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CONDITIONS FOR THE FORMATION OF DEEP CONVECTIVE ACTIVITIES OVER NIGERIA

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ABSTRACT

Some mean flow parameters and dynamic processes necessary for the formation of widespread deep convective activities over Nigeria have been investigated and their interactive roles identified. These parameters include the low-level and the 700mb winds known as African Easterly jet (AEJ), spatial distribution of the vertical shears variability of the Zonal and meridional winds, the spatial and temporal of the height of the moist layer, and the anomalies of equivalent potential temperature and specific humidity. Wide spread thunder storms and/or organized line squalls were fond to exist on days of well defined African Easterly Jet (AEJ) with a higher concentration of storms/squalls around the left entrances and right exists in contrast with the middle latitude situation where weather development is normally expected around the right entrances and left exits of jet streams. Positive (westerly) low-level (boundary layer) zonal and meridional wind shears were found to be more important to storm initiation due to their overturning effects. On the other hand, negative (easterly) low-level shears led to suppression of convective activities. The depth and strength of convective activities were found to be affected by a deepening of the moist layer (represented by the height of the positive meridional (V) components of the wind) in the preceding twenty-four hours. A reasonably deep layer of moisture of at least 1.5km favours widespread deep convection.
Mappings of positive vertical wind shears height of the moist layer greater than ~0.5km were found to have very high correlation with areas of line squall/thunderstorm occurrence while anomalies of the equivalent potential temperature and specific humidity gave minimal correlation with convection.

Keywords: Thunder storms, Line Squall, African Easterly Jet, Wind Shears, Convection.

INTRODUCTION

West African Convective Systems (WACS) are usually triggered off and maintained by some mean flow parameters and dynamic processes which normally do not act in isolation but act through major interactive mechanisms. The most important flow parameters and dynamic processed in the life circle of West African Convective systems are: Insolation (low-level temperature fields);

Low level convergence associated with asymptotes of convergence or vortices;
Upper-level radiative cooling through down-drafts;
Mid-Tropospheric jet (The African Easterly Jet-AEJ)
Low-level Wind profile (surface to 850mb level winds);
Vertical shears of the zonal and meridian winds;
Depth and strength of the meridional components of the South-west monsoon (height of the moist layer);
Vertical instability;
The Richardson's number and static instability and
The anomalies of he equivalent potential temperature and specific humidity.

These flow fields and processes interact in a number of complex ways initiating convective transports which destabilize the atmosphere causing weather phenomenon like thunderstorms, line squall and hurricanes (convective systems or activities) to occur. Although the identification of some of these parameters and processes have been carried out by Eldridge (1957), Okulaja (1970), Burpee (1972), Aspliden at al (1976), Omotosho (1976), Moncrief kand Miller (1976), Obasi (1974), and

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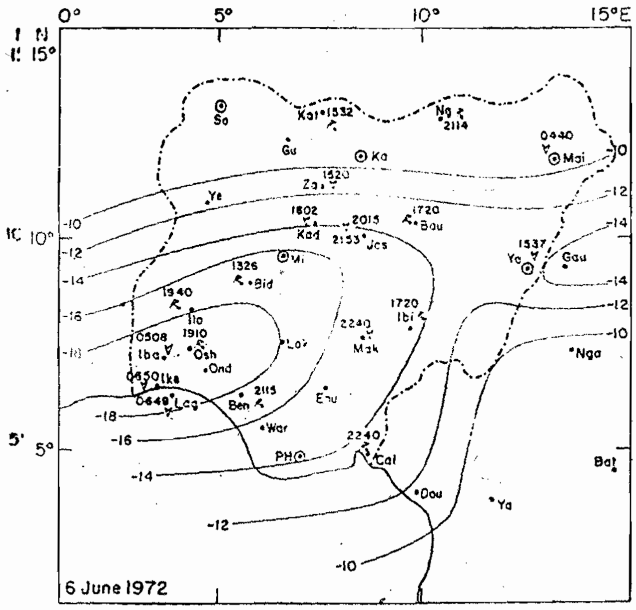

Fig. 1a : ZONAL COMPONENT OF THE WIND AT 700mb.

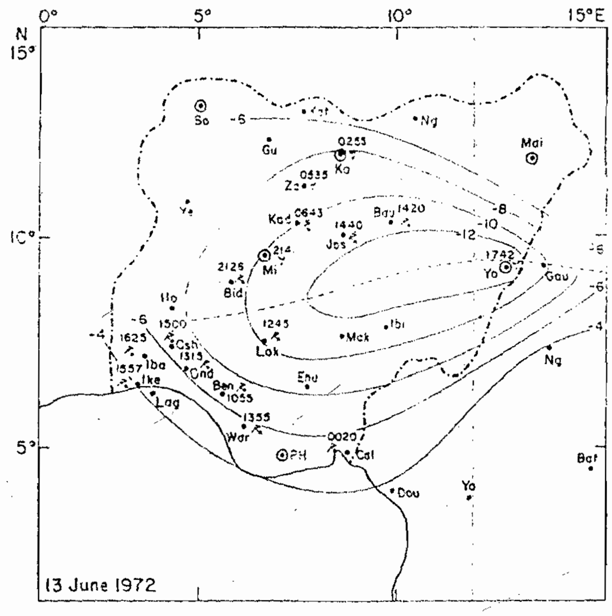

Fig. 1c : ZONAL COMPONENT OF THE WIND AT 700mb.

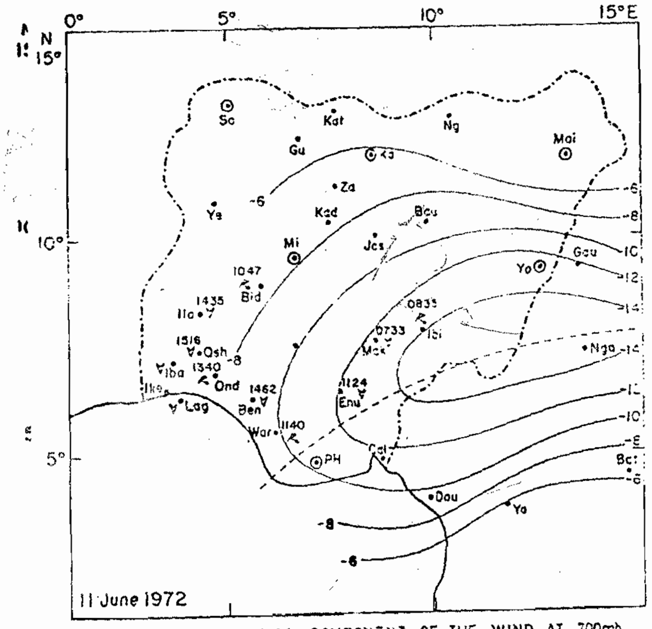

Fig. 1b : ZONAL COMPONENT OF THE WIND AT 700mb

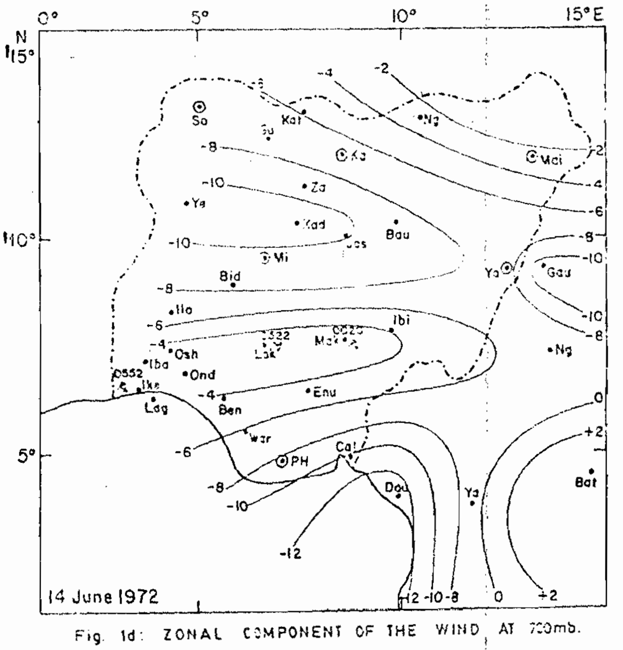

Fig. 1d : ZONAL COMPONENT OF THE WIND AT 700mb.

Balogun (1974, 1978), Omotosho and Okujagu (1995) it is the aim of this paper to further identifySSS practically the roles of some of these flow parameters and dynamic processes especially the low-level wind profiles, mid-Tropospheric jet, vertical shears of the zonal and meridional winds profiles, mid Troposheric jet, vertical shears of the zonal and meridional winds, height of the moist layer and he anomalies of equivalent potential temperature and specific humidity during days of little and widespread storm activities, and to investigate their combined effect and interactive roles in the development of deep convective systems. This is with a view to presenting a practical mini-model that could help the forecasting of these activities over Nigeria.

DATA ACQUISITION AND ANALYSIS

The data used for this analysis were obtained from the Nigeria Meteorological Center, Oshoodi, Lagos. Data for surface temperature, humidity, upper air wind velocity and thunderstorm/line squall were obtained from twenty-two(22) out of the twenty-eight(28) synoptic stations in Nigeria, including pilot balloon data from adjacent stations in Cameroon for this analysis. Sample data for June 1972 and 1973 were initially used, because these, years represented the years in which all Nigeria stations made the most consistent observations; however June 1972 was chosen for the analysis presented in this work because it has adequate and complete data for all the parameters that are used in the present type of study. Also, the mount of June is chosen because it represents the peak of south-west monsoon activity the entire West Africa with more frequent and widespread line squall/thunderstorm activities and a varied degree of suppressed convection. Although the conditions for all the days of June 1972 were investigated, only results of mine days (6th, 11th, 13th, 16th, 19th, 22nd, 23rd, and 24th) are presented in greater detail a case studies because they represent days of highly suppressed and very disturbed weather.

Analysis for each parameter is considered below.

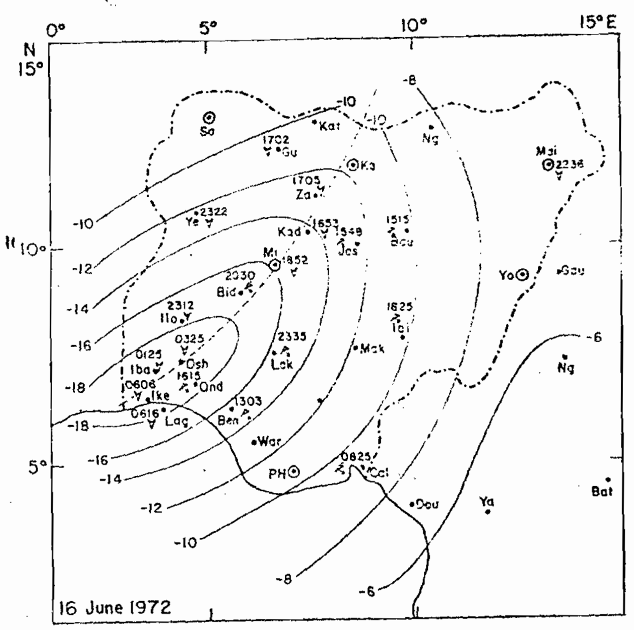

Fig. 1e : ZONAL COMPONENT OF THE WIND AT 700mb.

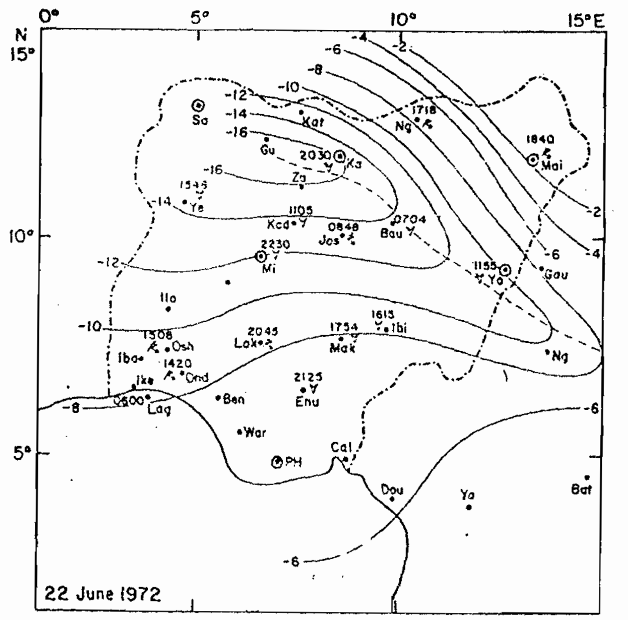

Fig. 1g: ZONAL COMPONENT OF THE WIND AT 700mb.

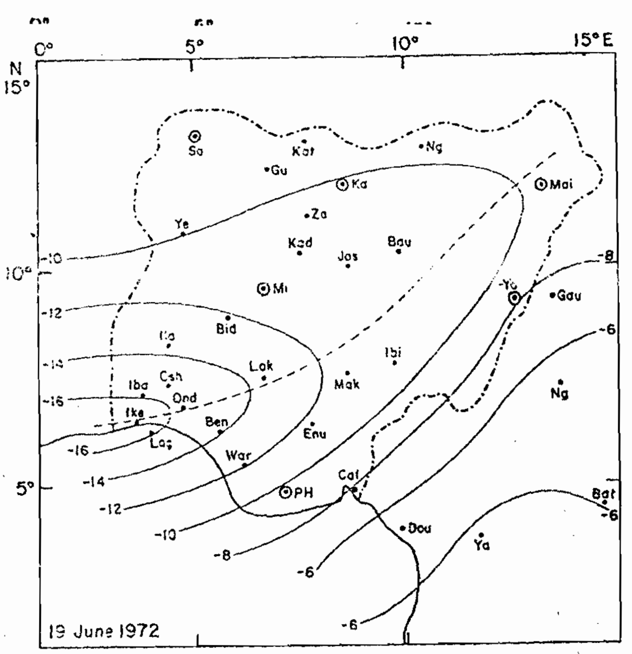

Fig. 1f : ZONAL COMPONENT OF THE WIND AT 700mb.

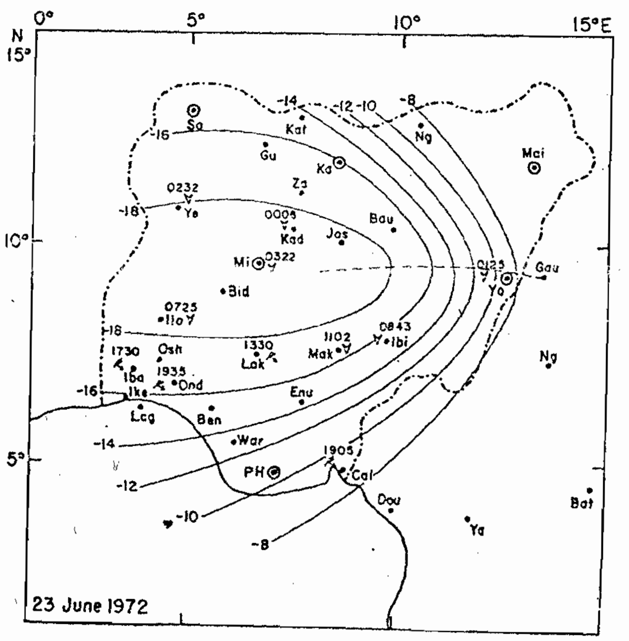

Fig. 1h : ZONAL COMPONENT OF THE WIND AT 700mb.

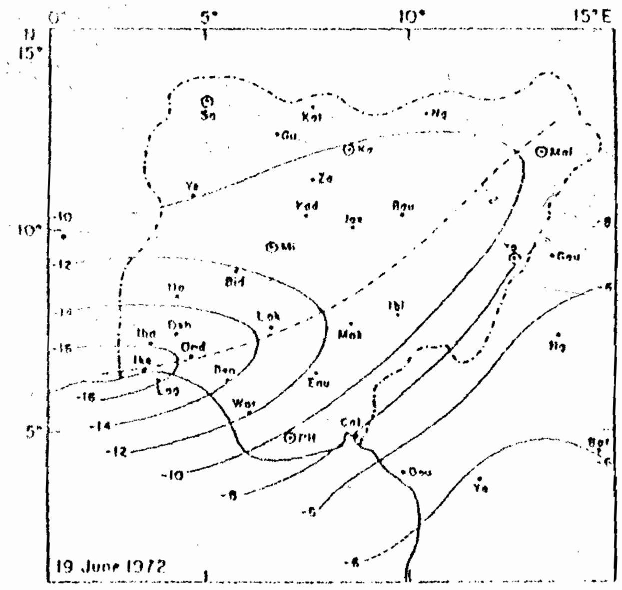

Fig 1f · ZONAL COMPONENT OF THE WIND AT 700mb

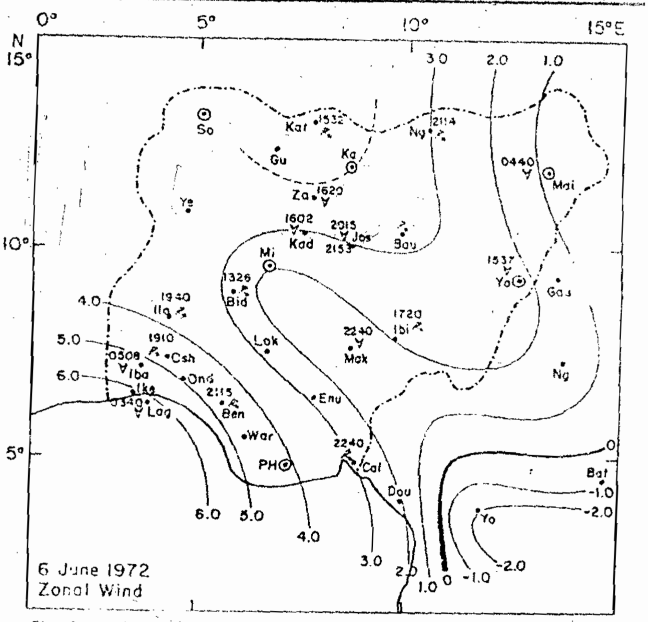

Fig 2a . VERTICAL SHEAR OF THE ZONAL WIND (Surface -900mb)

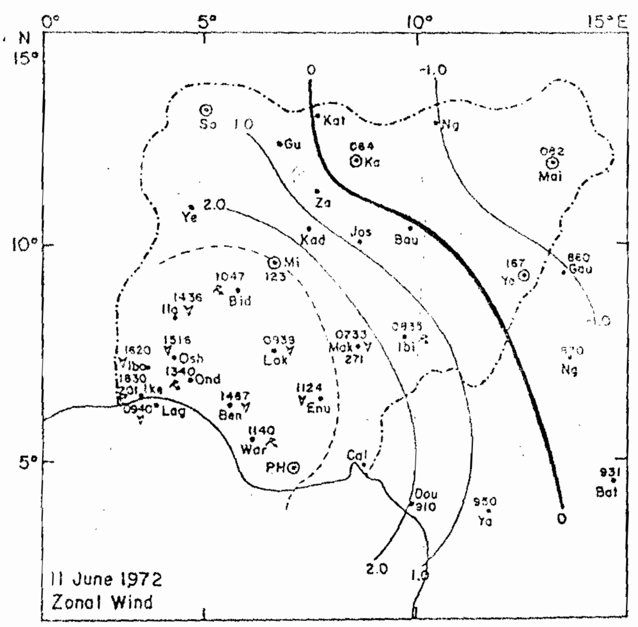

Fig. 3a: VERTICAL SHEAR OF THE ZONAL WIND (Surface-900mb)

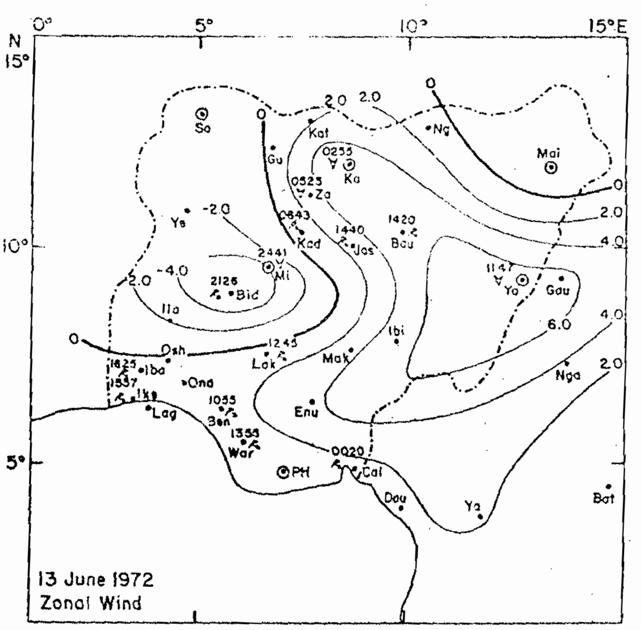

Fig. 4a: VERTICAL SHEAR OF THE ZONAL WIND (Surface-900mb)

THE LOW-LEVEL WIND PROFILES AND THE 700MB JET.

The wind data extracted for each level including the 700mb level (AEJ) were decomposed into zonal (U) and meridian (V) components in the following manner. Supposed that the wind speed at any level is given as ($\underline{V}$) and its direction from true north is θ, then the zonal component of the wind is given by = (U) = k($\underline{V}$) Sin θ ------- (1) And the meridional flow is V = ($\underline{V}$) Cos θ ---------- (2). The computed hourly values of V and U were then averaged on daily basis for June 1972. This method of resolution and averaging removes possible spurious errors which could introduce 'noise' in data and thus gave fairly representative wind for each level for each day.

VERTICAL SHEARS OF THE WIND

Analysis of the wind components was carried out to obtain the vertical shears of the wind within the boundary layer (i.e surface to 900mb) and the middle layer 950-850) as follows:

The zonal wind shear is given by the expression

$$\frac{du}{dz} = \frac{u_2 - u_1}{z_2 - z_1} \quad \ldots\ldots\ldots (3)$$

While the meridional wind shear is given as

$$\frac{dv}{dz} = \frac{v_2 - v_1}{z_2 - z_1} \quad \ldots\ldots\ldots (4)$$

ere U_2 and V_2 are the ; components of the wind speed at an upper level z2 and u1 v1 those a lower level z1

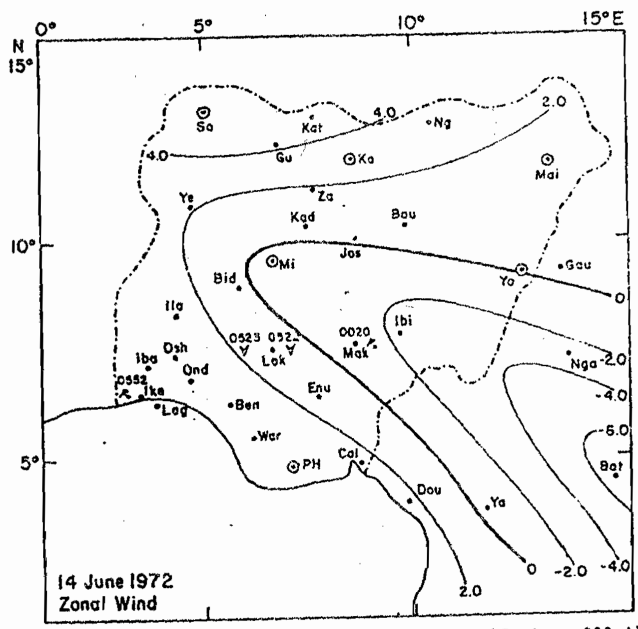

Fig. 5a: VERTICAL SHEAR OF THE ZONAL WIND (Surface -900mb)

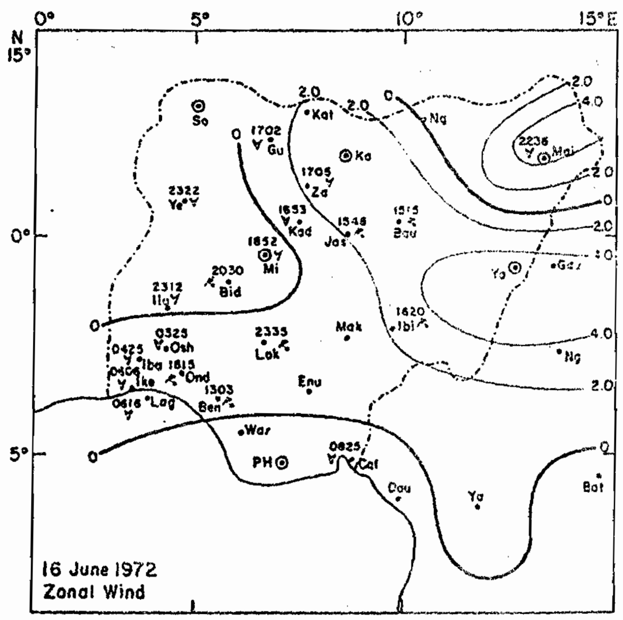

Fig. 6a: VERTICAL SHEAR OF THE ZONAL WIND (Surface -900mb).

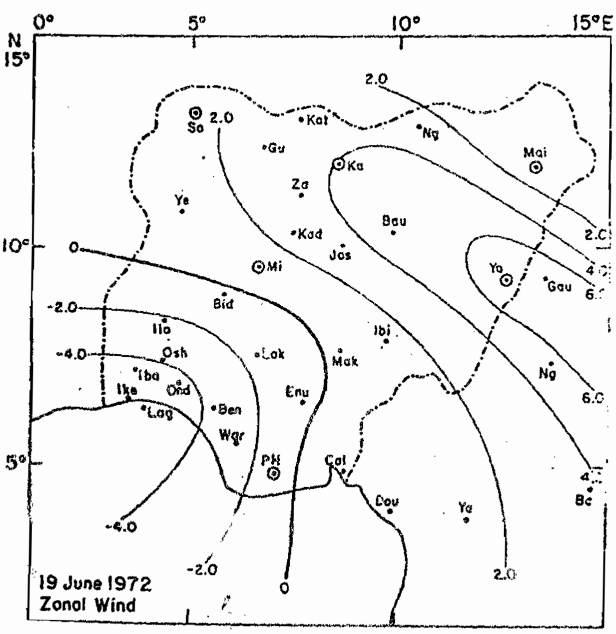

Fig. 7a: VERTICAL SHEAR OF THE ZONAL WIND (Surface - 900mb)

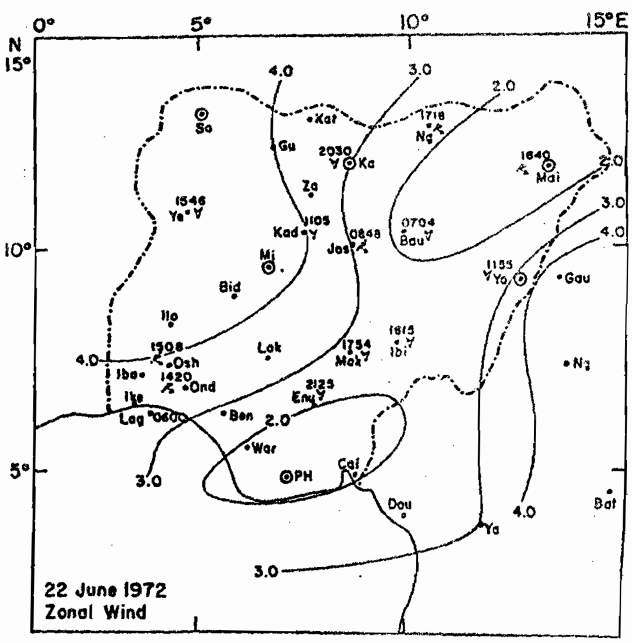

Fig. 8a: VERTICAL SHEAR OF THE ZONAL WIND (Surface -900mb)

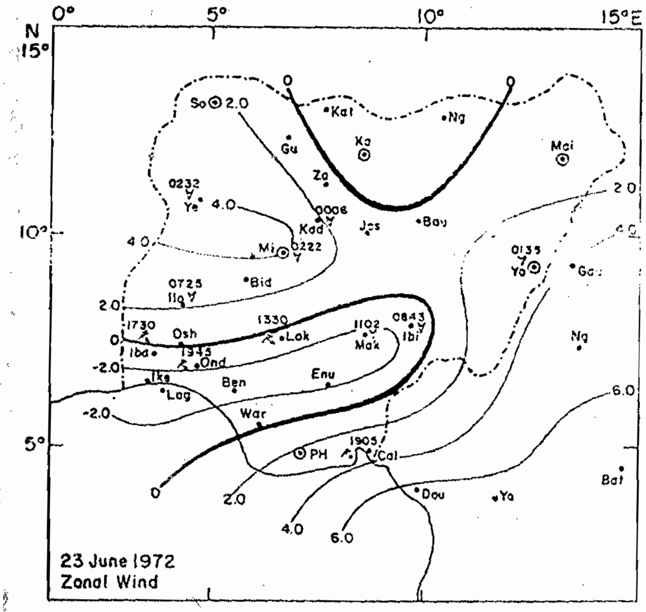

Fig. 9a: VERTICAL SHEAR OF THE ZONAL WIND (Surface - 900 mb)

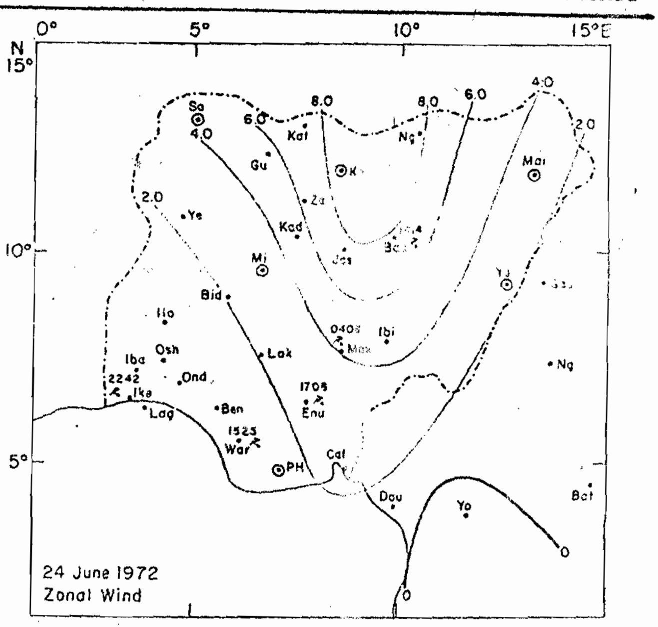

Fig. 10a : VERTICAL SHEAR OF THE ZONAL WIND (Surface - 900mb)

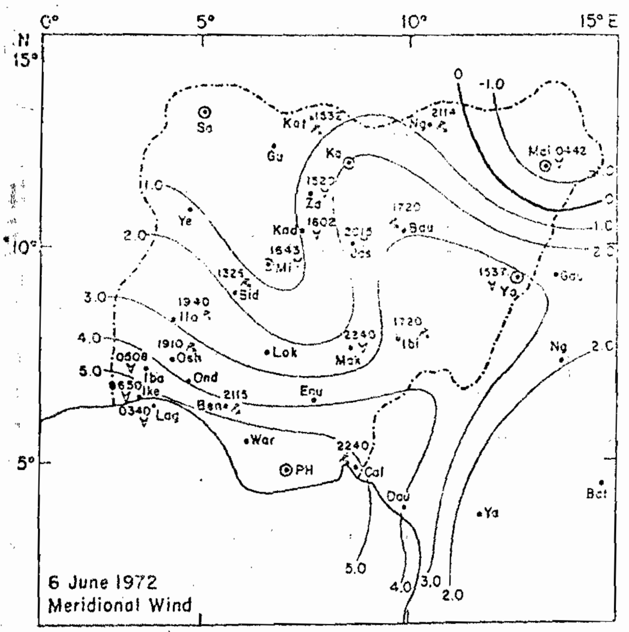

Fig. 2b : VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface-900mb)

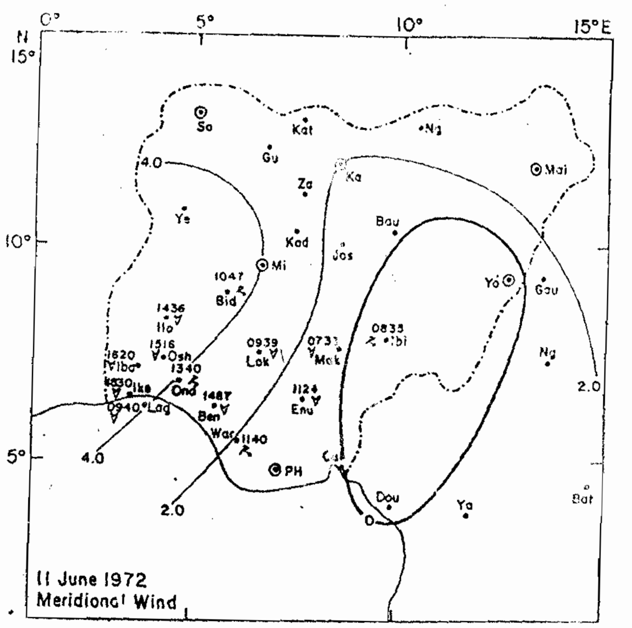

Fig. 3b : VERTICAL SHEAR OF THE MERIDONAL WIND (Surface-900mb)

HEIGHT OF THE MOIST LAYER

The depth of the meridional component of the wind given by h_{mv} is a good measure of the height of the available moisture and the departure from the mean (h'_{mv}) is adequately represented or given by the level where the meridional wind component changes from southerly to northerly and is given by

$$h'_{mv} = h_{mv} - \bar{h}_{mv} \quad (5)$$

where $\bar{h}_{mv}$ is the long term mean of the height of the moist layer for June 1972 and h_{mv} is the height of the moist layer for the day.

THE ANOMALY OF EQUIVALENT POTENTIAL TEMPERATURE (Θ'E) AND SPECIFIC HUMIDITY ANOMALY (Q).

The anomaly of equivalent potential temperature (Θ'e) is a good measure of the available moisture and energy in an air mass while the specific humidity anomaly (q') is a good measure how moist an air mass is (Bets 1974), and are given by

$$\theta'_e = \theta_e - \bar{\theta}_e \ldots\ldots\ldots\ldots(6) \text{ and } q' = q - \bar{q} \ldots\ldots\ldots\ldots(7),$$

where $\bar{\theta}_e$, $\bar{q}$ are the long term means of equivalent potential temperature and specific humidity respectively for June 1972 and θ_e, q ;the equivalent potential temperature and specific humidity respectively, for the day. positive anomalies of equivalent potential temperatures and specific humidity are therefore represented by areas of warm and moist air while negative anomalies are represented by areas of cool and dry air.

ROLES OF THE FLOW PARAMETERS AND DYNAMIC PROCESSES ON CONVECTIVE ACTIVITIES:

In this section, the patterns of occurrence of convective systems (line squall/thunderstorm) on a daily basis for the days used as case studies throughout Nigeria.

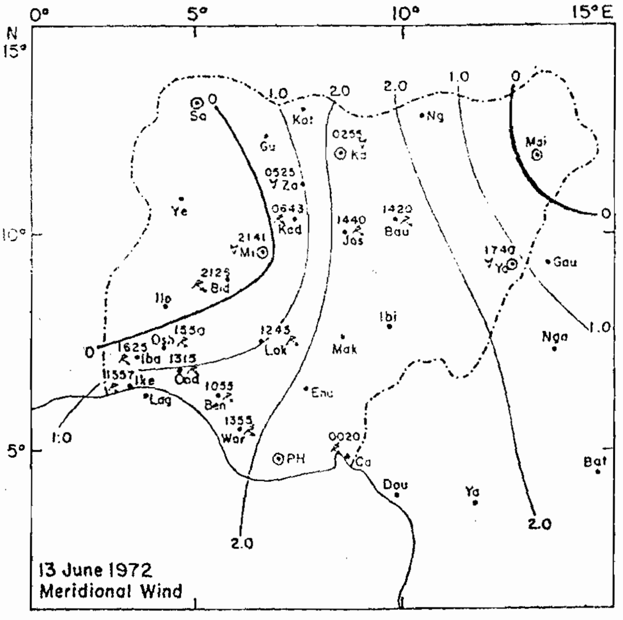

Fig. 4b: VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface - 900mb).

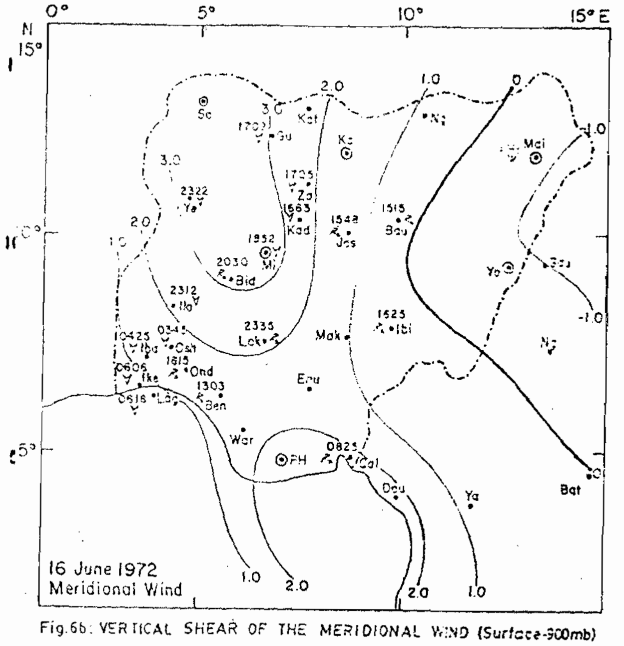

Fig. 6b: VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface-900mb)

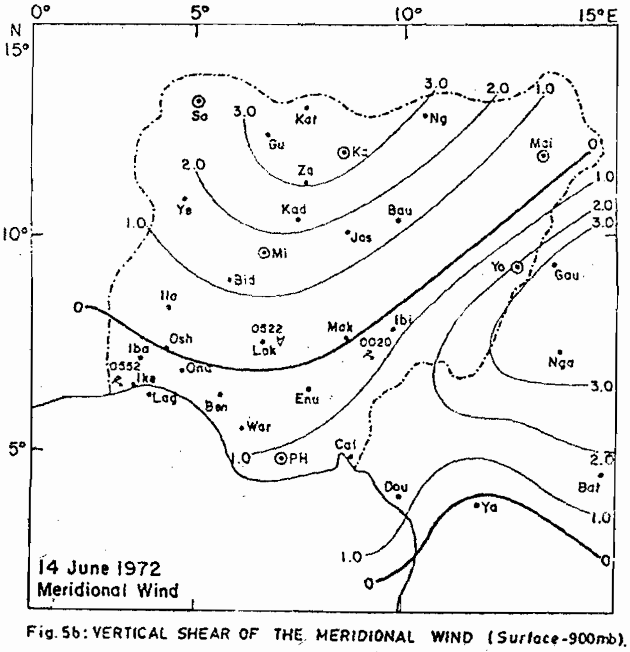

Fig. 5b: VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface-900mb).

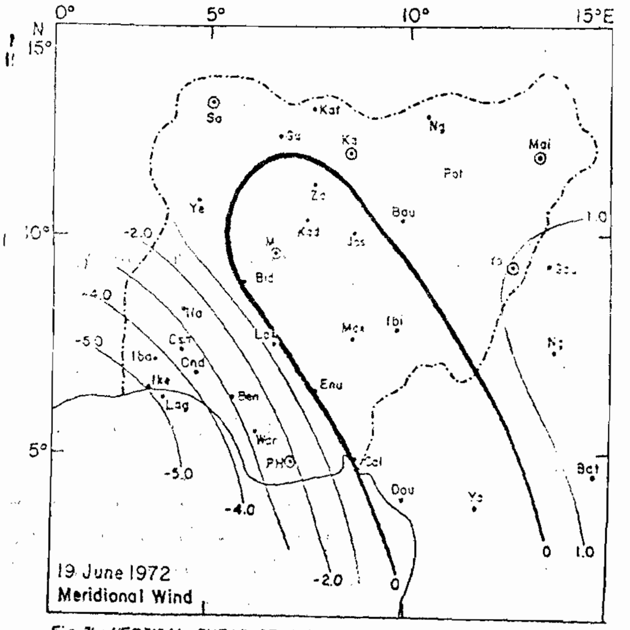

Fig. 7b: VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface-900mb).

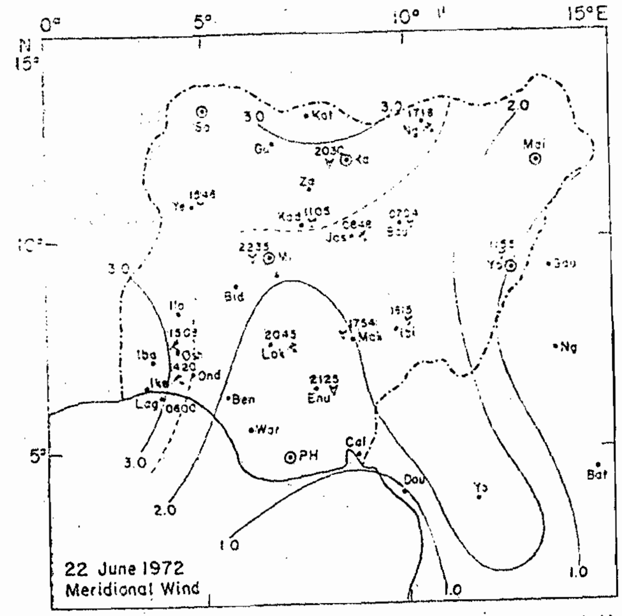

Fig. 8b: VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface-900mb).

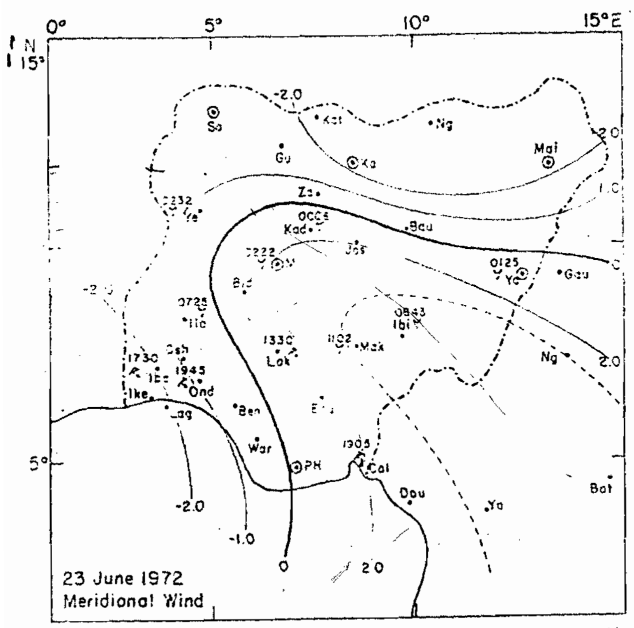

Fig. 9b: VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface - 900mb)

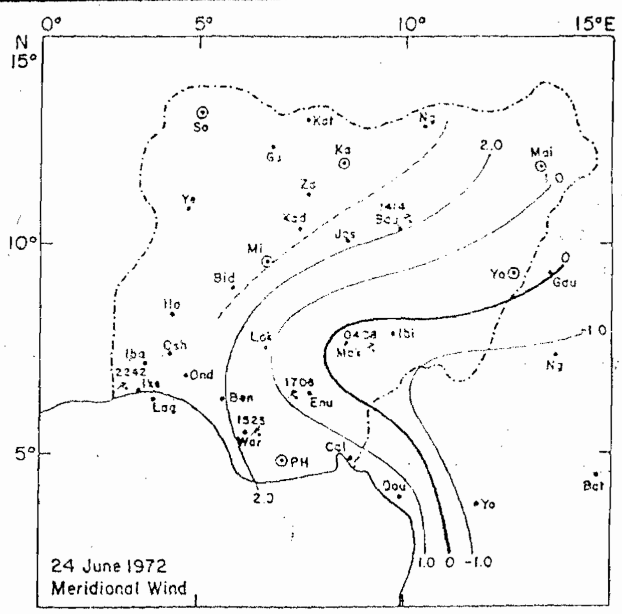

Fig. 10b: VERTICAL SHEAR OF THE MERIDIONAL WIND (Surface-900mb)

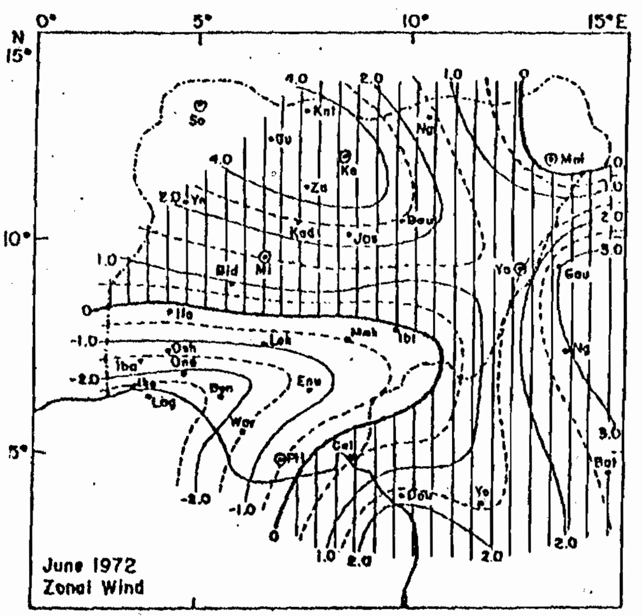

Fig. 11a: VERTICAL SHEAR OF THE ZONAL WIND (Surface-900mb).

The low-Level And 700 mb (AEJ) winds:

The computed values for U and V for each level were analysed to ascertain the role and influence of the strength of the low-level moist flow on convective systems.

The 700 Wind (AEJ)

Since it is believed that the African Easterly Jet (AEJ) indirectly aids line squall formation and maintenance by producing down-drafts which forces up the warm moist surface air into the storm cloud (Zipser, 1969; Moncrief and Miller, 1976) a daily analysis of the 700 mb wind was carried out in order to ascertain the role and influence of this jet on line squall occurrence. It was noted that while the distance between any two points here is rather too large to allow a definite conclusion to be made on the role of the AEJ on line squall occurrences, there are good indications of widespread thunderstorms and or organised line squalls on days of well defined AEJ as Figures 1a, 1b, 1c, 1g and 1l show for the 6th 11th 13th, 16th, 22nd 24th. In particular, the concentration of storms and squalls can be seen around the left entrances and right exits (1a, 1c and 1e) and line squall organization in these areas are noteworthy. This contrasts with the middle latitude situation where weather development is normally expected around the right entrances and left exists of jet streams.

Spatial Distribution of The Zonal and Meridional Wind Shears (Surface to 900 mb (i.e. low level Winds))

One of the conditions required for the organization of convection into rapidly propagating the squalls is strong low-level vertical wind shears (Moncrief and Miller, 1976; Balogun, 1978) and this appears to be the most crucial for a few important reasons. Firstly, vertical wind shear is an important property of the near surface wind fields on which depends vertical transport of momentum

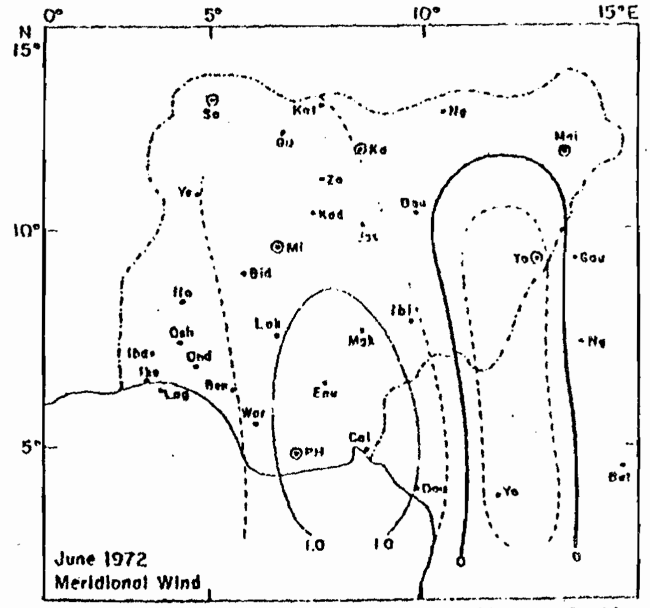

Fig. 11b: VERTICAL SHEAR OF MERIDIONAL WIND (Surface - 900mb)

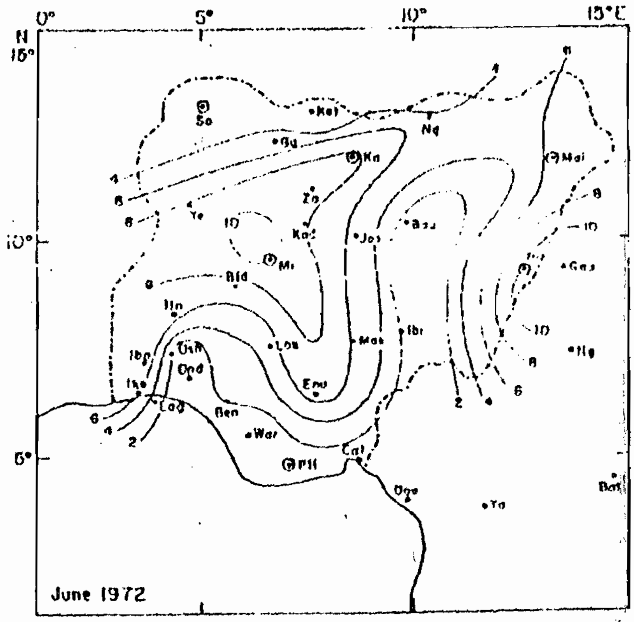

Fig. 12b Total Line Squalls

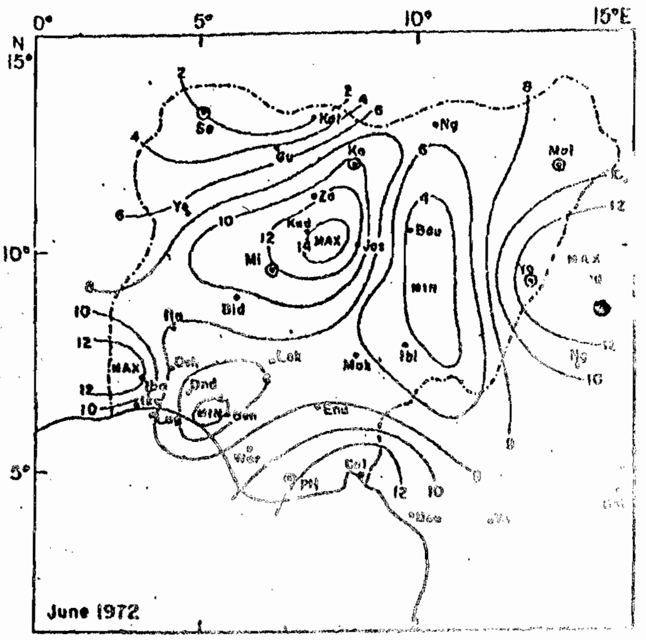

Fig. 12a Total Line Squall/Thunderstorm

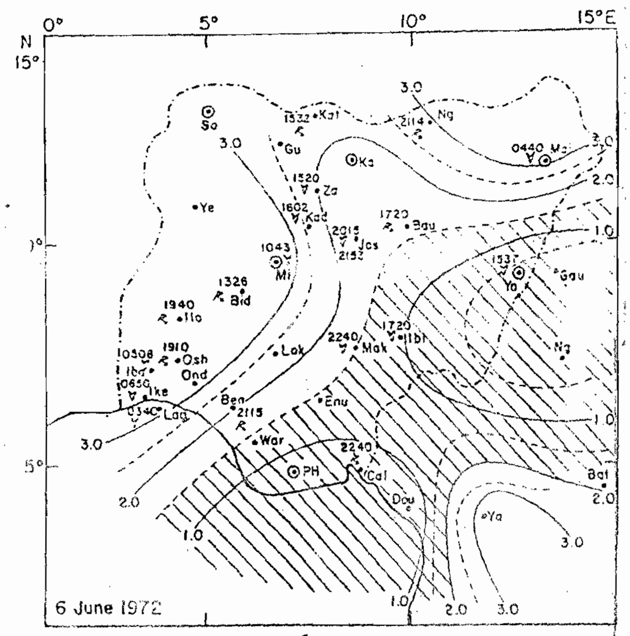

Fig. 13a: hmv (x 10³)m OF V-COMPONENT

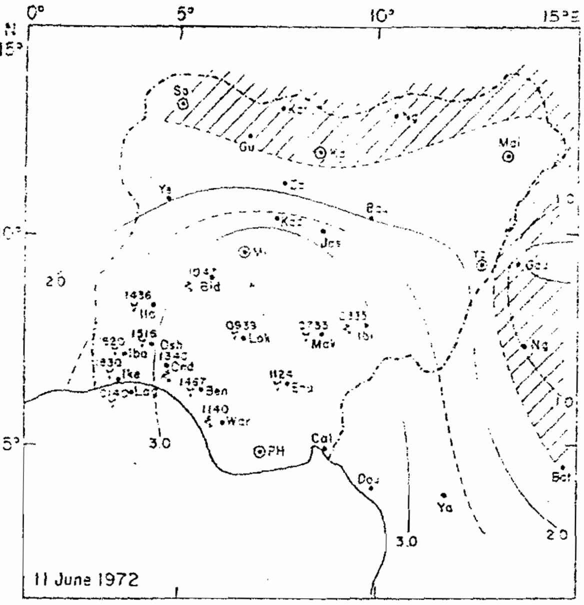

Fig. 13b: hmv ($\times 10^3$) m OF V-COMPONENT

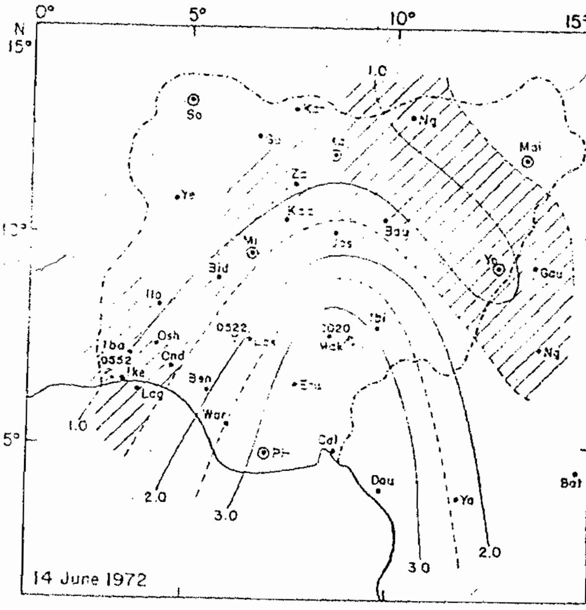

Fig 13d: hmv ($\times 10^3$) m OF V-COMPONENT

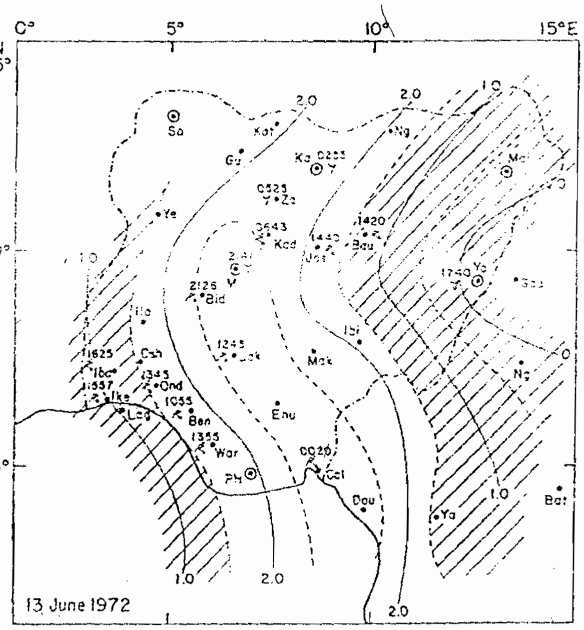

Fig 13c: hmv ($\times 10^3$) m OF V-COMPONENT

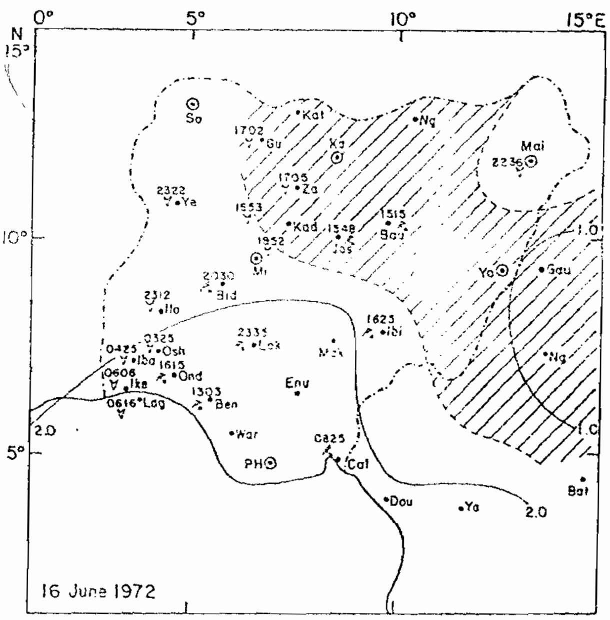

Fig. 13e: hmv ($\times 10^3$) m OF V-COMPONENT

heat and moisture to higher levels. Secondly, strongly, sheared systems translate at higher speeds (Hane, 1973) and consequently, the relative inflow of warm moist low-levels air is stronger, thus aiding squall generation and sustenance. Furthermore, a strong easterly jet is necessary for convective overturning as well as down drafts in squall formation (Moncrief and Miller, 1976). The horizontal distributions of the vertical shears of the zonal wind is shown in Figures (2a – 10a), while those for the meridional components are shown in Figures (2b – 10b).

Although it is not possible to actually define a threshold value for the shears of the zonal and meridional wind necessary for the development of deep convective systems from such a small and not-so-dense data network, surface to 900 mb vertical shear greater than zero (i.e $\Delta U / \Delta Z$) ($\Delta V / \Delta Z$) > 0) will be taken to be a reasonable lower condition. Thus strong westerly (positive) shears favoured increased line squall occurrence, especially if the boundary-layer positive shears are over lain by strong negative (easterly) shears aloft. The zonal and meridional wind shears for the 6th (Figure 2a and 2b) had positive (westerly) values everywhere within the region except the Southeast frying of the country (Figures 3a and 3b). the squall storm pattern for that again show a better agreement with the zonal than with the meridional shear distributions. There were no storm/squall occurrences to the north but widespread storm/squall occurred over the South part of the country (Sough of 10 N).

On the 13th (figures 4a and 4b) negative wind shears prevailed in the west –northeast regions with westerly shears else where in the country for zonal and meridional components. There were a few storms reported over those regions with negative shears. How ever, some areas to the southeast with positive shears were not affected by any storm. It would appear from this, that other consideration which may be more important were at play here than the vertical shears of the wind. The distribution of zonal wind shear for the 24th does not agree well with that of line squall whereas the meridional wind shear distribution was a little more consistent (figures 5a and 5b) On the 16th (figure 6a and 6b) there was general consistency between storm occurrence and the areas of positive (westerly)wind shear, Nevertheless, some storms occurred over places with negative (easterly) zonal shear but with positive meridional shear, suggesting different roles of the wind shear themselves and the significance of other basic flow parameters and dynamic processes in line squall formation. It is clear that storms/squalls were prevalent if both the zonal and meridional wind shears were greater than zero. It is also interesting to note that in general, few or no storms were observed over areas

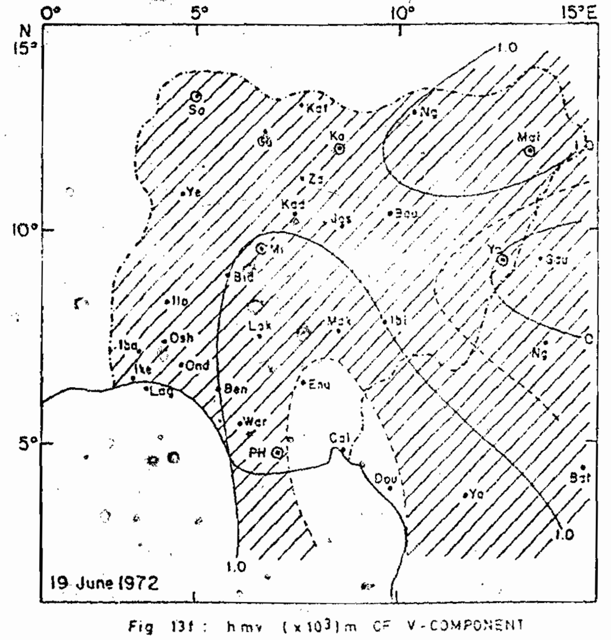

Fig 13f : hmv (x10³)m OF V-COMPONENT

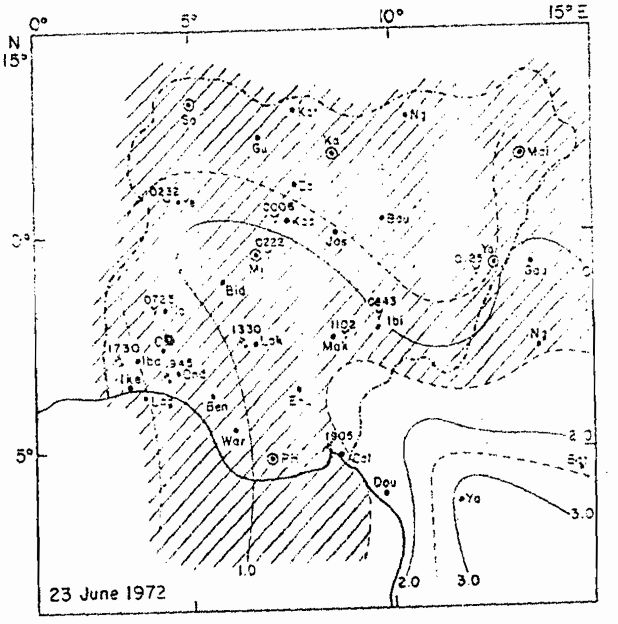

Fig 13h : hmv (x10³)m OF V-COMPONENT

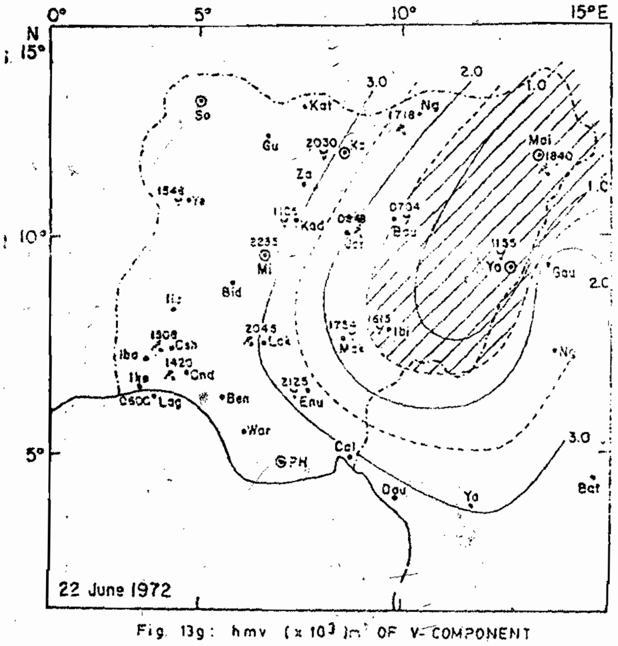

Fig. 13g : hmv (x10³)m OF V-COMPONENT

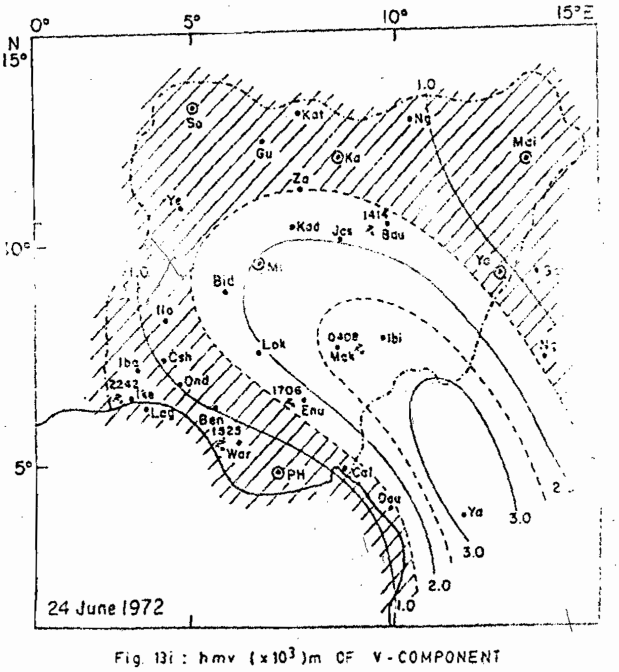

Fig. 13i : hmv (x10³)m OF V-COMPONENT

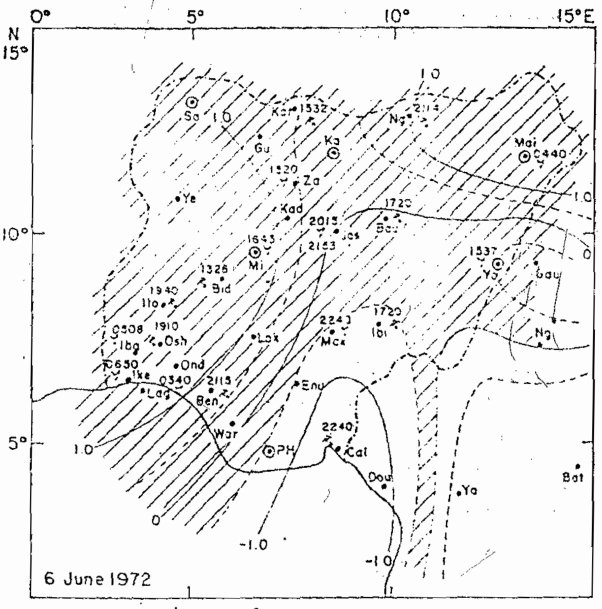

Fig. 14a: $\dot{h}$mv (x10³) FROM V-COMPONENT OF WIND

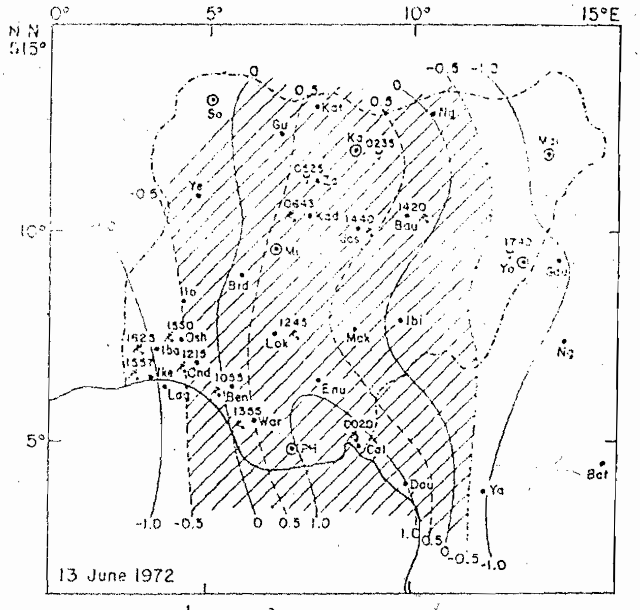

Fig. 14c: $\dot{h}$mv (x 10³) FROM V-COMPONENT OF WIND

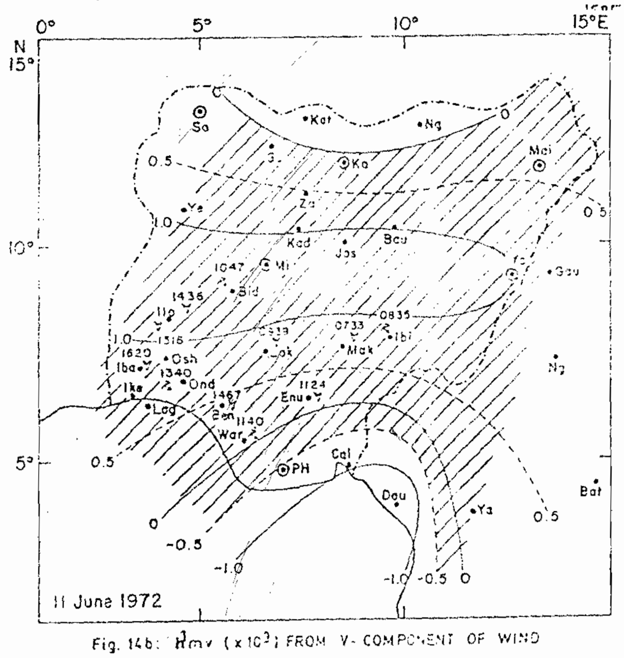

Fig. 14b: $\dot{h}$mv (x10³) FROM V-COMPONENT OF WIND

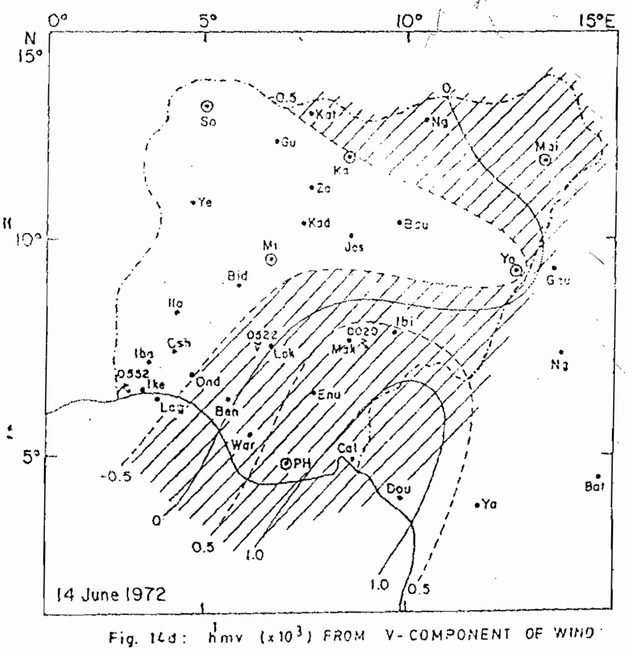

Fig. 14d: $\dot{h}$mv (x10³) FROM V-COMPONENT OF WIND

where the zonal shear in greater than zero and the meridinal shear is less than zero, but widespread storms do occur if the zonal shear is less than zero and the meridional shear is greater than zero, (Figures 2a, 5b, 6a and 10a, 10b).

It was on the 19th (Figure 7a, 7b) that the greater inconsistency was found between wind shear and thunderstorm occurrence. While positive zonal shears dominated the country except over a narrow tongue from the southeast to the northwest. The meridioanal distribution was seen to be more consistent with line squall occurrence of that day. No line squall activity was reported for that day throughout the country. Obviously, this is proof that while wind shear is an important term in the Richardson's number defined by $Ri, = \frac{\bar{\theta}}{\theta}\frac{d\theta}{dz}\left(|\frac{dv}{dz}|\right)^{2}$

(a necessary criterion for convective phenomenon), it is not a sufficient condition for storm generation. This suggests that the static term $d\theta/dz$ is as important as the wind shears. The available data here is incapable of being used to compute Ri as there are four radio sonde stations in the are covered by this work. As noted, the fact that few or no storm were observed over areas with negative meridional shear may well means that the shear of the meridional wind is a very crucial basic flow property for storm development. Westerly shears prevailed everywhere on the 22nd

(Figures 8a and 8b) and were generally in good agreement with the thunderstorm occurrence for that day. Storm/squall occurrence over areas with negative zonal wind shears but not over areas with negative meridional shears is again noteworthy for the 23rd (Figures 9a and 9b), and further emphasize the importance of other parameters and processes in, squall/storm formation. As on the 19th, Figures 10a and 10b for the 24th were inconsistent with the suppressed connective situation for that day. The mean monthly low-level zonal wind shear is in good agreement with the monthly total for both line squall only and line squall/thunderstorms (Figures 11a, 12a and b), while the mean monthly meridional shear was more consistent with line squall distribution than with the total line squall and /thunderstorms, (Figures 11b, 12a and 12b).

In general, westerly (positive) zonal and meridional shear prevailed at low-levels for most days of June, while a persistent easterly (negative) shear of the zonal wind dominated the middle-level (850-700 mb) above the boundary westerly shears. The middle shears are not as consistent with line squall/thunderstorm as the low level shears. This suggests that the boundary layer positive shears may be more important to storm due to their over turning effect.

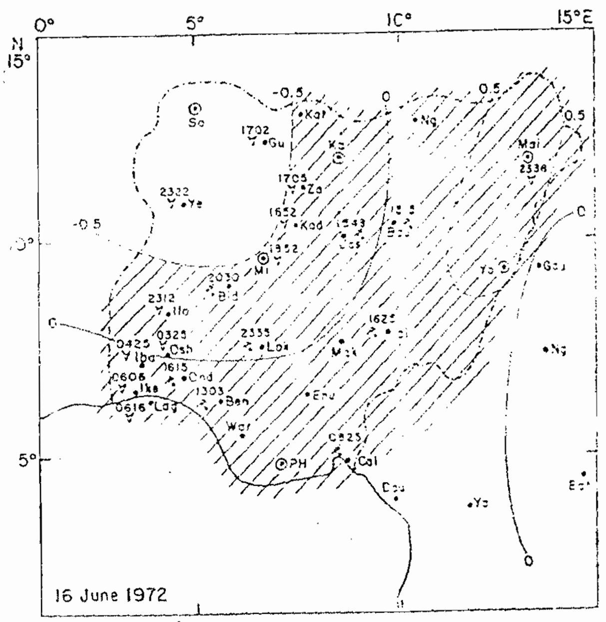

Fig 14e: h'_{mv} $(x\,10^3)$ FROM V-COMPONENT OF WIND

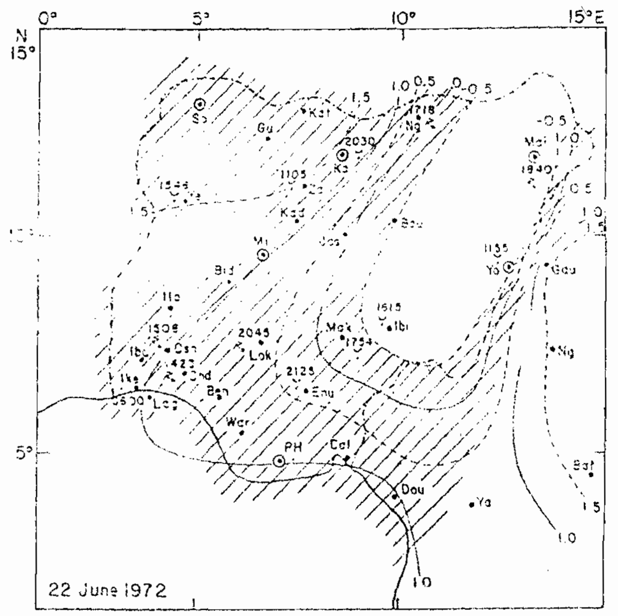

Fig 14g: h'_{mv} $(x\,10^3)$ FROM V-COMPONENT OF WIND

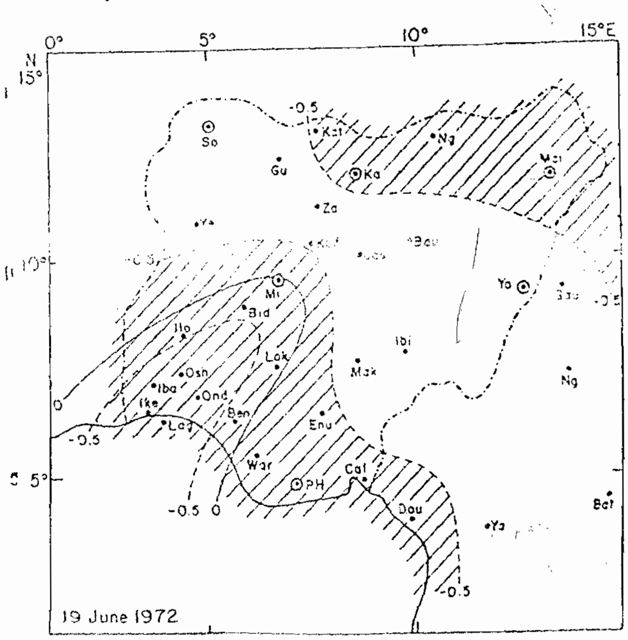

Fig. 14f: h'_{mv} $(x\,10^3)$ FROM V-COMPONENT OF WIND

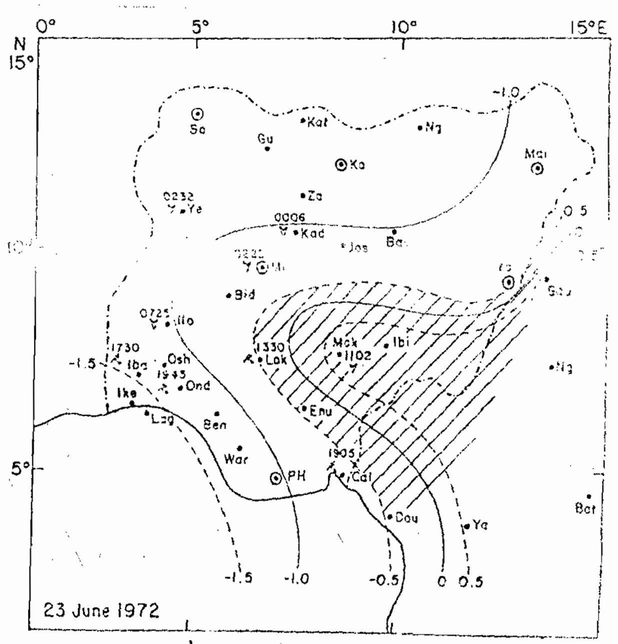

Fig. 14h: h'_{mv} $(x\,10^3)$ FROM V-COMPONENT OF WIND

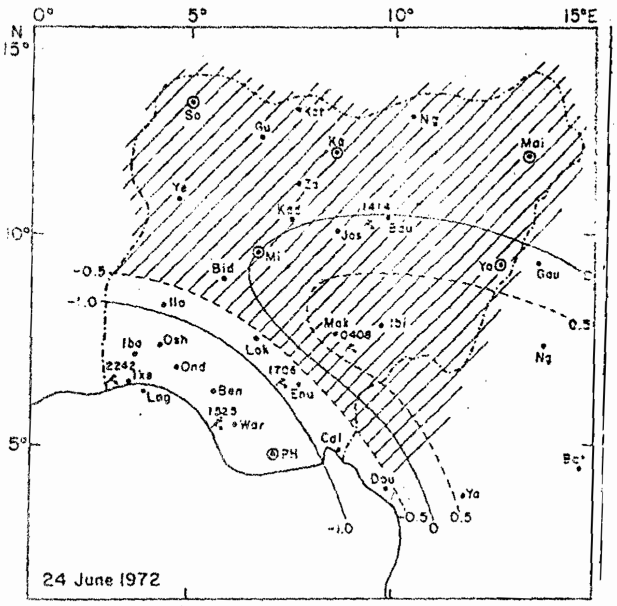

Fig. 14i : h_{mv} ($\times 10^3$) FROM V-COMPONENT OF WIND

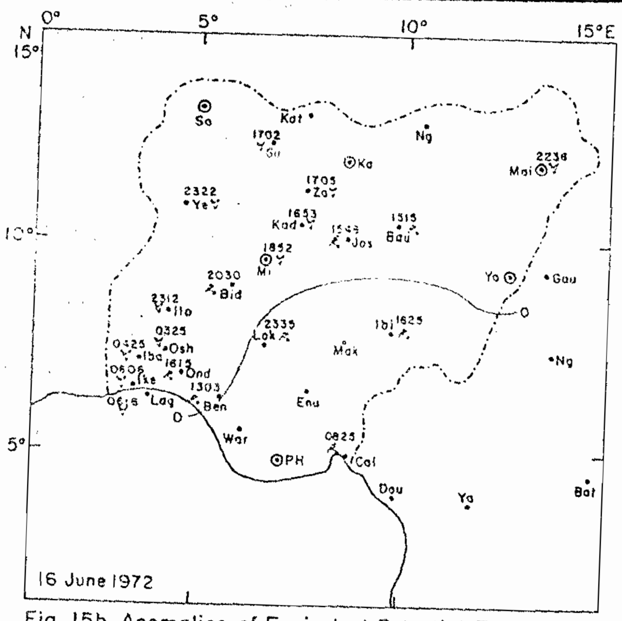

Fig. 15b Anomalies of Equivalent Potential Temperature

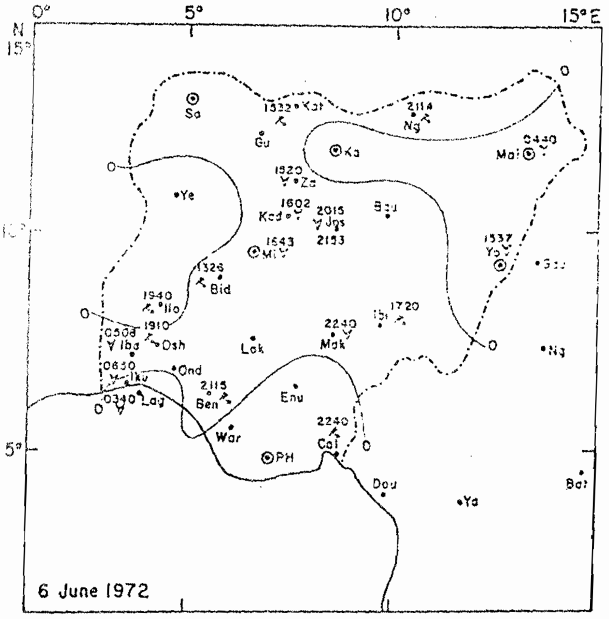

Fig. 15a Anomalies of Equivalent Potential Temperature

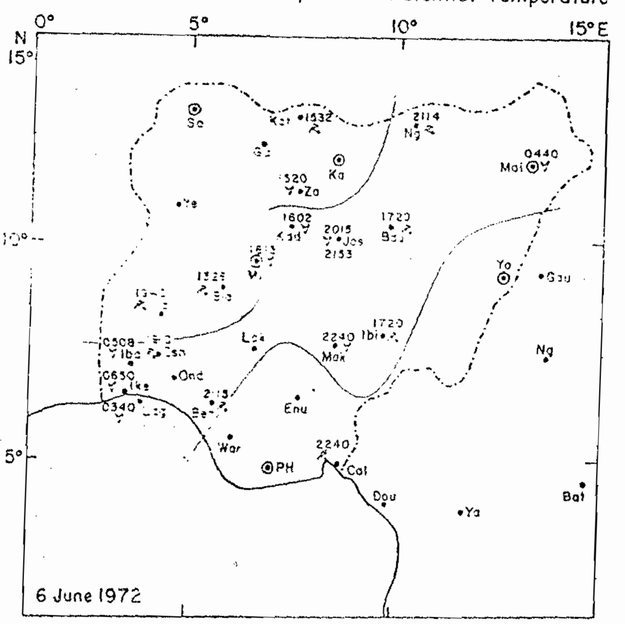

Fig. 16a Anomalies of Specific Humidity

THE SPATIAL AND TEMPORAL VARIABILITY OF THE HEIGHT OF THE MOIST LAYER

Since latent heat of condensation is the major source of energy for tropical convective systems, it follows that the vertical and horizontal distributions of moisture are important for storm development and survival. The shape and extent of the coast of west Africa shows that only the meridional component of the wind could bring in bundant moisture to the inland areas of the region, therefore the depth of the meridional (V) component of he wind is assumed to be a good measure of the depth of available moisture in this work. Moisture depth (h_{mv}) greater than 15km (i.e. a sufficiently deep southerly flow) preceded (for about a day) widespread line squall/thunderstorm occurrences (Figures 13a – 13i). The depth and extent of convective activities is also affected by the deepening or otherwise of the moist layer in the preceding twenty-four hours. For example the widespread deep convection that prevailed throughout the country on the 6th was preceded by a large increase in the depth of the moist layer on the previous day (5th) to a depth higher than 1.5 km over most of the country (Figure 11a). A more or less similar moisture build up occurred from the 10th to the 11th when the depth of 2.0 km reached just No of 10N (Figure 13b). It was noticed that there was suppression of convection over areas North of 10°N on the 11th probably because the moisture depth did not increase significantly during the preceding twenty-four hours. The situation on the 13[th] is a good example of the influence of the depth of the moist layer as squalls and storms were observed almost exclusively in areas with moisture depth greater than 1.5 km (figure 13c). The gradual decrease of the moist layer below 1.5 km by the 14[th] over the North and Southwest sector started on the 12[th], leaving only the Southeast areas with deeper moisture layer. There are only isolated deep convective activities in the later areas on the 14[th] (Figure 13b). It is noted that boundary layer vertical wind shears were positive only over a very small portion of the areas with height of most layer greater than 1.5km. on the 16[th] (Figure 13e) only a relatively small part of the central areas of the North have relatively shallow (less than 1.5 km) moist layer.

On the 19[th] however, almost all parts of the country were under shallow layer (less than 1.5 km) of moisture ladden air as can be seen in Figure 13f. This shows another good consistency with the suppressed situation everywhere on this day. Figure showed deep moist layer (greater than 1.5 km) everywhere except over the Northeast corner of Nigeria on 22[nd] and this again agrees with the convective development over this area. A significant inconsistency between moist layer depth and deep convection occurred on the 23[rd] (Figure 13h) when all the country had shallow moisture layer,

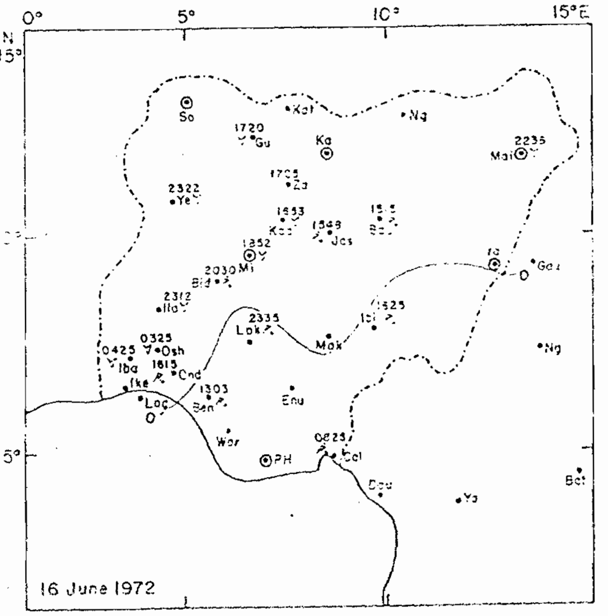

Fig. 16b Anomalies of Specific Humidity

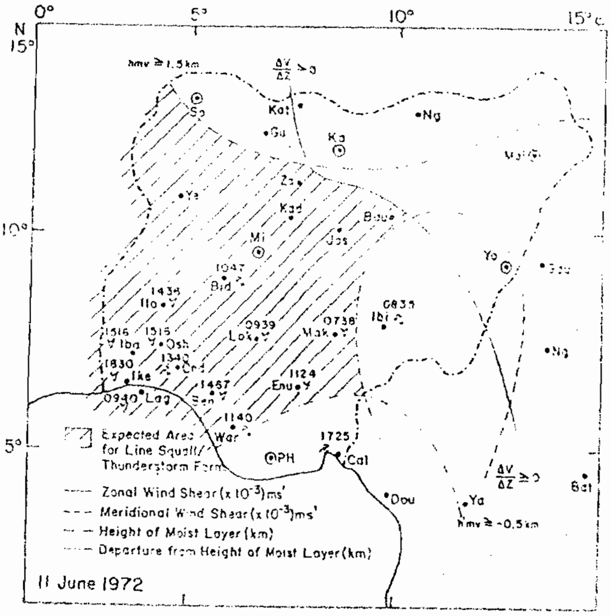

Fig. 18a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

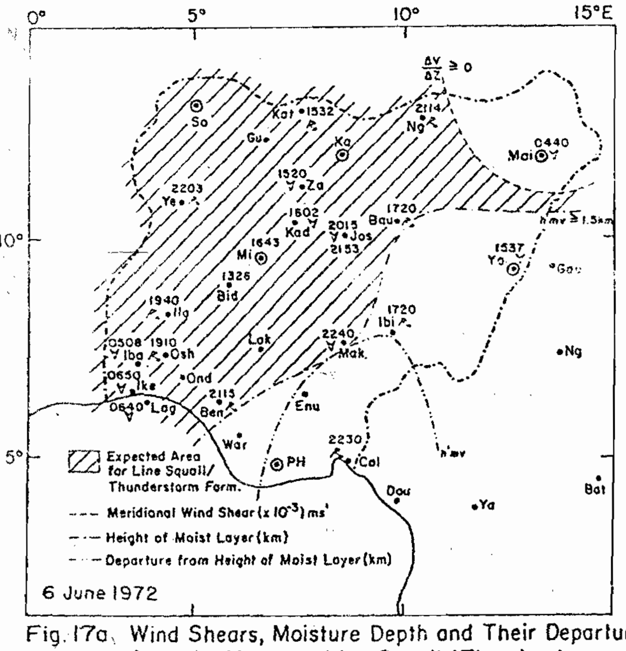

Fig. 17a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

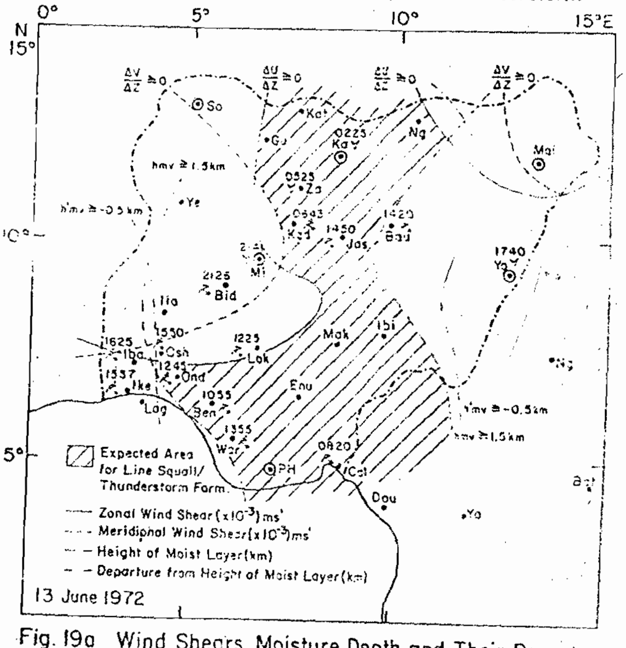

Fig. 19a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

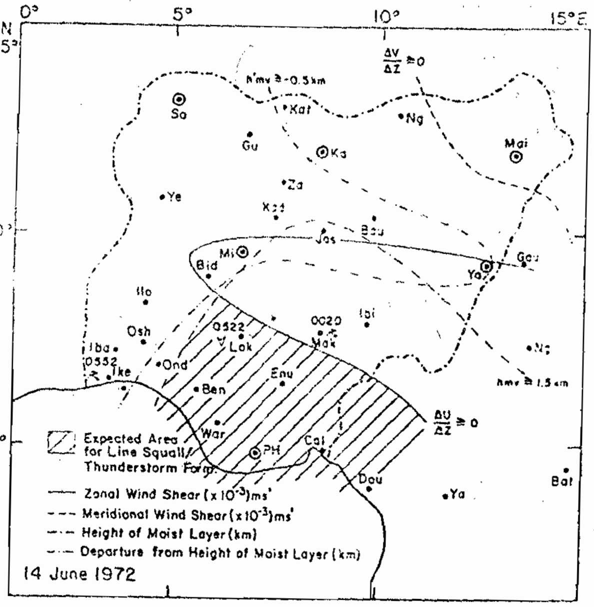

Fig. 20a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

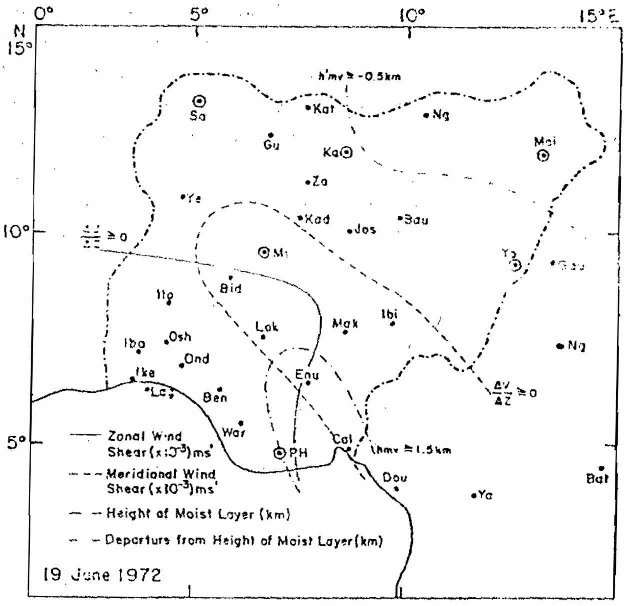

Fig. 22a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

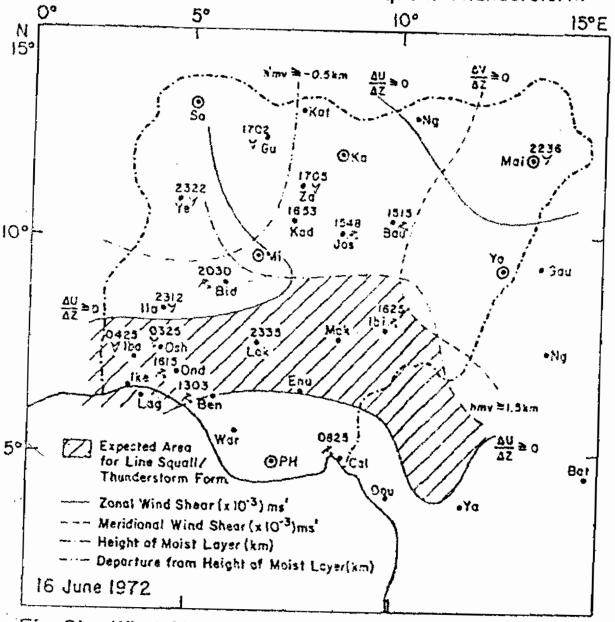

Fig. 21a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

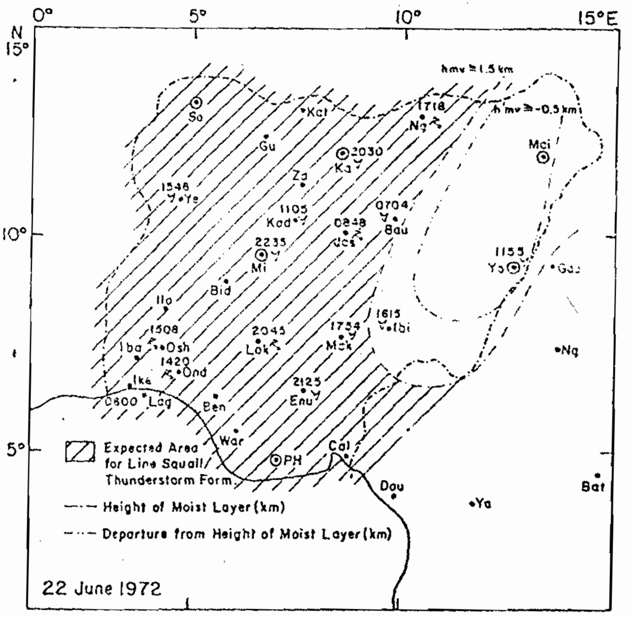

Fig. 23a. Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

but scattered squalls and storms occurred during the night and early morning hours, a few hours following the 22nd (with very deep moist layer). Probably later on the 23rd the moisture layer started to increase generally and by the 24th had reached higher than 2 km over the Southeast areas of Nigeria (Figure 13l). So far it has been shown that a reasonably deep layer of moisture of at least 1.5 km deep favours widespread, deep and active convection. It is not possible in the present study to suggest an upper limit for the depth of the moist layer since only one month's data was used and height of the moist layer would increase through the month of July to attain a maximum height.

Departures of the Height of Moist Layer from the Mean

The relevance of the departure of the height of the moist layer from the mean (represented by the meridional component of the wind) are also investigated. It was found that departures of the height of the moist layer (h'_{mv}) greater than –0.5 km is generally consistent with areas of deep convection whereas lower departures (i.e. h'_{mv} >0.5km) led to suppressed conditions. Convection is especially enhanced if the departures (h'_{mv}) increased in the past twenty-four hours indicating a gradual building up of moisture. This was in fact the case on the 6th, 16th, 22nd and 23rd when the

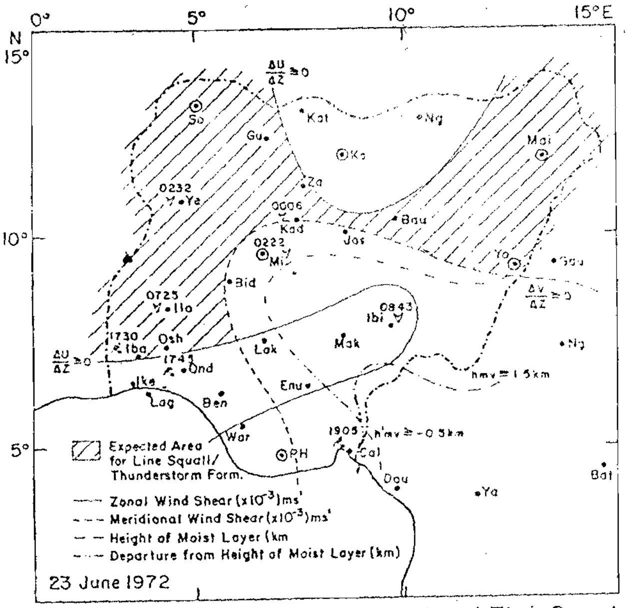

Fig. 24a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

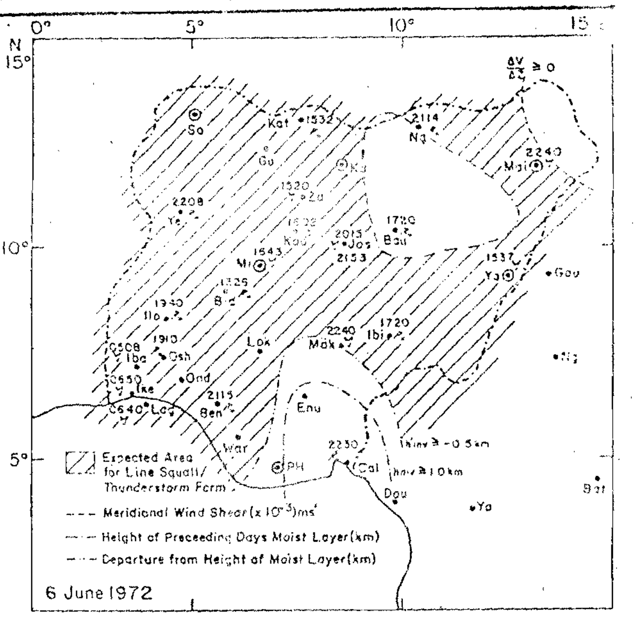

Fig. 17b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

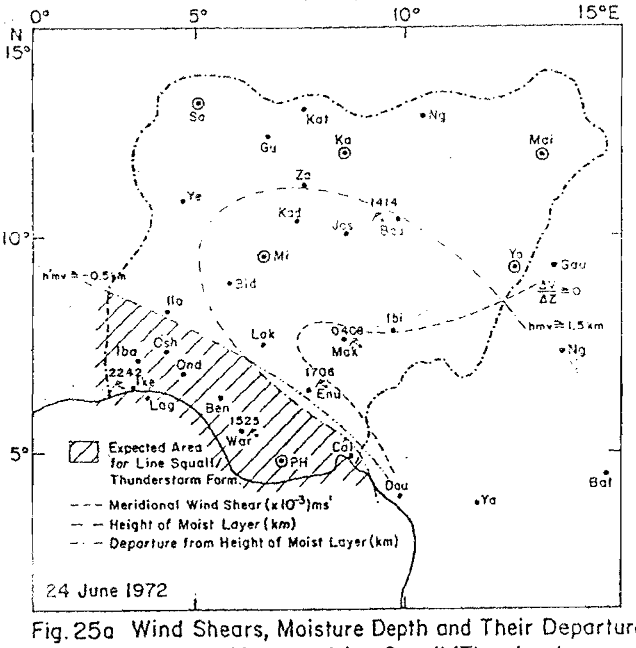

Fig. 25a Wind Shears, Moisture Depth and Their Departures from the Mean vs. Line Squall/Thunderstorm

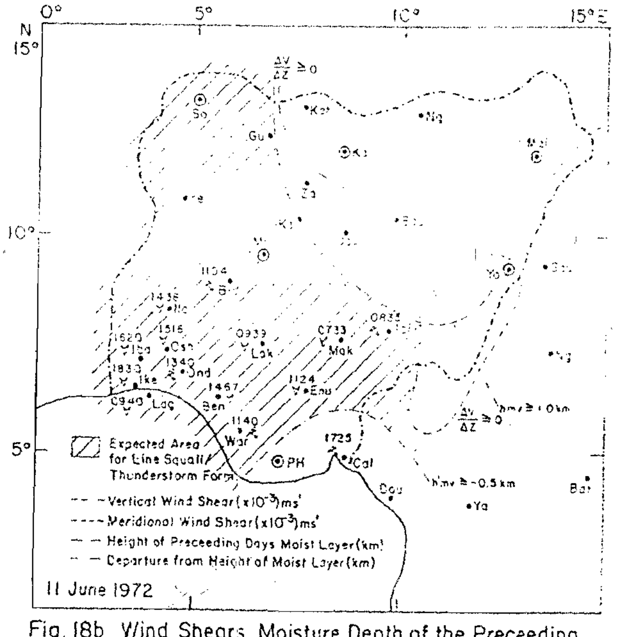

Fig. 18b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

departures were generally greater than –0.5 km. There is good agreement between the convective activities on those days and he departure pattern as shown of Figures 14a, d, g and h.

Departures were generally greater than – 0.5 km over most places on the 11th and 13th which are slightly in agreement with the widespread convective activities South of 10N on the 11th and in most places over Nigeria on the 13th even though a decrease in the build up of the departures occurred from the 10th to the k11th from the 12th to the 13th. Figures, 14b and c. On the 19th, moisture depth anomalies are less than – 0.5 km in most places over Nigeria except the Northern sector and there had been a gradual decrease of the moist layer over these areas in the preceding twenty-four hours. These are in good agreement with the highly suppressed situations on that day Figure 14f. On the 14th (Figure 14d) the departures were less than –0.5 km in most places following a reduction in the preceding twenty-four hours. It is noted that only isolated storms were reported on this day. From all the analysis presented so far, it is clear that actual depth rather than their temporal variabilities are crucial to deep convective development.

ANOMALIES OF EQUIVALENT POTENTIAL TEMPERATURE (θ'_e) AND SPECIFIC HUMIDITY (q')

Equivalent potential temperature and specific humidity and their anomalies can be used in explaining the behaviour of the atmosphere, especially, rainfall distribution and line squall formation. (Adefoalu, 1970; Burpee, 1972; Bets, 1974 and Obasi, 1974). It was therefore necessary to carry out daily analysis of these parameters to ascertain their roles and influences on convective development. No good correlation was found between line squall / thunderstorm and the anomalies of equivalent potential temperature or with the anomalies of specific humidity in this work, although Adelolalu (1970) found ϕ^{1}_{e} to show some correspondence with monthly rainfall and line squall. Therefore the results for only two days 6^{th} and 16^{th} are presented here for completeness and clarity. It can be said that the reason for the conflicting findings may be due to the fact that Adefolalu's work was based on a monthly mean whereas the present work is a daily analysis which covered days with varied degrees of convective activities.

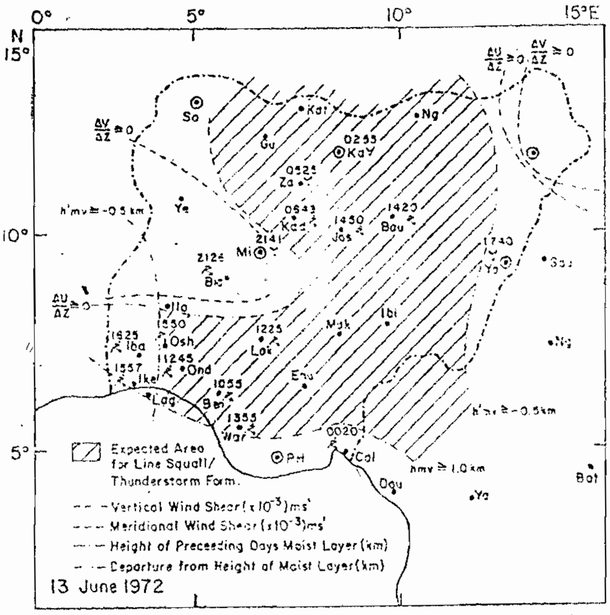

Fig. 19b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

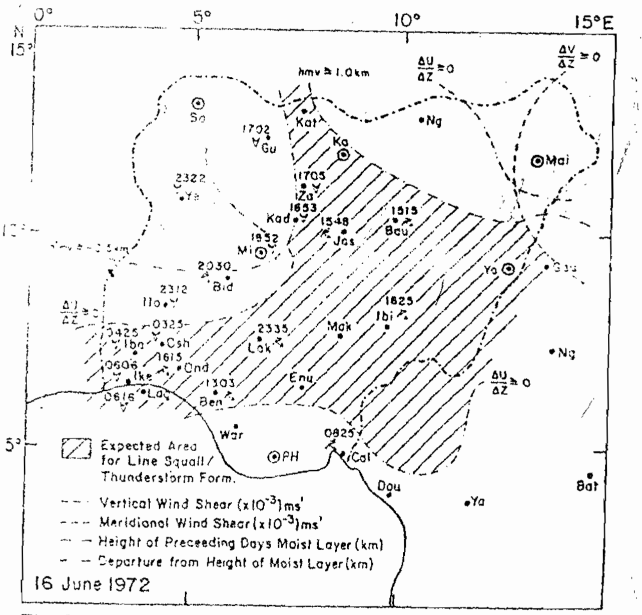

Fig. 21b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

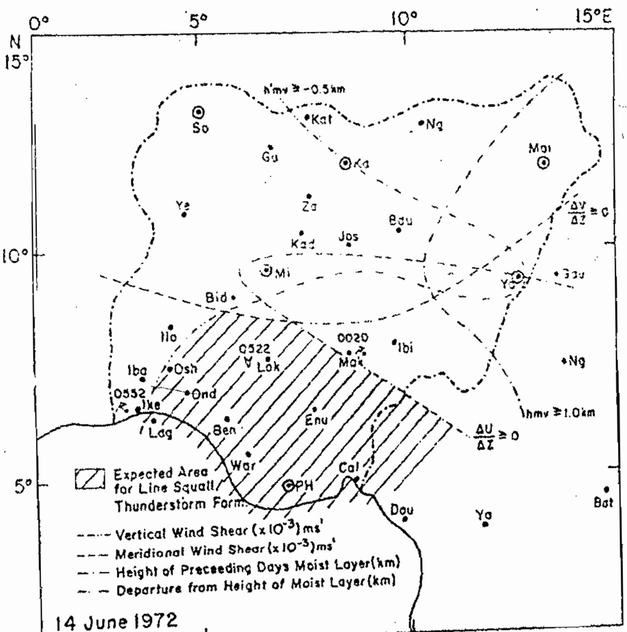

Fig. 20b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

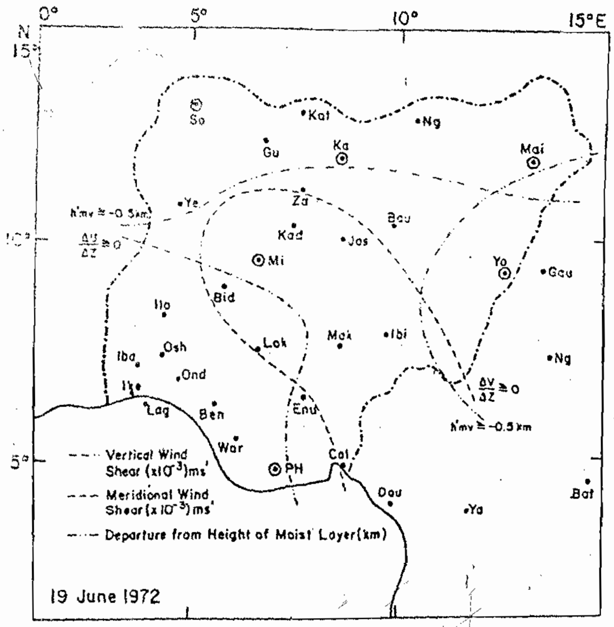

Fig. 22b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

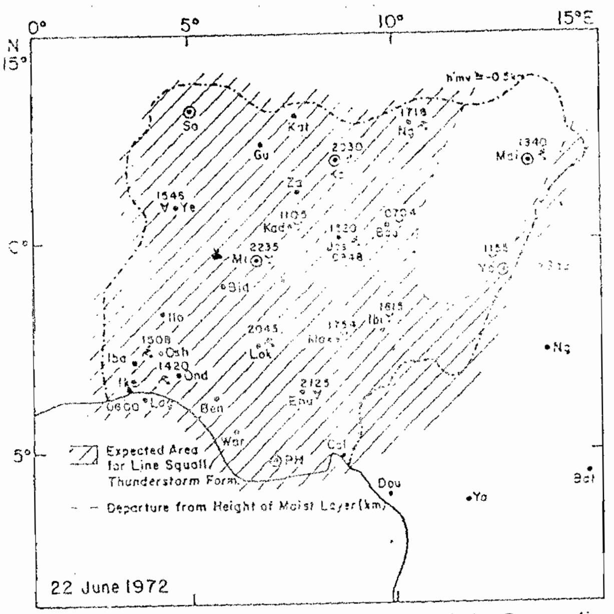

Fig. 23b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

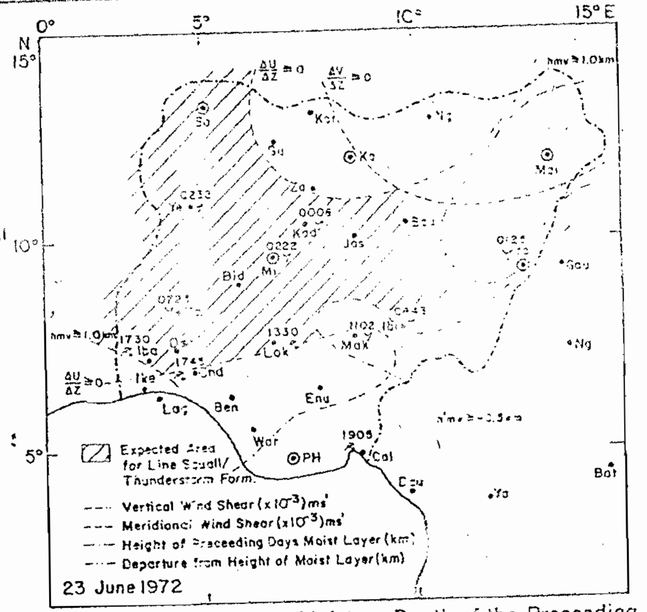

Fig. 24b Wind Shears, Moisture Depth of the Preceeding Day and Their Departures vs. Line Squall/ Thunderstorm

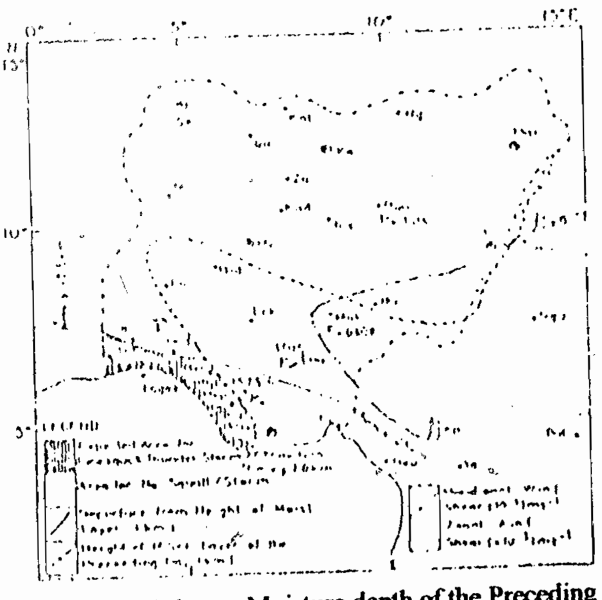

Fig 25b Wind sheers, Moisture depth of the Preceding Day and Their departures Vs line Squad / thunder Storm for the 25th.

Interactive Roles of the Flow Parameters/Dynamic Processes on Convective Systems

It is clear from the results so far presented that the individual flow parameters and processes do not have the same degree of control on line squall/thunderstorm development. Convective activities were found to have better correlation with the spatial distributions of vertical wind shears, the height of the anomalies of the surface equivalent potential temperature and specific humidity. Hence the mapping of those parameters having high correlation and those having minimal correlation were considered separately to enable as assessment of their complimentary roles and degrees of control over deep convective development. Mappings of the parameters/processes for the previous days (i.e the days preceding the ones used as case studies) are also presented to give a clearer view and better understanding of the conditions of the days under investigation.

Mappings Of The Spatial Distribution And Vertical Wind Shears, Height Of The Moist Layer And Its Variability Versus Linesquall/Thunderstorm Occurrences (Figure 17 – 25)

If the spatial distribution of the vertical wind shears, Height of the moist layer and its viability were the only parameters controlling development of deep convective, it would be expected that convective activities would occur in zone of common interplay for these parameters. Thus from synoptic and dynamic view points, the hatched regions in the figures represent the areas where the interplay of these parameters, should satisfy convective development. In such areas, scattered deep convection as well as line squalls are expected to occur while suppression of convection should prevail in the unhatched regions. It is obvious from the figures for the mappings of ($\underline{\Delta U}$ / ΔZ), ($\underline{\Delta V}$ ΔZ), h_{mv} and h'_{mv} versus line squall/thunderstorm, for the days under study (Figures 17a – 25a) and the preceding days (Figures 17b – 25b) that most storm/squall occurrences fall within the hatched regions on most of the days. However, the mappings are deficient on some days. This is to be expected since the parameters mapped out here are only a part of a very large and basic flow properties and dynamic processes listed in the introduction.

There appears to be almost perfect correlation between wind shears/depth of moist layer and line squall/thunderstorm development on the 6th, 11th, 22nd and 23rd (Figure 17, 18, 22, 23 and 24). Although on the 11th the observed storm activity was not wide spread enough to cover the expected (hatched) area (of the preceding days mapping), being limited to the South of 10N, however, the situation improved for the mapping of he day of the storm squall occurrence (Figure 18a and b.). The 19th was an interesting case. There was no common ground between any of the mapped paramete3rs (wind shears and moisture depths) and no deep convective activity was observed also (Figure 22). The consistency between most of the figures is noteworthy. Only isolated thunderstorms or non at all occurred on any day or any area where no common sector is found between the basic flow parameters. The 13th (Figures 19 and 21) were exceptions and this may be due to other important factors (e.g. static stability $\partial\theta / \partial z$ which are not considered in the present

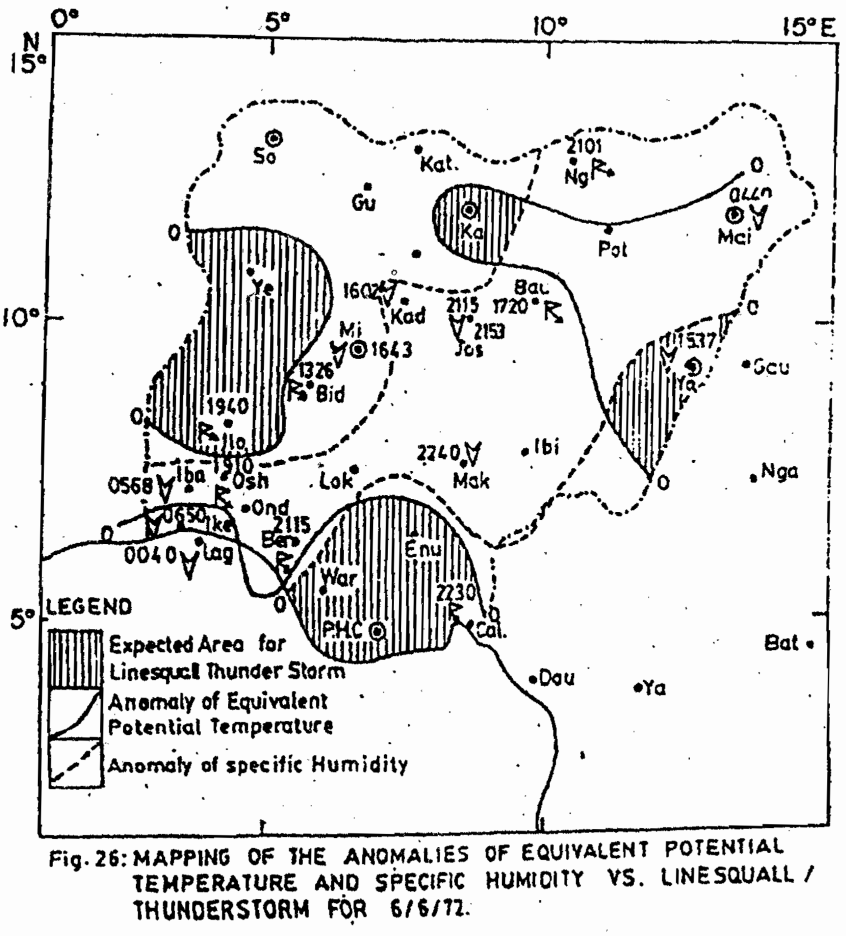

Fig. 26: MAPPING OF THE ANOMALIES OF EQUIVALENT POTENTIAL TEMPERATURE AND SPECIFIC HUMIDITY VS. LINESQUALL / THUNDERSTORM FOR 6/6/72.

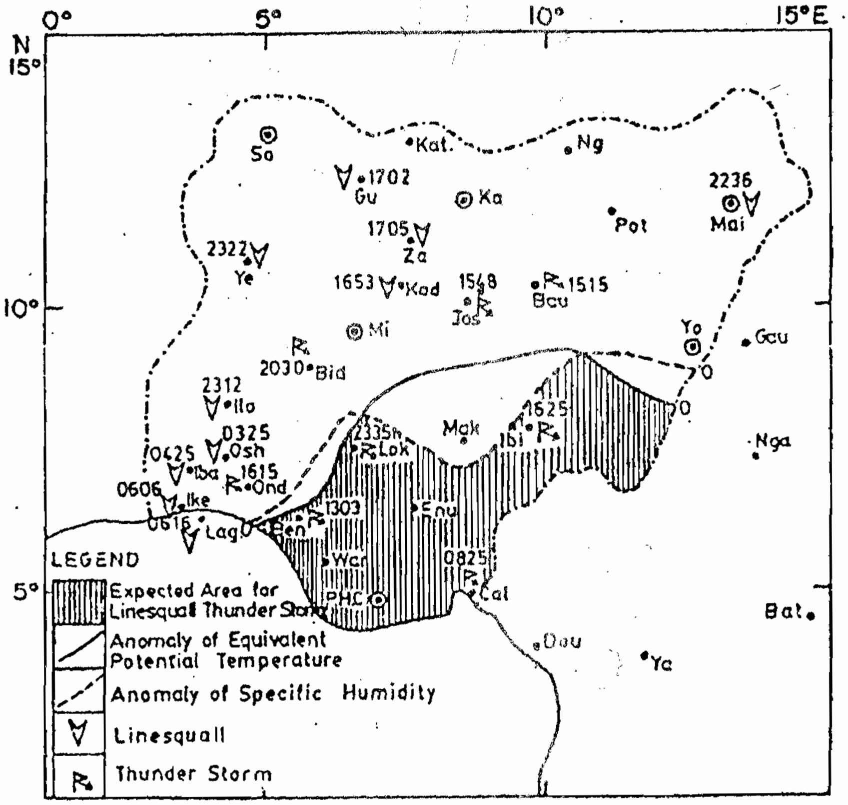

Fig. 27: MAPPING OF ANOMALIES OF EQUIVALENT POTENTIAL TEMPERATURE AND SPECIFIC HUMIDITY VS. LINESQUALL/THUNDERSTORM FOR 16/6/7

work. This may also explain the situation on the 14th (Figure 20). It was noticed that on the 24th (Figure 25), only a small portion of the coastal region should be expected to be convectively active. This was mostly consistent although a few isolated thunderstorms occurred inland.

Since the degree and extent of correlation vary, it is therefore expected that convective development will also depend on the nature of the interplay between the parameters mapped out to obtain the above results and other parameters and processes not considered in this work. Hence a consideration of the roles of some of these other parameters and processes would be necessary for a better or complete understanding.

Mapping of Anomalies of Equivalent Potential Temperature and Specific Humidity Versus Line Squall/Thunderstorm Occurrence

Unlike the boundary layer wind shears and height of the moist layer, no consistency was observed between line squall/thunderstorm and $\theta^{1}{}_{e}$ and q^{1}. This was true for all the days investigated. Hence only two of such days are again presented for completeness (Figure 26-27). The hatched areas again represent the expected squall/storm areas. The reason for this inconsistency may be two fold. Firstly, better correlation may be obtained if $\theta^{1}{}_{e}$ and q^{1} are computed and mapped at specific synoptic hour (say 1200 or 1400 GMT) on each day. Secondly, only the shear factor of the Richardson's number mentioned earlier have been investigated.

CONCLUSION

In this study, some mean flow parameters and dynamic processes were investigated. These are: the low-level and the 700mb (AEJ) winds; vertical shears of the zonal and meridional winds; height of the moist layer and their anomalies of the equivalent potential temperature and relative humidity. It was discovered that there was good correlation between widespread thunderstorm and or organized line squall (convective systems) and well defined AEJ, low-level zonal and meridional wind shears and the height of the moist layer and their anomalies than with anomalies of equivalent potential temperature and specific humidity and low-level winds for all the days investigated. In particular, high concentration of storms and squalls were found around the left entrances and right exits of the AEJ. Also, low-level zonal and meridional wind shears were found to be most consistent with line squall/thunderstorm occurrences for most of the days studied. Positive (Westerly) shears were accompanied by wide spread and/or organized deep convection while negative (Easterly) shears were associated with suppressed conditions. Few or no storms were observed over areas where the zonal shear is positive and the meridional shear is negative, nut storms did occur if he zonal shear was Easterly (negative). These suggest that there are varying degrees of control of the component wind shears on thunderstorm/line squall development.

The intensity and extent of convective activities are also affected by the height of the moist layer, the deepening of the moist layer in the preceding twenty-four hours and their departures from the mean. A reasonably deep layer of moisture of at least 1.s5km and departures of at least -0.5km favored wide spread deep convection. The results of the mapping suggest that out of the parameters investigated in this work, an interplay or interaction of the spatial distribution of the vertical shears of the zonal and meridional winds and the spatial and temporal variability of the height of the moist layer were most crucial to convective systems formation. Mappings of equivalent potential temperature and specific humidity versus line squall/thunderstorm show little or not correlation.

To obtain a compete understanding of the synoptic conditions necessary for convective development, we need a denser network of Radiosonde and pilot balloon over Nigeria and adjacent te4rritories which will aid further mapping of both the parameters and processes investigated in this work and those listed in the introduction which were not investigated. Nevertheless, what has been presented here can serve as a predictive model for the forecasting of line squall and thunder storm over Nigeria.

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