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On 'Isobaric divergences' in Nor'wester situations over Gangetic West Bengal and neighbourhood

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1. The importance of upper air thermal patterns in the inhibition and generation of pre-monsoon thunderstorms over Bengal has been brought out by Ramaswamy and Bose (1953 a, 1953 b). In one of these studies (1953a) stress was laid upon the grid formation between the thermal winds and actual winds (700-500 mb level), which showed advection of colder air aloft as well as a potential source of energy due to formation of solenoids. It was further noticed by the same authors that the thunderstorms tended to be a maximum in the area east of the thermal trough line where the thermal winds had a pronounced southerly component. The cold pool or trough being essentially an area of cyclonic vorticity, it was felt that although the advection of colder air was very important, the cyclonic vorticity had its own contribution in making the atmosphere more suitable for the generation of thunderstorms (Ramaswamy and Bose, 1954). The effect of thermal vorticity and its relations to the isobaric divergence between two isobaric levels has been discussed by Sutcliffe (1947). He has shown that an idea of the distribution of the thermodynamically significant term dp/dt* with height can be inferred from a knowledge of relative divergence term, which can be calculated with comparative ease with a suitable technique described by Sawyer and Matthewman (1951).

It is obvious that any perturbation from lower level (whatever be its cause) would be accelerated if it reaches a layer of convergence or more correctly in a region where dp/dt is negative. Similarly any perturbation from lower level would be damped if it reaches a layer where dp/dt is positive. A composite picture of the suitability of various layers about the receptivity of lower level perturbations, therefore, could be assessed if the distribution of the term dp/dt with height could be ascertained. This has been done in the present note by computing relative divergence term for some specific Nor'wester situations. As far as afternoon Nor'westers are concerned the simple type (Fig. 1) with low level convergence and upper divergence is not suitable since in that case Nor'wester should occur at any time of the day. The complex type described by Sutcliffe with a probable structure shown in Fig. 2, seems, however, to be a suitable model for the purpose. In this model, there are alternate layers of convergence and divergence with the consequence that the term dp/dt becomes positive through a certain depth (the depth being dependant on the distribution of divergence pattern in the atmosphere) at some intermediate level between 1000 and 500-mb surfaces. It follows, therefore, that the vertical perturbations from lower levels would completely be damped in this layer (shown as AA′ in Fig. 2) where dp/dt is positive, unless some other agency operates upon the lower level perturbations to enable them to break through the layer AA′. It is also apparent that once the perturbations

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*The "subsidence and "ascent" can easily be defined by the thermodynamically significant term dp/dt being positive or negative as the term dp/dt is defined directly by the integral of isobaric divergence of velocity above

$$dp/dt = -\int \text{div}_p V \, dp$$

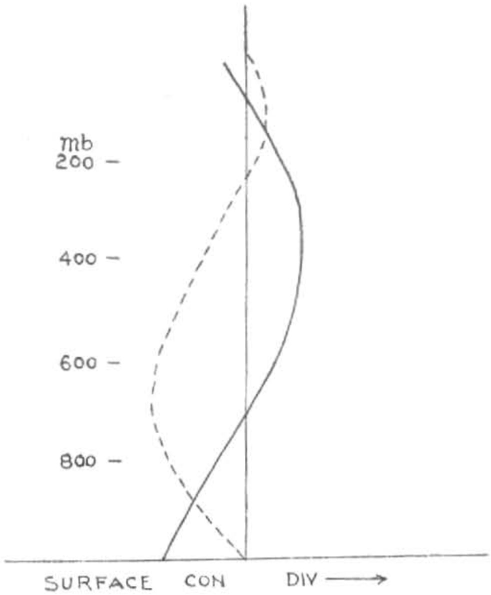


Fig. 1. Simple cyclogenetic type (after Sutcliffe)

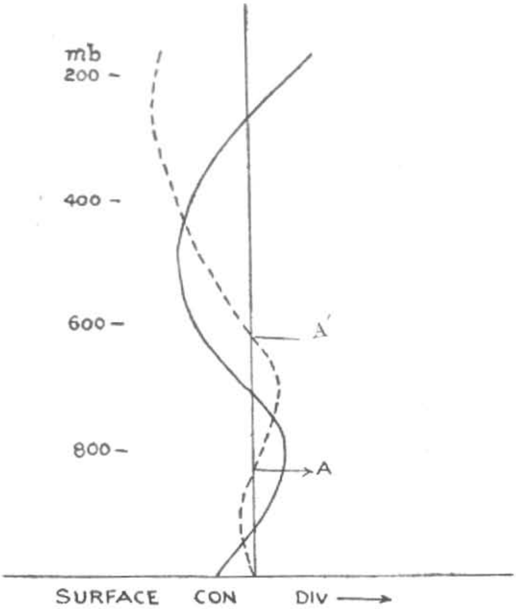


Fig. 2. Complex type

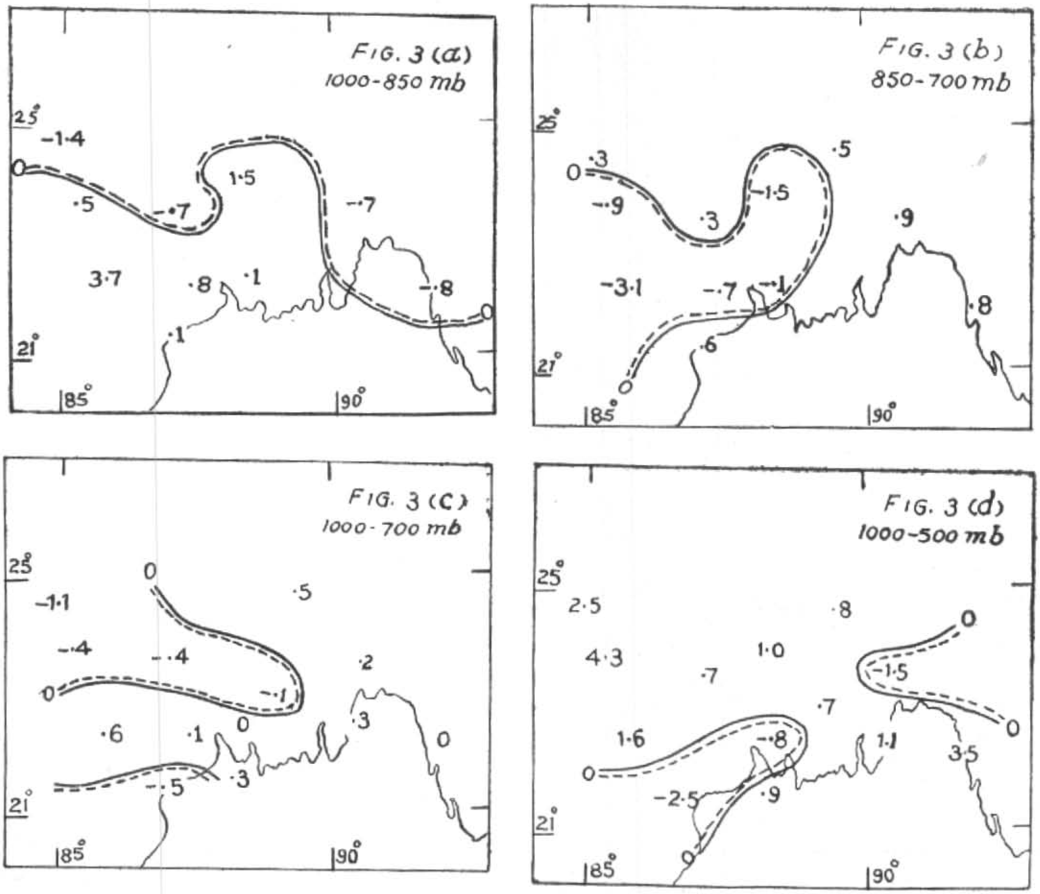
(Dashed curve shows variation of dp/dt with height; full line represents divergence as a function of pressure in a vertical column through atmosphere; AA′ (Fig. 2) shows the portion in the lower troposphere where dp/dt is positive)

are able to break through this layer AA′, the cloud growth would be very rapid and reach enormous heights due to favourable environment (please see dp/dt curve of Fig. 2). Thus the presence of divergence in lower layers is requiring the aid of insolation to overcome this lower divergence and to reach the convergent layers aloft where perturbations grow. Incidentally this brings out the role of intermediate layers in the formation of Nor'westers. If the layer AA′ be too thick, inspite of lower level and upper level conditions being favourable nothing would occur, but on the contrary with thin layer AA′ Nor'westers will break out with less favourable lower layer conditions.* It may be noted in passing that the favourable upper level structure is an absolute necessity for the development of Nor'wester clouds to great heights though the lower layers play a significantly important role.

It may be pointed out that as we are dealing with a complex structure no significant result can be expected by computing "relative divergence" between usual two levels, *i.e.*, between 1000 and 500-mb surfaces though in a majority of cases, as the convergence in upper layers seems to play a dominant role, we may find the relative divergence to be negative between these two layers.

In order to map out reliably the variation of dp/dt with height, one must, therefore, work out relative divergence for thin slices of atmosphere. Some useful results, however, can also be inferred by computing relative divergence between three or even two layers. In fact these computations have been done for three layers (1000-850, 850-700 and 700-500-mb surfaces) only on two days and on other four cases, computations have been carried out for 1000-700 and 700-500 mb surfaces. As this study is entirely of a preliminary nature, computations have been carried out only over Gangetic West Bengal and adjoining areas, and corrections for map-projection, g and for the variation of coriolis

*High level thunderstorms in contradistinction to the thunderstorms with low base as is usually observed, can however take place with this complex structure even with a lower level divergence provided moisture in layers above AA′ is adequate for the formation of clouds



Figs. 3(a) to 3(d). 14 April 1952

parameter have not been taken into account.

2. Discussion of cases

Case 1—14 April 1952

Occurrence of Nor'westers with comparatively unfavourable synoptic situation

Relative divergence between 1000-850, 850-700, 1000-700, 1000-500 and 700-500 mb surfaces are shown in Figs. 3(a) to 3(e). It will be seen that the relative divergence is mostly positive between 1000-850 mb level over the region of thunderstorms over Gangetic West Bengal and adjoining districts of Orissa, whereas it is negative in the layers 850-700, 1000-500 and 700-500 mb sufraces. A probable structure of the vertical distribution of dp/dt with height and the divergence pattern over Calcutta is shown in Fig. 3(g). Though there is no computational evidence for extending dp/dt curve above 500 mb level—this has been done on the assumption that the divergence above 500-mb level should suitably adjust itself so as to compensate lower level convergence. It should, however, be emphasised that the figure is only qualitative and is, primarily, meant to depict the nature of dp/dt curve with height. Fig. 3(f), shows the difference between the relative divergence between 700-500 and 1000-700 mb surfaces. These values are mainly negative over the region of occurrence of thunderstorms.

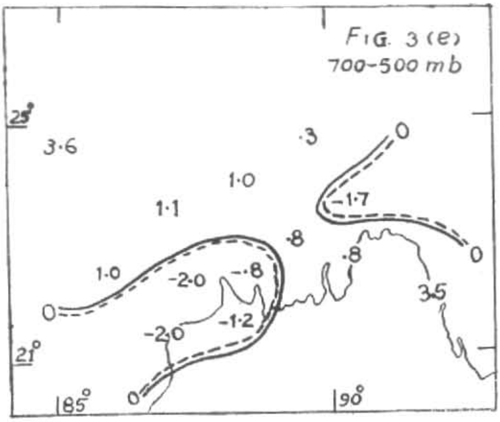


Fig. 3(e). 14 April 1952

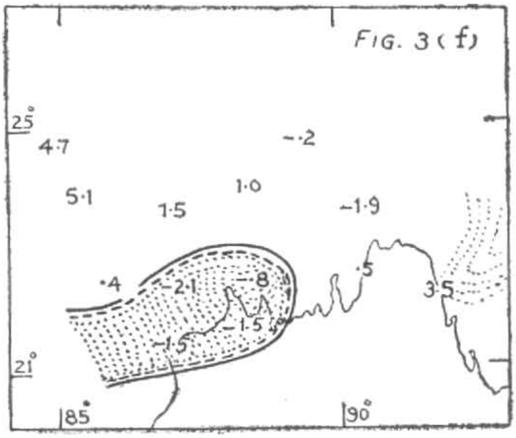


Fig. 3(f). 14 April 1952

(The dotted areas show the areas of thunderstorms)

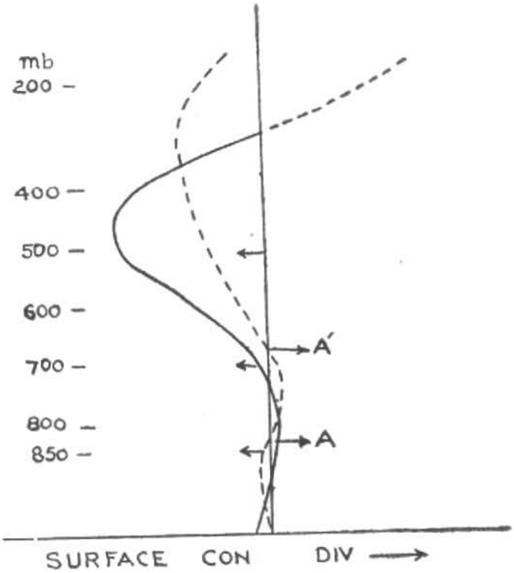
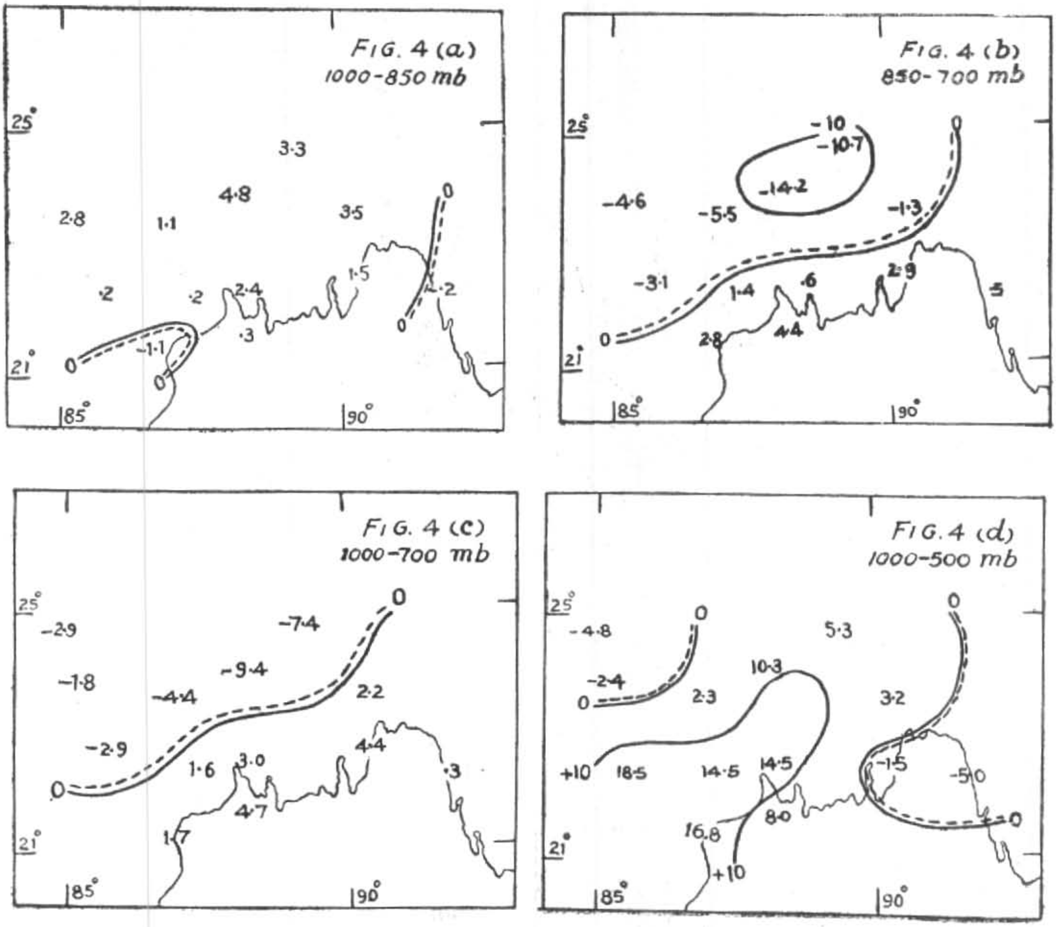


Fig. 3(g). A probable structure of variation of divergence (full line) and distribution of dp/dt (dashed curve) on 14-4-1952 in the neighbourhood of Calcutta



Figs. 4(a) to 4(d). 23 April 1952

Case II—23 April 1952

Non-occurrence of Nor'wester with comparatively favourable synoptic situation

The relative divergence between different isobaric levels are shown in Figs. 4(a) to 4(e). The most interesting feature is shown on 700-500 and 1000-500 mb surfaces. The relative divergence values on these charts show pronounced positive values over the region of non-development of thunderstorms. Fig. 4(f) shows the difference between the relative divergence terms between the 700-500 and 1000-700 mb surfaces. The values on this chart also show mostly positive values over the region of non-occurrence of thunderstorm. The marked dissimilarity between the charts on this day and those of Case 1 is quite interesting.

A probable distribution of dp/dt and divergence pattern with height on this day in the neighbourhood of Calcutta is shown in Fig. 4(g).

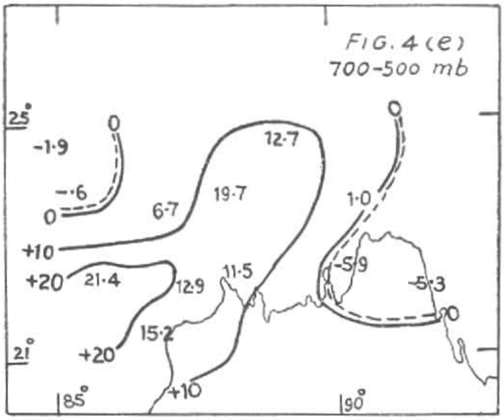


Fig. 4 (e). 23 April 1952

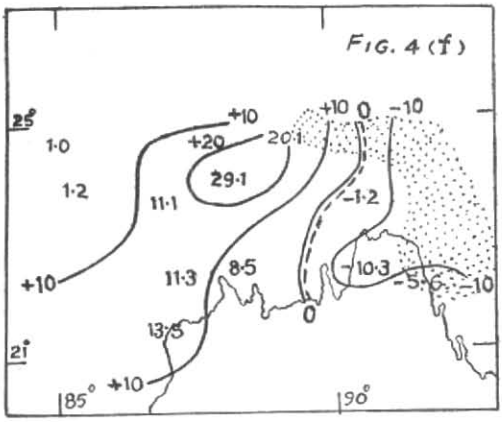


Fig. 4 (f). 23 April 1952

(The dotted area shows the area of thunderstorm)

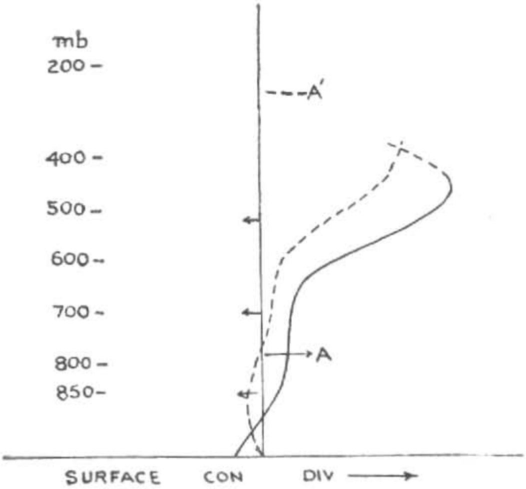


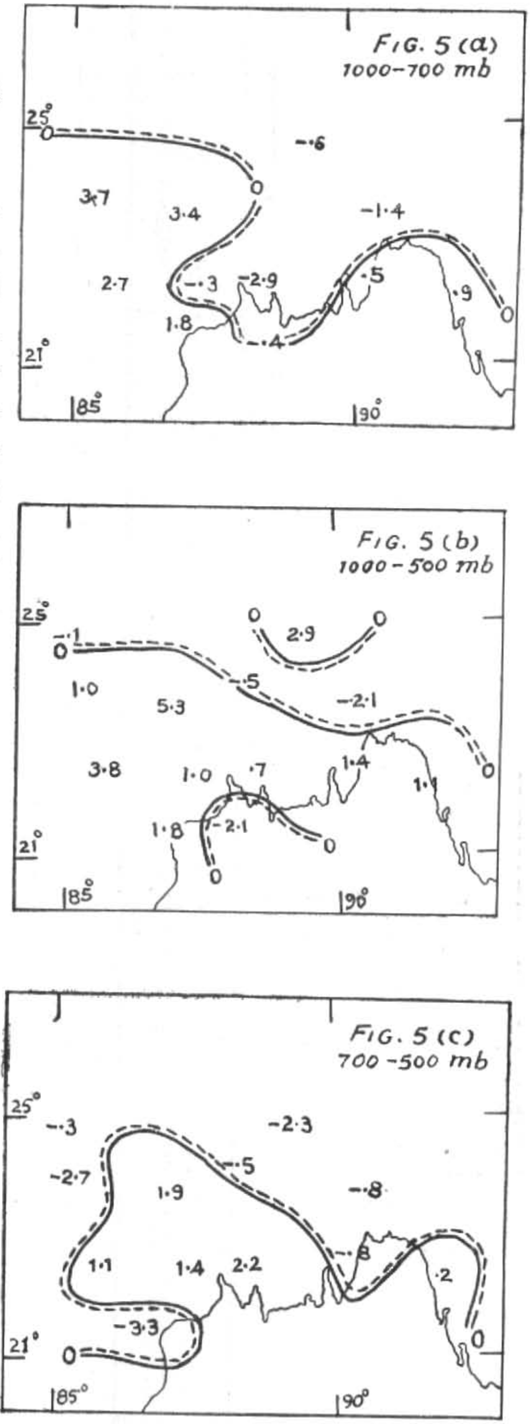
Fig. 4(g). A probable structure of variation of divergence (full line) and distribution of dp/dt (dashed curve) on 23-4-1952 in the neighbourhood of Calcutta

Case III—18 to 21 April 1952

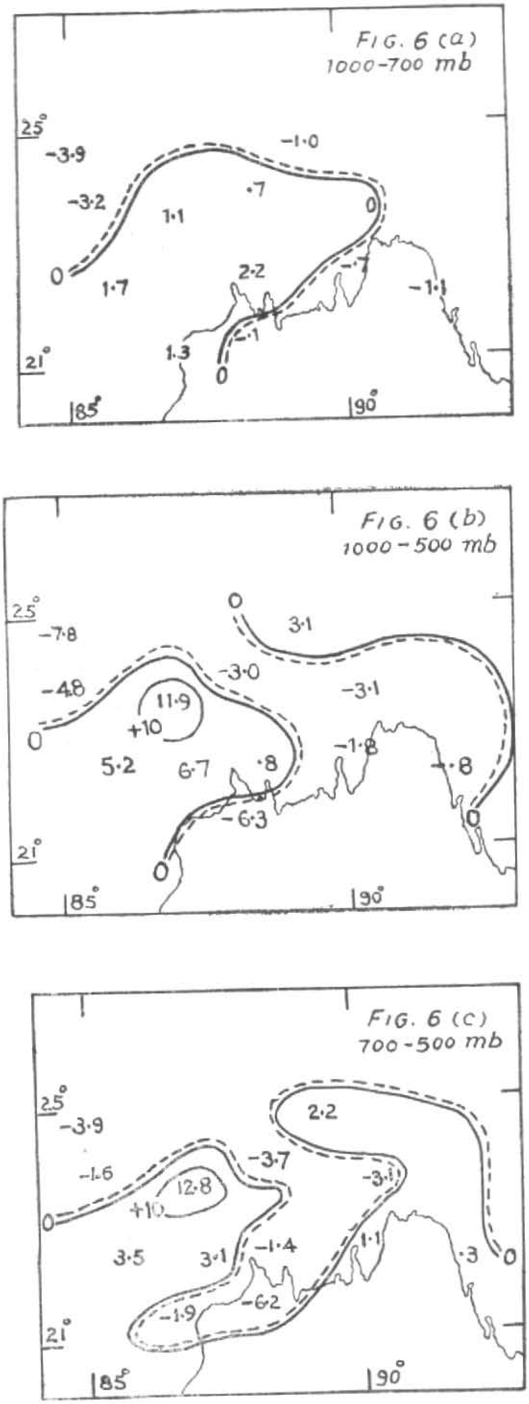
Normal cases, occurrence of Nor'westers with usual synoptic situations

In these cases the relative divergence patterns between 1000-700, 1000-500 and 700-500 mb surfaces on 18, 19, 20 and 21 April 1952 have been shown in Figs. 5(a) to 5(c), 6(a) to 6(c), 7(a) to 7(c) and 8(a) to 8(c) respectively. It will be seen from the above diagrams, that the relative divergence patterns between 1000-500 mb surfaces do not show much agreement between the region of thunderstorms and the distribution of relative divergence terms. The distribution of values of relative divergence, however, shows a better correlation between the region of thunderstorms and areas of negative relative divergence terms [cf. Figs. 5(c) and 6(c) with 9(a) and 9(b)]. The difference between the relative divergence terms between 700-500 and 1000-700 mb surfaces shows a remarkable consistency. On all these days thunderstorm areas, more or less, within the limits of computational approximations, coincide with the areas where the difference of values of the relative divergence terms between the above mentioned surfaces are negative—Figs. 9(a) to 9(d).

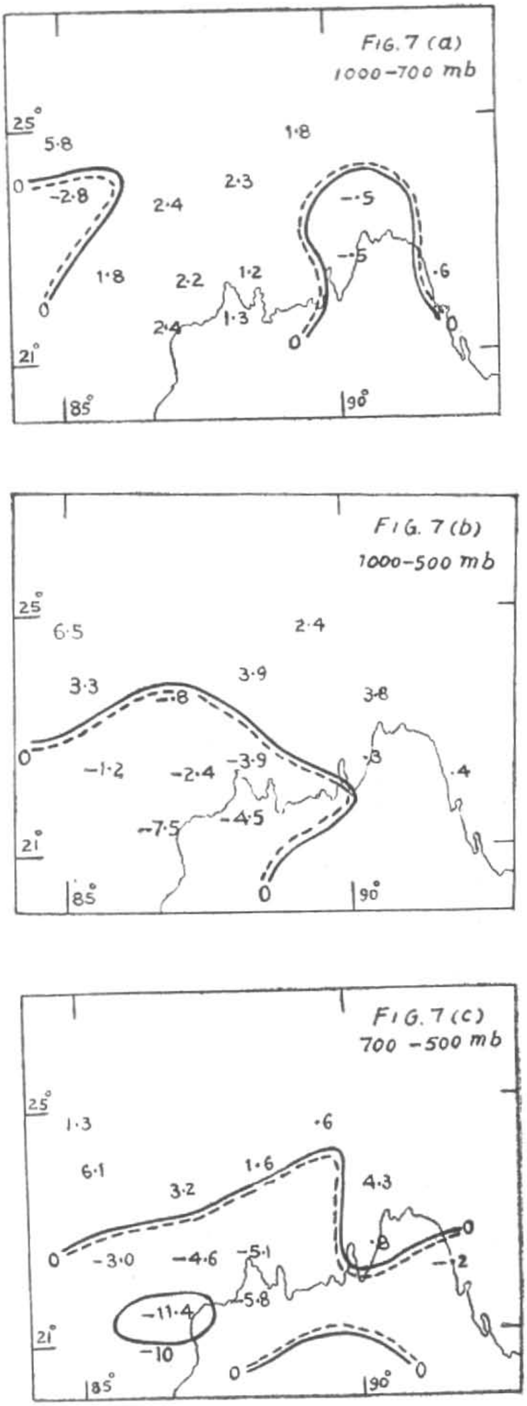
In all these figures the unit of relative divergence term has been expressed in un its of 10^{-2} hr^{-2}. The areas of thunderstorms have been shown only on charts which show the difference between 700-500 and 1000-700 mb surfaces, by stipled areas.



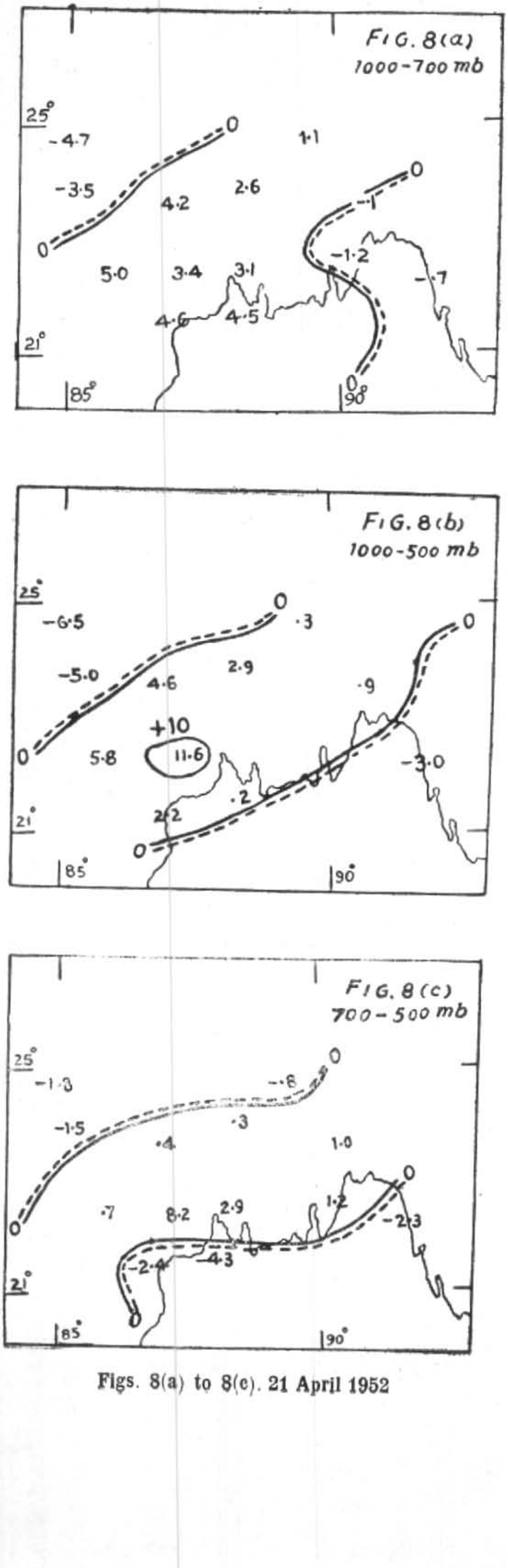
Figs. 5(a) to 5(c). 18 April 1952



Figs. 6(a) to 6(c). 19 April 1952



Figs. 7(a) to 7(c). 20 April 1952



Figs. 8(a) to 8(c). 21 April 1952

3. Summary of results

The limited number of days studied herein, though do not allow any broad generalisation to be made, some tentative conclusions can, however, be attempted on the basis of the above study.

(a) During the Nor'wester season, the thermal structure is usually complex over the Gangetic West Bengal and neighbourhood.

(b) Because of the complexity of the thermal structure an indication of the weather developments cannot always be inferred from the surface charts alone (inclusive of pressure tendencies).

(c) The middle layers of the lower troposphere also play an important role in the generation or inhibition of Nor'westers.

(d) Upper level convergence which in some cases may even be greater than the surface convergence, seems to play a dominant role in the growth of Nor'wester clouds to great heights.

(e) On days of Nor'wester developments the surface convergence seems at first to decrease with height, becomes negative at some intermediate level and then again increases with height upto about 500-mb level.

(f) There is a tendency for thunderstorms to occur, in this season, over the region where the mean divergence between the uppermost and lowermost layers of 1000 to 500-mb layer, is less than the divergence at intermediate, *i.e.*, 700-mb layer.

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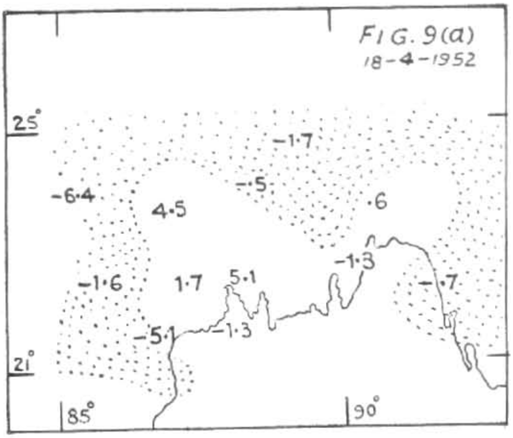

Fig. 9(a)

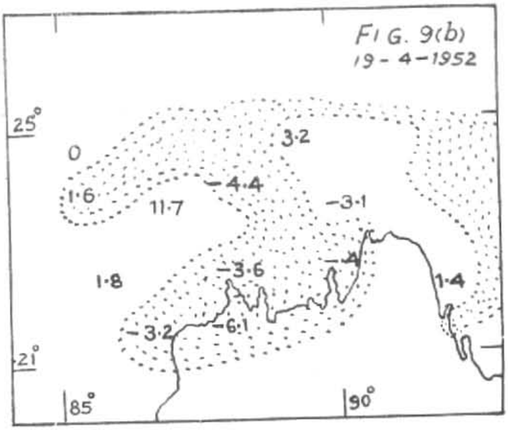

Fig. 9 (b)

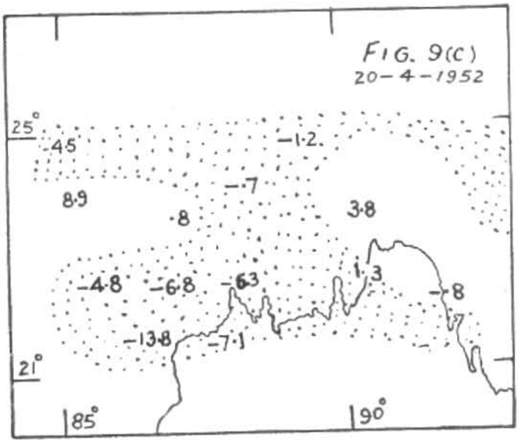

Fig. 9 (c)

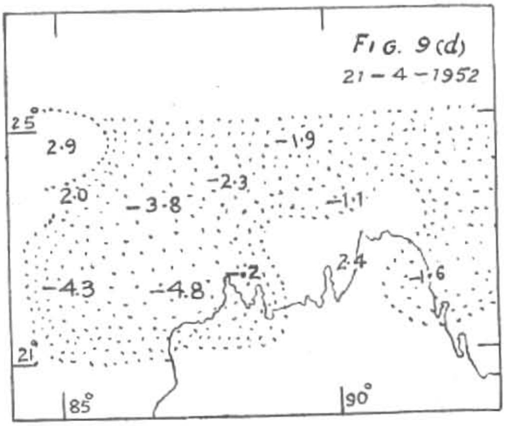

Fig. 9 (d)

(The dotted areas show the areas of thunderstorms)

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