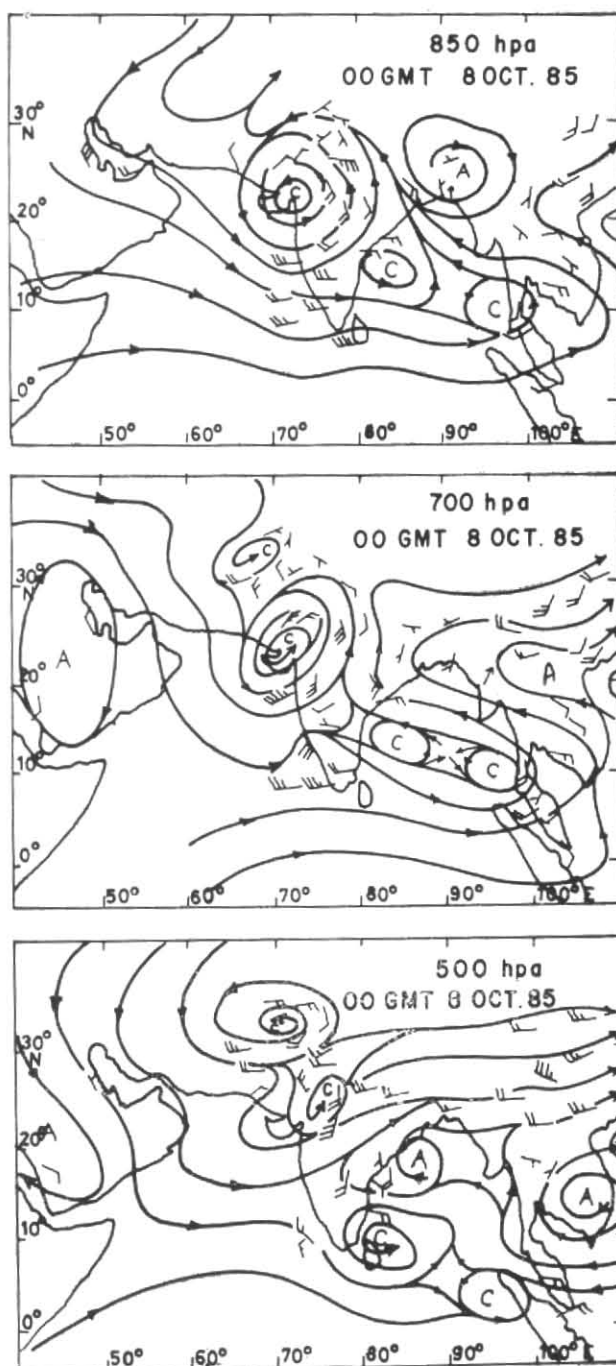


Fig. 2. Depiction of interaction between the tropical and extra-tropical systems at 00 GMT of 8 October 1985

## 2.2. Cyclonic storms of 7-12 October 1985

The position of trough in the extra-tropical westerlies at 500 hPa level on 9-12 October is shown in Fig. 1. The trough has remained practically stationary and in fact shown some retrogression between 10 and 12 October

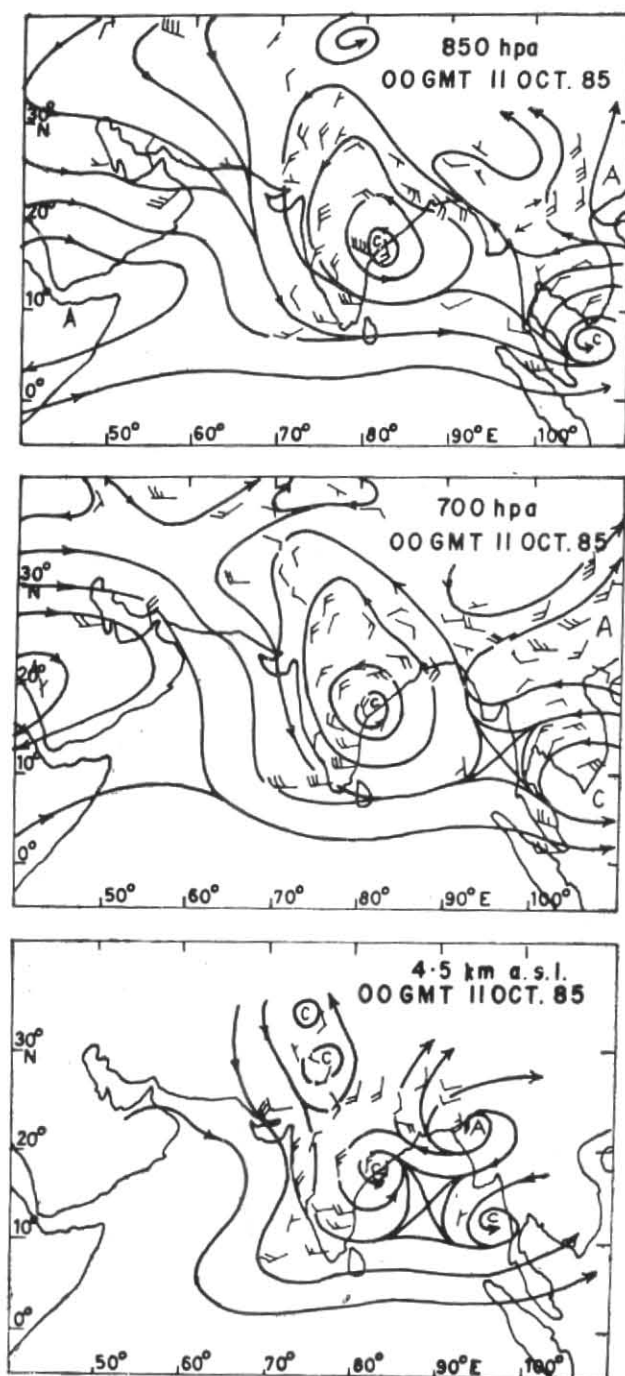


Fig. 3. Depiction of interaction between the tropical and extra-tropical systems at 00 GMT of 11 October 1985

after the second system intensified into a cyclonic storm at 03 GMT on 10 October. The interaction between the extra-tropical and tropical systems is very pronounced at 00 GMT of 11 October when the two systems maintained independent circulations at 4.5 km level (Fig. 3). At 500 hPa and above, the extra-tropical system opens up into a westerly trough. In the lower tropospheric levels of 700 and 850 hPa, the tropical system extends its circulation up to 35° N with moist southerlies from the Bay of Bengal in its eastern sector.

Between 00 GMT of 10 October and 00 GMT of 11 October, the changes that took place in the upper air circulation patterns at 200 hPa are suggestive of the dynamics of steering current for the cyclonic storms in the post monsoon season. The cyclonic storm has moved  $2\frac{1}{2}^\circ$  westward between 03 GMT and 12 GMT of 10 October. Thereafter, it has moved northwestward between 12 GMT of 10 October and 03 GMT of 11 October. The sub-tropical anticyclone (STA) over the Bay of Bengal at 200 hPa has undergone considerable

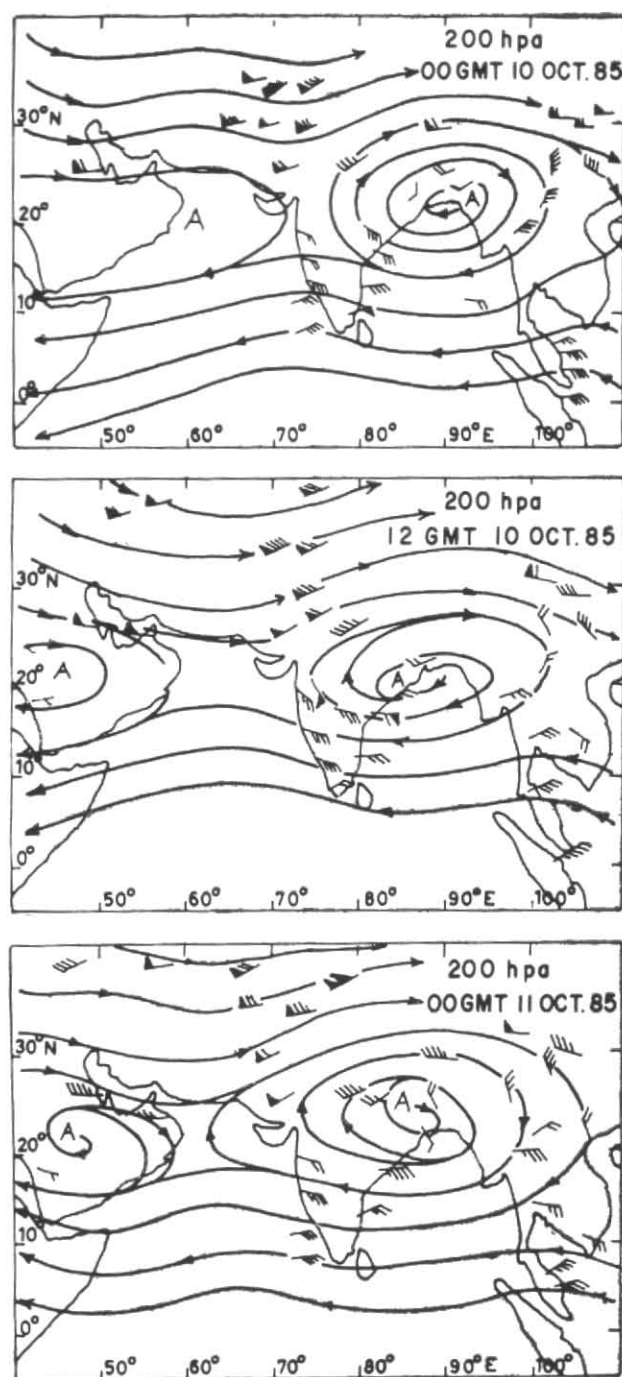


Fig. 4. Modification of the sub-tropical anticyclone at 200 hPa

modification within 24 hours by the outflow from this cyclonic storm. The winds have strengthened in its northwest and southwest sectors at 12 GMT of 10 October and it has extended westward at 00 GMT of 11 October (Fig. 4). Under no circumstances the anticyclone at 200 hPa can be said to have provided the steering current for the cyclonic storm underneath. On the other hand, the trough in the extra-tropical westerlies at 500 hPa provides the steering current for the northward movement of the tropical system in the present case. Satellite imagery of 12 and 13 October with sheered

clouds ahead of trough lends support to this conjecture.

### 2.3. Cyclonic storm of 13-17 October 1985

The interaction between the tropical and extra-tropical system in this case is prominently observed at 700 hPa on 00 GMT of 15 October 1985 (Fig. 5). The tropical system has intensified into a cyclonic storm at 03 GMT. The extra-tropical circulation of 700 hPa opens up into

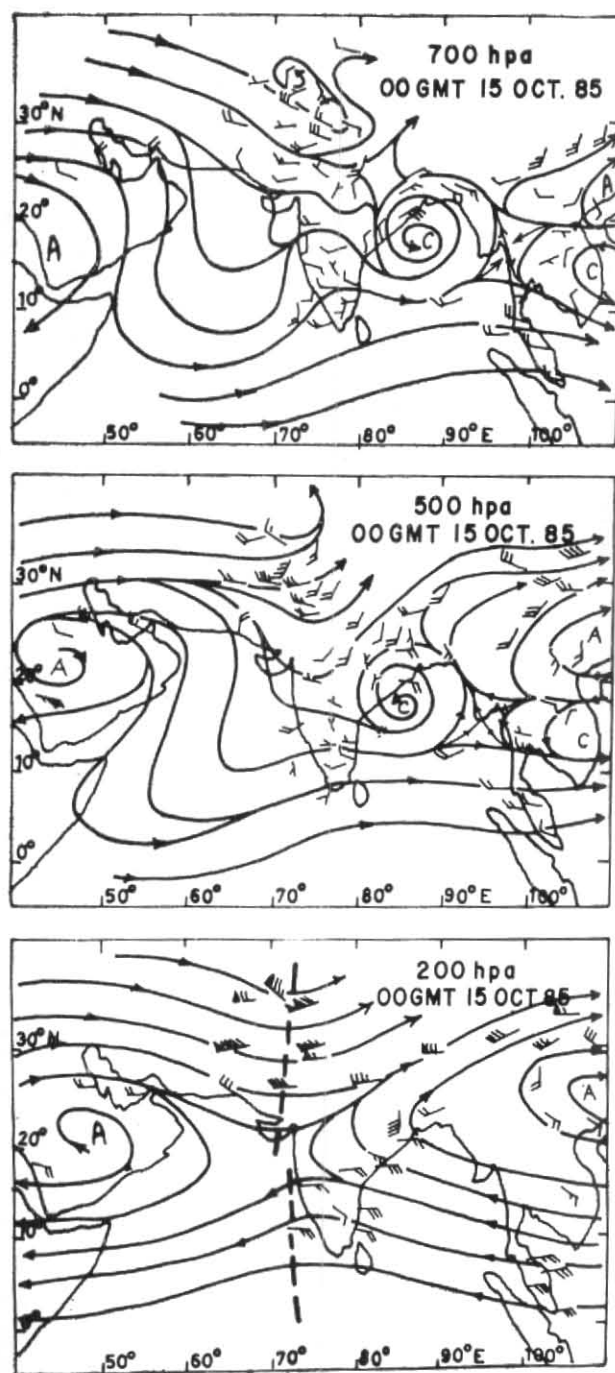


Fig. 5. Depiction of interaction between the tropical and extra-tropical systems at 00 GMT of 15 October 1985

a trough at 500 hPa and above. The subsequent intensification and movement of the tropical storm is controlled by this extra-tropical westerly trough. Its eastward movement and position on different days from 13 to 18 October are shown in Fig. 1. The STA at 200 hPa obviously does not provide the steering current on 15 October.

#### 2.4. Cyclonic disturbance of 15-18 October 1985

Remnant of a cyclonic storm that hit Vietnam coast on 15 October emerged as a low pressure area over

northeast Bay of Bengal on 18 October. But it became unimportant on 19 October. In this case also, it is observed that an extra-tropical circulation embedded in a westerly trough at 500 hPa was lying some  $20^\circ$  to the north, west of tropical disturbance, when it lay over Thailand on 16 October. Subsequently the extra-tropical system moved northeastward. When the tropical system emerged into the Bay of Bengal on 18th, it lay west of this westerly trough and the interaction between them became insignificant. Also, the stream lines converging into the tropical low were from land. The system, therefore, could not develop further.

### 3. The withdrawal of SW monsoon

The withdrawal of monsoon begins from the cessation of rainfall over northwest India in September. The normal dates of withdrawal and the actual dates in the year 1985 are given in Fig. 3 of Rama Sastry *et al.* (1986). In 1985 the withdrawal has followed the formation of three cyclonic storms in the Bay of Bengal in the first fortnight of October. It took place rapidly between 19 and 21 October from the States north of  $13^\circ\text{N}$ . The aggregate of these happenings is suggestive of the following climatological-cum-synoptic forcing in the atmosphere :

- (i) Southward extension of the extra-tropical westerlies and embedded systems and their interaction with the tropical systems on an enhanced scale.
- (ii) West to eastward displacement of the upper tropospheric westerly trough from its quasi-stationary position along  $70^\circ\text{E}$  in monsoon season to  $90^\circ\text{E}$  in post monsoon season.
- (iii) The withdrawal is accompanied by an appearance of the sub-tropical anticyclone over central India at 850 hPa level when there is still some cyclonic activity at 700 hPa. The NE monsoon is established in the next process when a high is formed over central India in the lower tropospheric levels and flow is from land into sea. At this time the sub-tropical anticyclone extensively covers central India at 700 hPa level.

### 4. Discussion and concluding remarks

The quasi-stationary position of mid-latitude upper air westerly troughs along  $70^\circ\text{E}$  during monsoon season and along  $90^\circ\text{E}$  during other seasons is in keeping with the over all distribution of tropical heat sources, viz., Tibetan plateau during monsoon season (Koteswaram 1960, Flohn 1960, Yanai 1984) and Malaysian Indonesian region during other seasons (Murakami 1984) when the eastward propagating westerly troughs come to their quasi-stationary position, they amplify. At this time, if any tropical disturbance is favourably situated to be in phase with these westerly troughs, the interaction between them is most pronounced. During the process of this interaction, the mid-latitude westerly troughs deepen in the upper tropospheric levels. Closed cyclonic circulations develop at the mid-tropospheric levels both in the mid-latitude westerlies and the tropical easterlies. In the lower troposphere, the tropical circulations and the easterly waves in which they are embedded extend deep into the northern latitudes with extensive northward protrusion of moist southerlies. The upper



air westerly troughs may subsequently even retrogress. Thus, a steering current is generated as a result of this interaction process. This steering current is most amplified at the mid-tropospheric levels where the tropical system lies either ahead of the westerly troughs or is observed embedded in it and is, therefore, driven north-eastward. Again in October 1985, in all the three cases where the development has occurred, the systems have moved over relatively warmer seas. Even otherwise the SST in the Bay of Bengal and the Arabian Sea were warmer from normal values. With the warmer seas the evaporation becomes a source of moisture, sensible and latent heat required for the inception and growth of cyclonic disturbances. The eastward movement of the quasi-stationary feature of westerly trough from its position along  $70^{\circ}\text{E}$  to  $90^{\circ}\text{E}$  has, thus, been even accelerated by the formation and intensification of the four post monsoon cyclonic disturbances. Also during this year there has been a clear demarcation between the withdrawal of SW monsoon from States, north of  $13^{\circ}\text{N}$ , on 21 October and the onset of NE monsoon on 24 October. The withdrawal is accompanied by the appearance of sub-tropical high over the central India in the lower tropospheric levels. The NE monsoon is established when there is anticyclonic flow from land into the sea in the lower tropospheric levels and high pressure cells appear even at mid-tropospheric levels (700 hPa).

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