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551.515.12:551.515.8:551.558.1 (67)

# Interaction of lower level westerly waves with Intertropical Convergence Zone over central Africa during summer season

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ABSTRACT. The movement of the lower level westerly waves over southern Africa and its inuuence on Intertropical Conversence Zone over central Africa has been examined. The daily fluctuations in the intensity and northward displacement of ITCZ have been found to be associated with the passage of the lower level frontal systems. The southern edge of ITCZ becomes weak when two westerly waves move across south Africa in quick succession. This results in a spell of very little rainfall over Zambia.

## 1. Introduction

The cold fronts with associated westerly waves in the lower levels move across the southern parts of the subcontinent throughout the year. These rarely extend north of Latitude 25 deg. south during summer season, as the subtropical high pressure systems restrict their equator-wards penetration. However, these exercise their influence indirectly and have considerable effect on the weather over central Africa.

The sequence of changes in the pressure patterns and pressure falls and rises associated with the eastward moving frontal systems in middle latitudes are linked with the daily fluctuations in position and intensity of the southern edge of the Intertropical Convergence Zone (SITCZ) and Zaire Air Boundary (ZAB)—the leading edge of the airmass from Zaire. It was formerly known as Congo Air Boundary (CAB).

The mean position of ITCZ and the ZAB in the month of January as prepared by Torrance (1972) is shown in Fig. 1. With the southward movement of the sun the SITCZ enters Zambia in the last week of November or early December with its mean position about 15 deg. S and attains its southern most position in January. Its mean position is near latitude 17 deg. S in January and February. It shifts back northwards in March and attains the mean position near 14 deg. S.

The day to day variations in the positions of the SITCZ are fairly large. It can be seen as far south as 24 deg. S and as far north as 8 deg. S on the synoptic surface charts.

The ZAB Starts penetrating into northwestern parts of Zambia by the middle of October. Moving southeastwards rather irregularly, in a series of pulses, it attains eastern most position in early January, when its mean position at the surface is running from Sesheke to Mbala through Ndola. The ZAB also suffers frequent and rapid displacements from its mean position particularly in the beginning of the rainy season.

FOX (1969) discussed the passage of a medium level westerly wave over south and central Africa during post rainy season and its effect on the weather over Zambia. Kumar (1979) discussed the interaction of upper westerly waves with ITCZ over central Africa. This study has been further extended and the movement of the lower level westerly waves over southern Africa, and its influence on ITCZ and ZAB over central Africa has been discussed in this paper.

## 2. Sequence of events associated with the movement of lower level westerly wave

As the surface cold front associated with an extratropical depression in the oceanic area south of subcontinent advances towards the southwest coast the pressure starts falling over the southwest

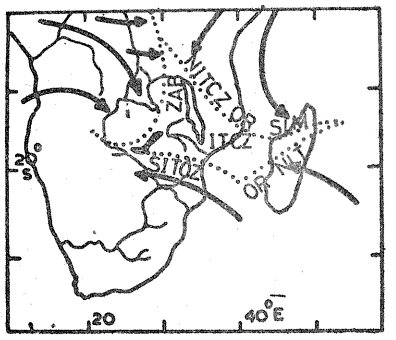


Fig. 1. Intertropical Convergence Zone, Mean position, January (after Torrance)

Africa and the cape. A north south oriented surface trough in the westerlies develops over southwest Africa extending upto southcoast where invariable the coastal low is simultaneously developed.

As the pressure falls ahead of the front extend to Natal coast, the Atlantic ocean anticyclone ridges eastwards over southwest and southern coast of the subcontinent and the westerly trough is seen swinging counter-clockwise.

With further eastward movement of the surface cold front alongwith temperate depression, the pressure falls extend northwards and winds in Rhodesia and Zambia tend to back to northeast or even north and northwest in Rhodesia. A convergence asymptote oriented northwest-southeast occasionally forms at 700 mb between northwesterly airstream ahead of the trough axis and northeasterly airstream over central Africa emanating from the quasi-permanent anticyclone situated near Malagasy. When the surface westerly trough reaches over Natal and south Mozambique coast, it becomes more marked and is found to be linked up with the seasonal low which is generally situated over Caprivistrip or northern Botswana. Henderson (1972) has shown the Linkage of surface cold front with ZAB/ITCZ to form a broad cloud band of disturbed weather oriented NW-SE. In some cases when this cloud band is well marked the ZAB/ITCZ previously oriented E-W, appears to become more meridional tending to fall in line, as it were, with the Cloud band. The cloud band appears to become more compact more organised and more active in the region of Linkage. The band of disturbed weather takes three to four days to clear the subcontinent, after which the ZAB/ITCZ resumes the normal Zonal patterns. When the Link-up does not occur, the band of disturbed weather is usually less broad, less organised and less active. The zonal characteristics of the ZAB/ITCZ are then more pronounced.

### 3. Discussions

In order to study the interaction of the lower level westerly waves with ITCZ and ZAB and their effect on weather over Zambia, the synoptic surface and upper aircharts for the months of December to March during the five rainy seasons 1972 to 77 were examined.

Three different types of interaction of the lower level westerly waves with ITCZ and ZAB were identified.

(*i*) Intensification and movement of ZAB/ITCZ under indirect influence of the westerly waves.

(*ii*) Weakening of ITCZ/ZAB when westerly waves move in quick succession.

(*iii*) Temporary disintegration of ITCZ over the subcontinent under the influence of deep amplitude westerly trough on rare occasions. This type of interaction was discussed by Kumar (1979).

The typical case studies for the first two types of interactions are presented. For the better comprehension of the discussions, the location maps of Zambia and Africa south of equator are depicted in Figs. 2(a) and (b) respectively.

### 4. Case study I

*Intensification and movement of ITCZ/ZAB*

On certain occasions, under the influence of lower level westerly wave, the SITCZ/ZAB is intensified and causes sudden increase in rainfall.

A good example of lower level westerly wave which moved across southern Africa during 27 to 31 January 1975 has been discussed below in detail.

A cold front was approaching the cape at 0600 GMT on 27 January 1975, the SITCZ was diffuse and could not be identified on the main land. The moist northwesterly wind from Zaire was affecting only extreme northwestern parts of Zambia. The tropical storm 'Deborah' was situated over south Mozambique channel (Fig. 3). The pressures were falling over the whole subcontinent ahead of the front with maximum falls of 7 mb over the south coast.

During the next 24 hours, the cold front with associated westerly wave in the lower levels moved rapidly across the cape province. It was trailing over Natal coast at 0600 Z on 28 January (Fig. 3). The associated coastal low was situated near Durban. The pressures were now rising over the southwest cape and were falling over the rest of the subcontinent with maximum falls of 7 mb over south Mozambique coast.

Under the influence of falling pressures, the moist Zaire air had moved east-south-eastwards and at 0600 GMT on 28 January, ZAB lay across Sesheke and Kwambwa. The SITCZ was reforming across northeast Botswana and northern parts of Rhodesia.

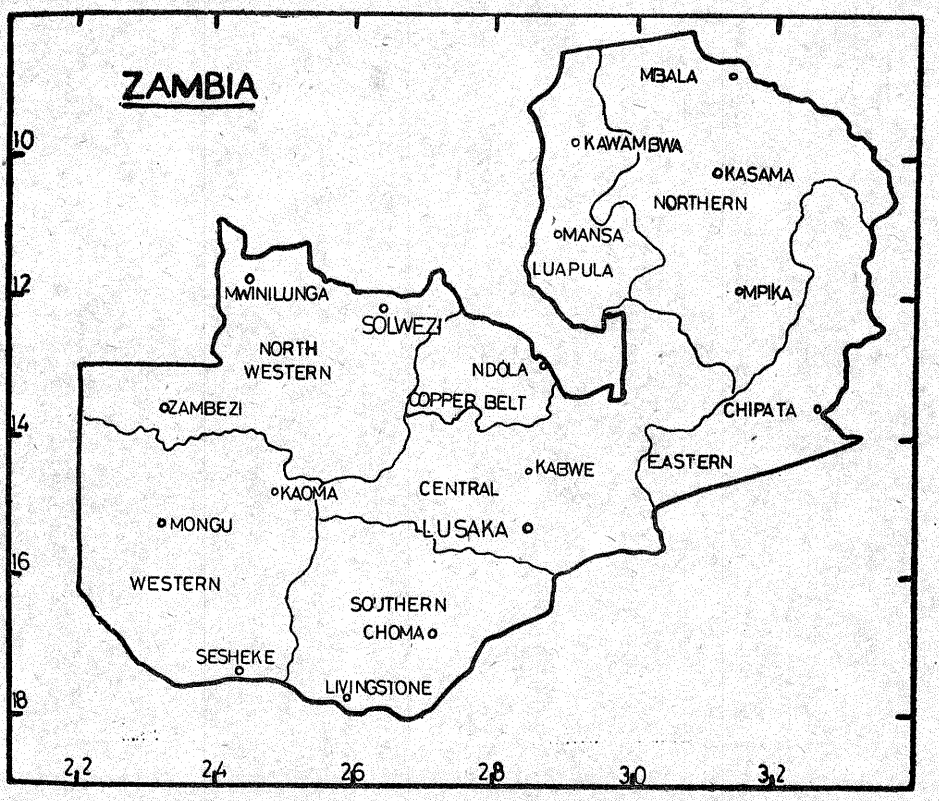


Fig 2(a). Location map of Zambia with its provinces and important stations

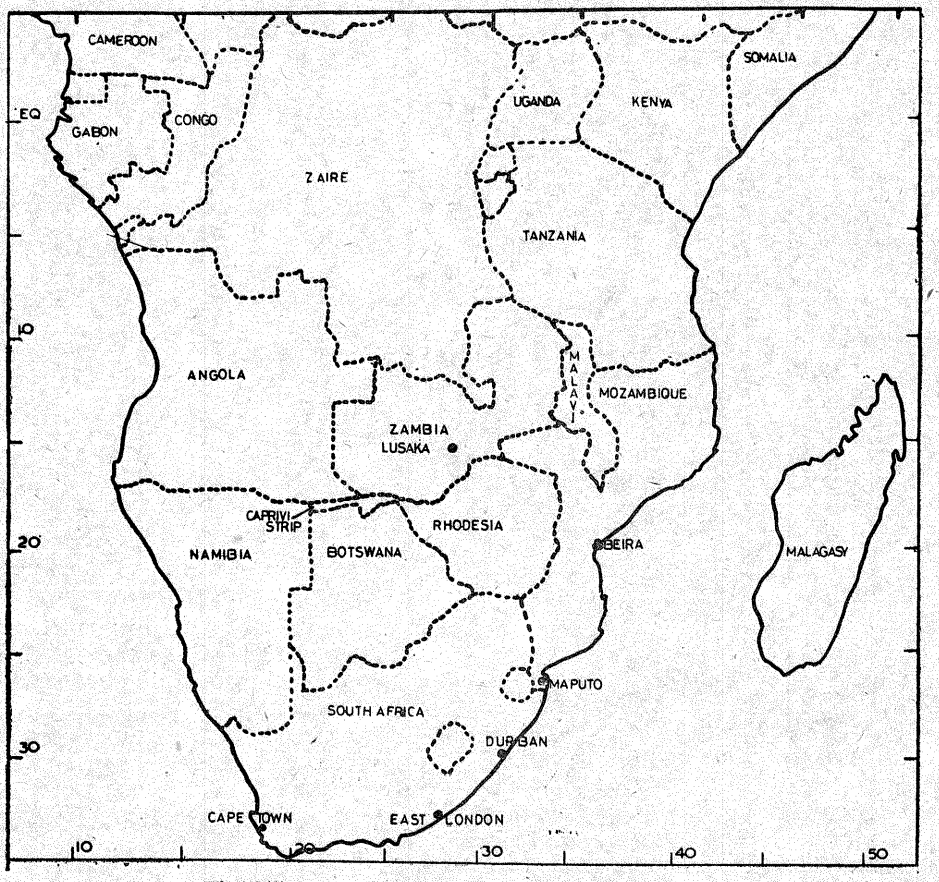


Fig. 2(*b*). Location map of Africa South of Equator

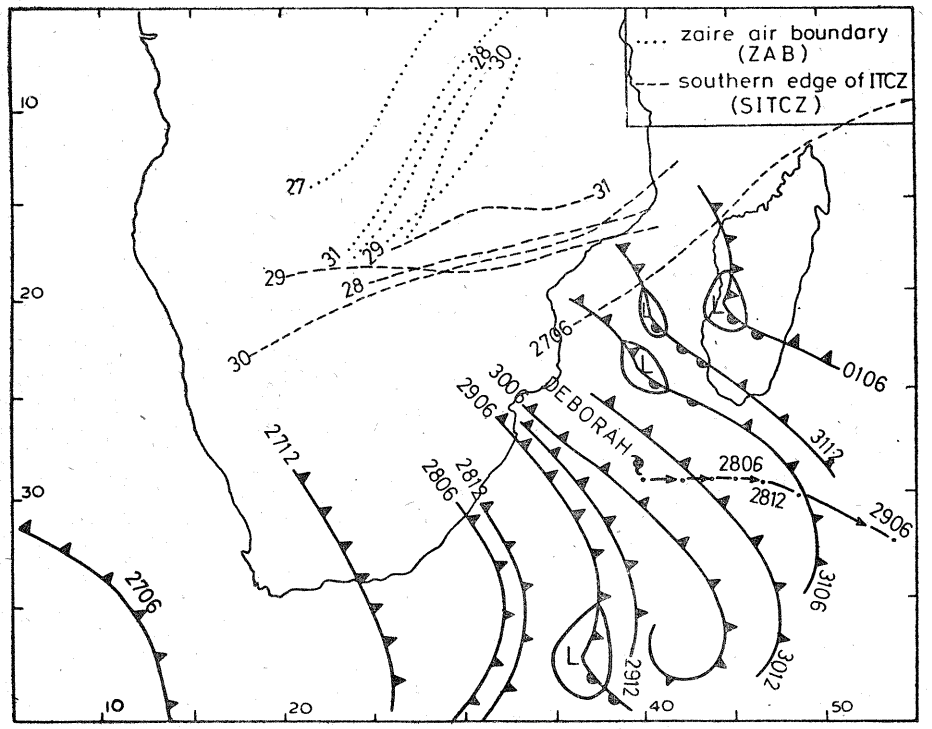


Fig. 3. The position of cold fronts, SITCZ & ZAB at the surface on successive days and Track of Tropical storm 'Deborah' during the period 27 January 1975 to 1 February 1975

The Atlantic Ocean Anticyclone (AOA) was ridging into southwest cape. The Tropical storm Deborah moved slowly eastwards and centred at 0600 GMT on 28 January at latitude 29 deg. S and longitude 45 deg. E.

The cold front moved very slowly during the next 48 hours (Fig. 3). At 0600 GMT on 29 January, it was trailing over south Mozambique coast and was just north of Maputo at 0600 GMT of 30 January.

This slow movement of the front may be attributed to the presence of the Tropical storm in the south Mozambique channel.

At 0600 GMT on 29 January, AOA was ridging into south Africa across the cape and hence pressures were rising over the cape with maximum of 4 mb over the south coast. Pressures were falling over the rest of the subcontinent with maximum falls of 3 mb over southwest Zambia.

The seasonal low was situated over northern Namibia. As a result of pressure falls the ZAB had advanced further upto the line extending from Livingstone to Ndola by 0600 GMT of 29 January and SITCZ maintained its position over Northeast Botswana and northern parts of Rhodesia.

On 30 January the cold front continued to trail over south Mozambique coast. In the rear of the front, AOA at 0600 GMT surface chart was situated south of the subcontinent and ridging into south Africa.

As a result, the pressures were rising over the subcontinent except over central and western parts of Namibia where they were falling. The maximum rises were of the order of 7 mb over Natal coast.

The SITCZ was still over northern parts of Rhodesia and ZAB also remained stationary. Except for light rainfall over northwestern province, dry weather prevailed over the rest of Zambia on 30 January 1975 (Fig. 4 a).

The upper air chart for 850 mb at 1200 GMT on 30 January 1975 (Fig. 5*a*) showed that the subtropical anticyclone situated just east of Malagasy was ridging into eastern half of Zambia and northwesterly flow was quite weak over the western half.

At 0600 GMT on 31 January 1975, the cold front at the surface was trailing over Beira. In the rear of this, the bud off high (1024 mb) was situated east of East London with central region near 33 deg. S, 32 deg. E.

The Continental High (1590 gpm) was ridging into northeastern Zambia. The SITCZ was diffuse over the surface. But the upper air chart for 850 mb at 0000 GMT on 31 January 1975 (Fig. 5*b*) showed that a convergence Asymptote between southeasterly and northeasterly airstreams had formed along Zambezi Valley. The Zaire Air Boundary lay from Livingstone to Solwezi.

The flow over Zambia was strengthening and tending to be easterly.

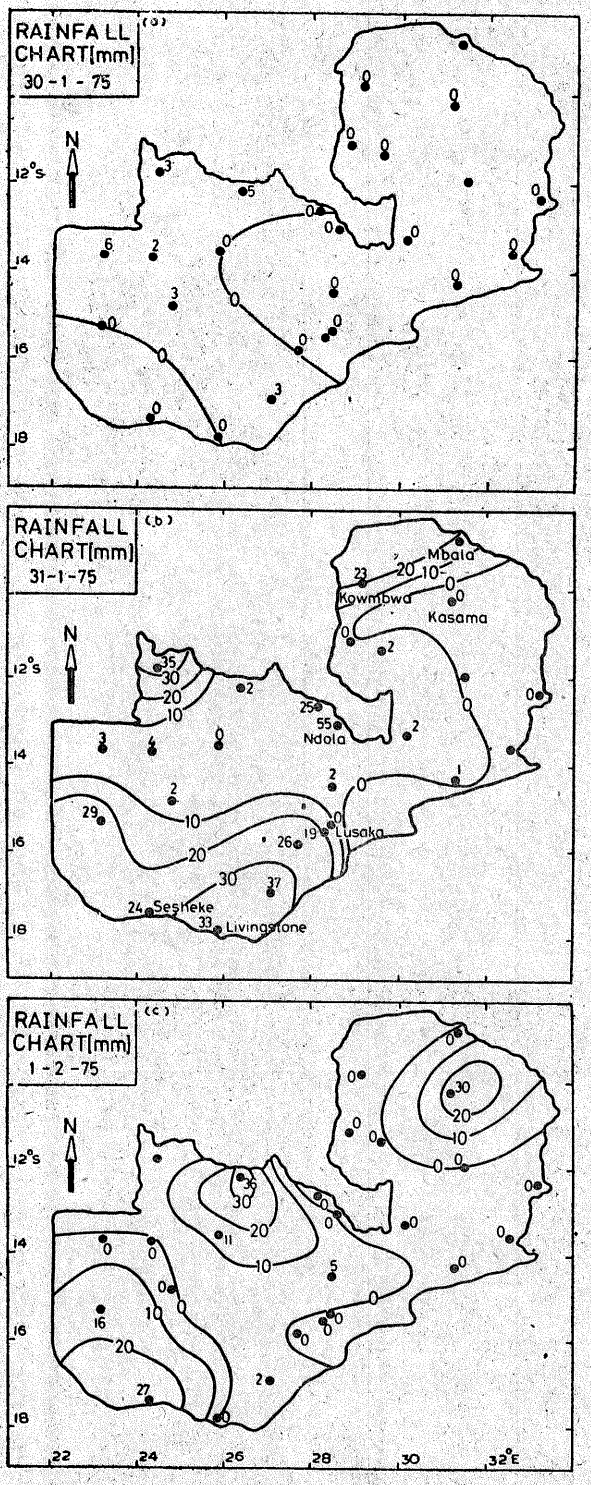


Fig. 4(a—c). Rainfall charts of Zambia from 30 January 1975 to 1 February 1975

Sudden increase in rainfall had occurred on 31 January over western half of Zambia especially over western, southern, central and copper belt provinces (Fig. 4b).

Another cold front was close to the cape and causing pressure falls along the south coast. The seasonal low was over northwestern Namibia.

During the next 24 hrs, the easterly flow further strengthened and the convergence Asymptote was not traceable on 0000 GMT charts on 1 February. As a result the rainfall over central copper belt and southern provinces decreased considerably on 1 February 1975 (Fig. 4c).

However due to the arrival of another cold front, the seasonal low moved over to the Caprivistrip and the shallow layer of moist Zaire air advanced into the western half of Zambia again by evening of 1 February 1975 (Fig. 5c).

As a result of this northwestern and western provinces continued to get light to moderate rainfall on 1 February 1975 (Fig. 4c).

The following Inference can be derived from this study:

(*i*) As the surface cold front reached Natal coast, the SITCZ reformed over northern parts of Rhodesia on 28 January 1975.

(*ii*) The cold front for next 48 hours moved slowly trailing over south Mozambique coast.

(*iii*) The pressure falls and rises associated with the front were propagated northwards to central Africa and caused advance or retreat of the ZAB. But SITCZ remained practically stationary from 28-30 January 1975 which may be due to the slow movement of the front.

(*iv*) The sudden increase in rainfall over the southern and central parts of ZAMBIA occurred due to the formation of convergence Asymptote between strengthening southeasterly and northeasterly airstreams along Zambezi Valley.

(*v*) The increase in rainfall occurred when the intense continental High over Natal and a high over ocean was situated 400 to 500 km southeast of East London.

(*vi*) The further strengthening of easterly airstream caused the decrease in rainfall over central and southern parts of the country.

**5. Case study II**

*Weakening of ITCZ/ZAB*

The surface cold fronts with associated westerly troughs in the lower levels moving across southern Africa affect considerably the intensity of Inter-tropical Convergence Zone. The weakening of SITCZ has been generally noticed over central Africa, when these waves move in quick succession.

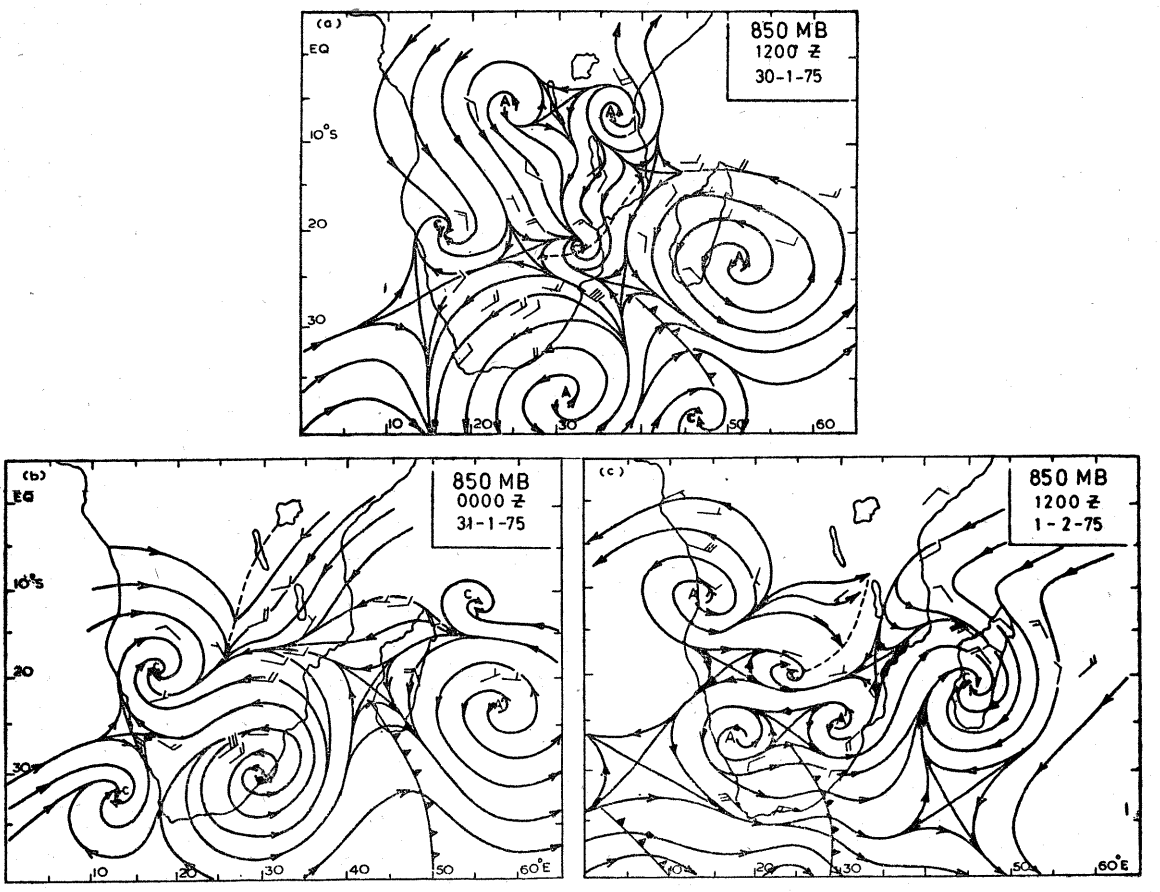


Fig. 5(a-c). 850 mb charts for 30 January, 31 January and 1 February 1975

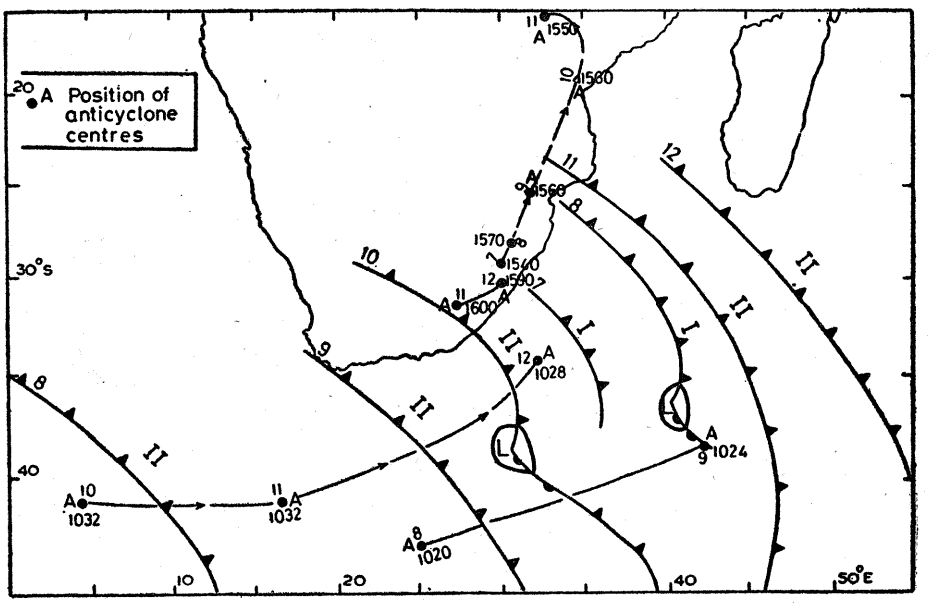


Fig. 6. The position of the cold fronts and centre of the anticyclones with central pressures in millibars over ocean and geopotential metres over land on successive days between 7 March to 12 March 1977

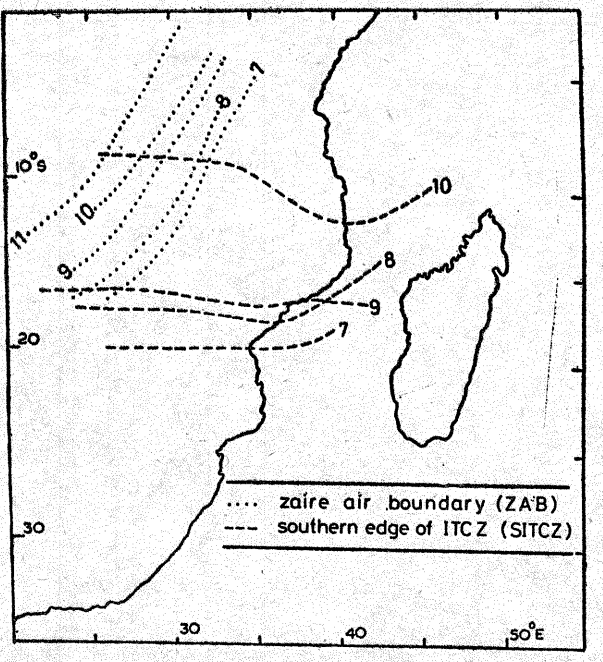


Fig. 7. The position of the SITCZ and ZAB on successive days between 7 March to 12 March 1977

During the rainy season 1976-77, the SITCZ remained very weak from 9 March to 12 March when insignificant amounts of rainfall occurred over Zambia. During the period 8 March to 12 March two cold fronts with associated westerly waves in the lower levels moved across southern Africa (Fig. 6).

On 7 March 1977 at 0600 GMT, two days prior to its weakening, the SITCZ was lying along Latitude 20 deg. S and was fairly active (Fig. 7). It had embedded vortices extending upto 600 mb Zaire Air Boundary was along the line passing through Livingstone, Lusaka and Kasama.

A cold front was trailing over southeast coast near Durban. In the rear of this, a continental High (1540 gpm) was situated over Natal coast. Small pressure rises of 2 mb were occurring over Natal coast and changes were insignificant elsewhere over the subcontinent. After 24 hrs at 0600 GMT on 8 March, a surface cold front was heading towards the southwest coast of the subcontinent. Ahead of this a bud off High (1020 mb) was situated south of the subcontinent.

The first cold front was trailing over South Mozambique coast and the pressures were rising over south Africa, with maximum rises of 6 mb. As a result of this the continental High over Natal had become intense (1570 gpm) (Fig. 6).

Under the influence of rising pressures, the SITCZ had moved north to Latitude 18 deg. south and ZAB retreated about 150 kms towards northwest (Fig. 6). The SITCZ was still fairly active with embedded vortex traceable upto 700 mb (Figs. 8*a* and 8*b*). Scattered rainfall had occurred over Zambia on 8 March (Fig. 9*a*) and was associated with the moist Zaire air.

By 0600 GMT of 9 March 1977, the first cold front moved away eastwards and the second was trailing over the cape (Fig. 6). The Continental High (1560 gpm) over Natal had moved northwards to Swaziland and slightly weakened, as small pressure falls were occurring over south Africa. But there were small rises over the central Africa.

The SITCZ had slightly moved northwards and weakened over northern parts of Rhodesia. The ZAB retreated further and lay across western and northwestern provinces.

Rainfall chart for 9 March Fig. 9(b) did not show any significant decrease in rainfall over Zambia.

By 0600 of 10 March 1977, the cold front was trailing over central cape province across East London. The continental High (1560 gpm) moved further northwards, without weakening and was situated north of Beira over Mozambique (Fig. 6). The intensity of the continental High was maintained because small pressure rises were still occurring over central Africa north of 20 deg. S.

The pressures began to rise rapidly over southwest Africa (maximum rises 9 mb over southwest cape) in the rear of the cold front. These

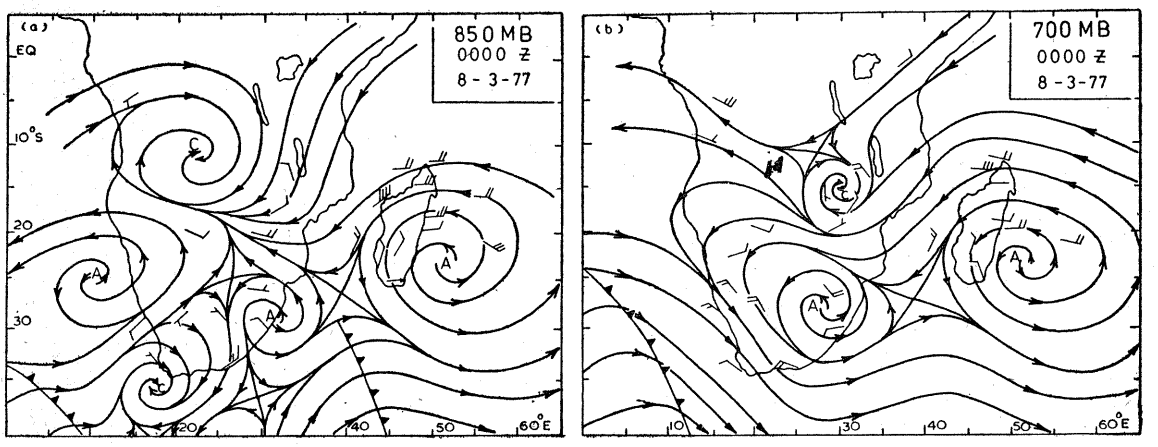


Fig. 8(a-b). 850 mb and 700 mb charts for 8 March 1977

were falling elsewhere with maximum falls of 6 mb over Natal coast.

The SITCZ further weakened and became diffuse over main land. The ZAB was across Northwestern province.

The gradual weakening of the SITCZ may be attributed to the injection of Anticyclonic vorticity into the zone of convergence, as the continental High moved northwards.

The flow became anticyclonic northeasterly to easterly over central Africa in the lower torposphere (Fig. 10*a* and 10*b*).

The rainfall charts from 10 March to 12 March 1977 (Figs. 9*c* to 9*e*) showed that very little rainfall had occurred over Zambia on three consecutive days.

The Surface cold front was trailing just north of Maputo at 0600 GMT on 11th and was moving eastwards across Mozambique channel during next 24 hrs.

The pressure falls over southeast Africa were propagated northwards and flattened the High over Mozambique. But due to the rapid pressure rises in the rear of the cold front over south Africa, a strong continental High (1600 gpm) had formed over southeast cape province. This High Started ridging northwards and the flat High over Mozambique became part of the ridge.

A strong High (1032 mb) was situated about 10 deg. of Latitude south of the cape Town and was moving eastwards (Fig. 6).

The SITCZ remained diffuse over main land and ZAB wasc lose to the northwestern borders of Zambia.

By 0600 GMT of 12 March 1977, the intense High over the ocean moved over to south Indian ocean at (34 deg. S; 33 deg. E). This together with continental High (1590 gpm) over Natal was ridging into central Zambia. Thus the lower level easterly flow was maintained over central Africa, on 12 March (Figs. 11a and 11b). The SITCZ continued to be diffuse over main land.

From the above mentioned discussions we may infer as follows :—

(*i*) An intense continental High (1570 gpm) formed over Natal in the rear of the cold front when it was trailing over South Mozambique coast.

The second cold front was heading towards the cape when Bud off high was situated south of the cape.

(*ii*) During the next 24 hrs, the continental High moved north about 3 deg. of Latitude and SITCZ also moved north about 2 deg. but weakened. The second cold front was trailing over the cape, and first moved away eastwards.

(*iii*) After 48 hrs of the beginning of first sequence the cold front was moving across the cape province and the continental High was over Mozambique just north of Beira. The SITCZ became diffuse at this stage.

(*iv*) The gradual weakening of SITCZ may be attributed to injections of anticyclonic vorticity into the zone of convergence.

(*v*) The SITCZ continued to be diffuse for next two days. This was due to the fact that before the first High flattened

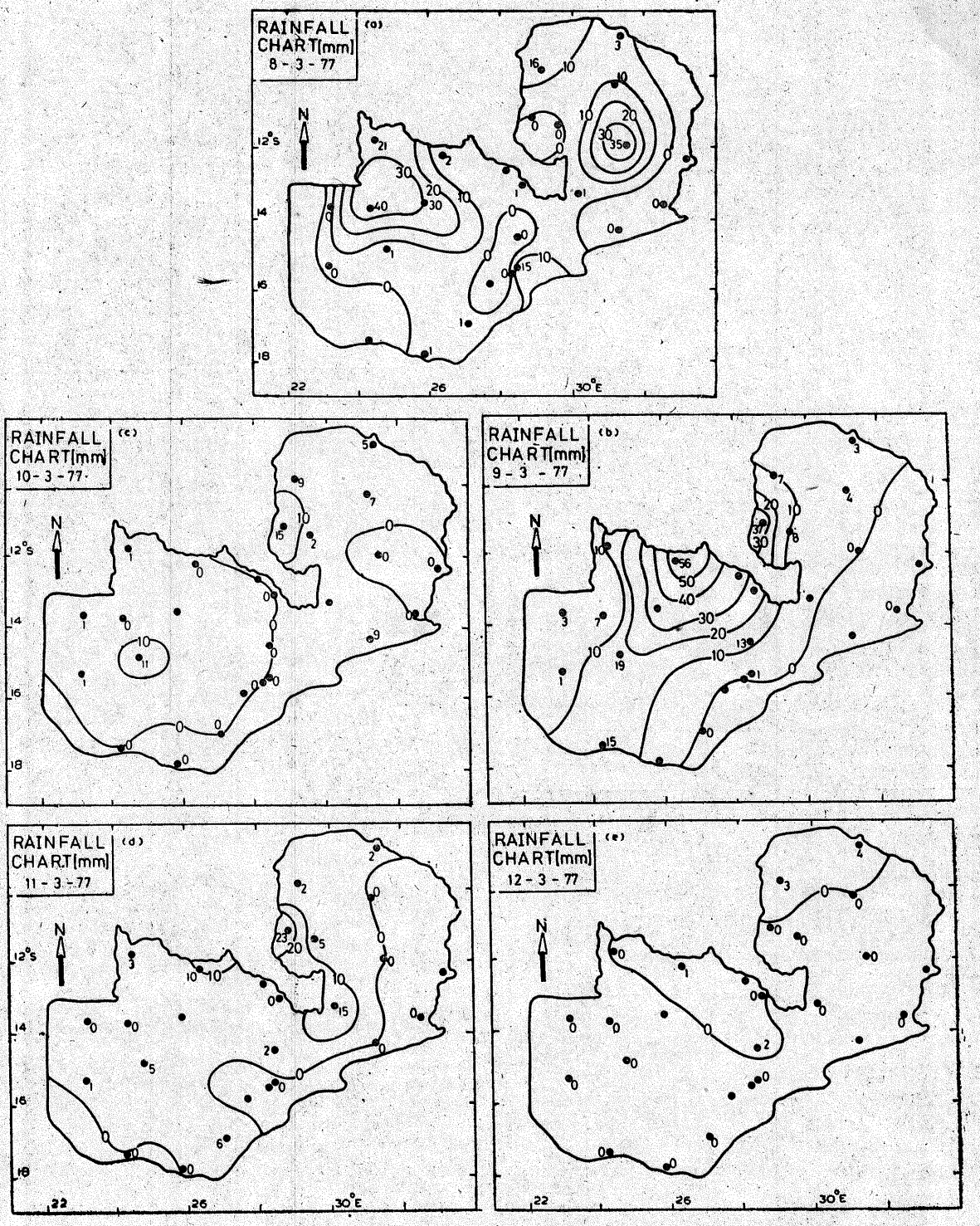


Fig. 9(a-e). Rainfall charts of Zambia from 8 March to 12 March 1977

over the north Mozambique, another intense High had already formed over the southeast cape. Thus it was obvious that the weakening of SITCZ over northern Rhodesia occurred due to the movement in quick succession of two westerl waves in the lower levels across south Africa.

## 6. Conclusions

The study has shown that the movement of westerly waves in the lower level across southern Africa, considerably influences the intensity of Inter-tropical Convergence Zone. The northward displacement of ITCZ is associated with the rising pressure over the subcontinent and

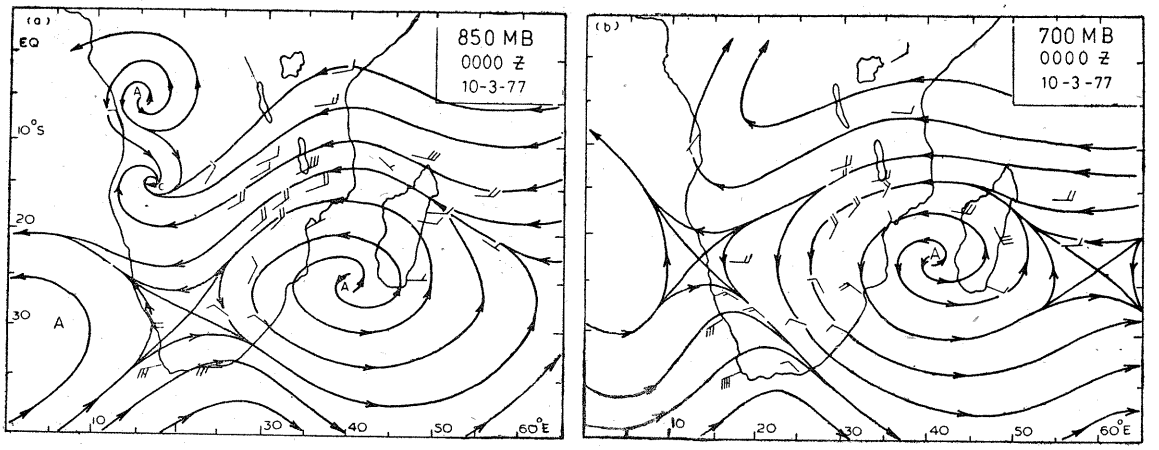


Fig. 10(a-b). 850 mb and 700 mb charts for 10 March 1977

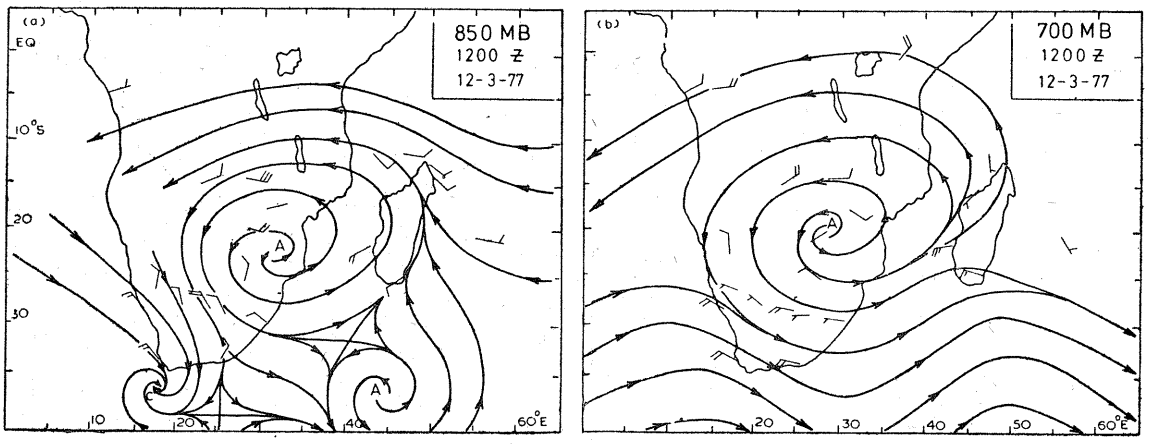


Fig. 11(a-b). 850 mb and 700 mb charts for 12 March 1977

Mozambique channel in the rear of frontal systems. The southward movement of ITCZ is little more complicated and can not be always related to the falling pressure ahead of the westerly wave.

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