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FORECASTING OF THUNDERSTORMS AT NAGPUR BY SLICE METHOD

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ABSTRACT. With a view to compare the results of analysis of Tephigrams based on the parcel method and the slice method, the Tephigrams of Nagpur for the months April 1947-June 1947 were examined. It was noticed that in general the slice method of analysis gave a better appreciation of the instability phenomena.

1. *Introduction.*

Thunderstorms constitute a very serious hazard to flying and it was thought advisable to examine whether this instability phenomena could be forecasted any better by the slice method (of the analysis of Tephigrams) than the parcel method. Scientifically the slice method originally suggested by Bjerkenes[1] and later developed by Petterssen[2] is more sound than the parcel method, but it was difficult to employ the slice method to our purposes.

Beers[3] suggested a practical way of doing so. The basic principle of analysis by the slice method consists in determining the effect of impulses from below which are transmitted through the atmosphere somewhat like a shock wave to layers above. This is done by finding the stability of various layers (slices) of atmosphere above the convective condensation Level (CCL) and integrating the effect for all layers, using circulation acceleration $\dot{C}$ as the quantitative measure of the stability of a stratum. Circulation acceleration is defined as

$$\dot{C} = \phi \frac{dp}{\rho} = - R \phi \frac{Tdp}{p} \text{ .... } (1)$$

neglecting the frictional forces and the term $2 \omega \frac{dF}{dt}$ where F is the projection of the path on the equitorial plane and ρ, p, T have their usual meanings.

The effect of an impulse or perturbation is to produce areas of ascending and descending masses of air in a horizontal region. Confining attention on a horizontal area which contains one unit of ascending and one unit of descending motion and assuming that in any such stratum average horizontal divergence is zero, we have :

$$M'V' + MV = 0 \text{ .... } (2)$$

Where M' and M represent the ascending and descending masses of air and V' and V are the corresponding velocities.

Assuming further that the condition of the atmosphere prior to being perturbed was barotropic and the motion is adiabatic above surface layer Beers has shown :

$$\dot{C}/K = (\gamma/\gamma_a - 1)\,(1 + M'/M) \text{ .... for dry ascent and descent .... } (3)$$

$\dot{C}/K = \left(\frac{\gamma - \gamma_m}{\gamma_d}\right)(1+M'/M)$........for wet ascent and wet descent.................(4)

$\dot{C}/K = \gamma/\gamma_d\,(1+ M'/M) - (\gamma_m/\gamma_d + M'/M)$.........for wet ascent and dry descent (5)

Where $K = R\,log\,\frac{p_o}{p_1}\gamma_d\,v'\Delta t$ and γ, γ_m and γ_d have their usual meanings.

It has been further shown by Beers that if $\dot{C}$ is negative for a layer (where p_o, p_1 are the pressures of the bottom and top of the layer perturbed and Δt is a small interval of time) the effect of the perturbation is an oscillation of simple harmonic type above the original position and hence stratification is stable one. On the other hand where $\dot{C}$ is positive, the perturbing velocities are increased with time, or in other words the stratification is an unstable one.

Thus while layers having negative value of $\dot{C}$ are uncongenial to large scale cumulus activity, reverse is the case for layers with positive value of $\dot{C}$. It is also evident that the value of $\dot{C}$ is dependent upon the values of M'/M and K or more precisely, on the linear thickness of the stratum. It has been found by experience that the value of $\dot{C}$ obtained by taking M'/M as 0·2 or 0·3 in middle latitudes gives the best results.

2. *Procedure adopted for the determination of* $\dot{C}$.

As the cumulus activity starts at the CCL, $\dot{C}$ is calculated for all layers above CCL to 500 mbs. The CCL is obtained by finding out the level where the isohygric corresponding to average humidity mixing ratio of the first three significant levels after the addition of another two grams to allow for the diurnal changes, intersects the sounding. The sounding is then divided into layers and are labelled wet, dry or intermediate, as defined later. These layers are further sub-divided into layers of similar lapse rates. The value of $\dot{C}$ is then determined for the various layers in the following way.

(*a*) *Wet layers* (*humidity 60% or above*).

The values of γ/γ_d and $\gamma_m\ \gamma_d$ are obtained for each of the three layers by marking off the temperature change along the sounding δT, dry adiabat δT_d and wet adiabat δT_m from whence one gets $\gamma_m/\gamma_d = \frac{\delta T_m}{\delta T_d}$ and $\gamma/\gamma_d = \frac{\delta T}{\delta T_d}$.

O·2 is selected as the value of M'/M and $\dot{C}/K$ is calculated. The linear distance between isobars bounding the layer is then measured against the linear scale for temperature at the base of a pseudoadiabatic diagram as so many degrees centigrade thick. The value of $\dot{C}/K$ previously obtained, multiplied by this factor gives the measure of stability of the layer or $\dot{C}$ in arbitrary units.

(*b*) *Dry layers* (*humidity 40% or less*).

γ/γ_d is first determined as above and using the same value of M'/M as for wet layers, $\dot{C}/K$ is calculated by simple multiplication using equation (3). This when multiplied by the thickness of the layer (so many degrees centigrade thick) gives the circulation acceleration $\dot{C}$ for dry layers.

(*c*) *Intermediate layers* (*humidity between 40 and 60%*).

For these layers the value of $\dot{C}$ is calculated by treating the layers separately as wet and dry and then mean of the two values of $\dot{C}$ is taken to be the value of $\dot{C}$ in arbitrary units.

The value of $\dot{C}$ is then summed up algebraically for all layers, and this gives the integrated measure of the stability of the atmosphere.

3. *Application of the above to the soundings of Nagpur.*

For this purpose the soundings of April, May and June 1947 were chosen. As is known during these months, insolation is the main factor for initiating the perturbation near the surface level.

The first thing that was considered was whether the insolation would be sufficient to raise the surface layers to the CCL obtained by the intersection of the isohygric for the surface layer with that of the sounding. A few simplifications could be made in the calculations of $\dot{C}$.

$$K = R \log p_0/p_1 \cdot \gamma_a v' \Delta t$$

$$= \frac{gz}{T_m} \cdot \gamma_a v \Delta$$

where T_m is the mean temperature of the layer between p_0 and p_1. Substituting for k in equations (3) and (5)

$$\dot{C} = \frac{gz}{T_m} \gamma_d v' \Delta t\, (\gamma/\gamma_a - 1)\ (1 + M'/M) \text{ for dry ascent and descent} \quad \ldots\ldots (6)$$

$$\dot{C} = \frac{gz}{T_m} \gamma_d v\ \Delta t\ \{\gamma/\gamma_d\ \ (1 + M^1/M) - (\gamma_m/\gamma_d + M'/M)\} \text{ for wet ascent and dry descent} \quad \ldots\ldots (7)$$

$$\gamma_d z = \delta T_d\,;\ \gamma z = \delta T \text{ and } \gamma_m z = \delta T_m.$$

We may neglect variations in Tm from layer to layer to a high degree of approximation since the main variation in $\dot{C}$ will be due to variation of δT, whence we get:—

$$\dot{C} = \delta T(1 + M'/M) - (\delta T_m + M'/M\ \delta T_d) \text{ for wet ascent and dry descent} \ldots\ldots (8)$$

$$\dot{C} = (\delta T - \delta T_d)\,(1 + M'/M) \text{ for dry ascent and dry descent} \ldots\ldots (9)$$

This simplifies the calculation of $\dot{C}$.

4. *Calculation of* $\dot{C}$.

Plot the upper winds of the hour nearest to the time of radiosonde ascent on the sounding. Then divide the sounding into layers of three categories having humidities greater than 60% (called wet) less than 40% (called dry) and between 40—60% (called intermediate), subdividing each of them further into layers of similar lapse rates. Where the humidity values have not been reported, the upper winds plotted on the sounding may be of help in assessing approximately the category of humidity those layers may belong to.

5. *Finding of mean CCL.*

For example the Tephigram of 14th June 1947 (Fig. 3) is taken. The mixing ratios of the three significant lower layers is 22 *g/Kgm* for 970 mb, 14.3 *g/Kgm* for 900 mb and 14·3 *g/Kgm* for 850 mb. The mean mixing ratio is $\frac{22+14{\cdot}3+14{\cdot}3+2}{3} \doteqdot$ 17·4 and hence the mean CCL is 755 mb. The layers between 755 to 570 mb. are wet and later dry. Lapse rate changes at 700 mb, 600 mb, 570 mb and 350 mb. To find δT_d for the layer 755—700 mb place a scale across the sounding parallel to the potential temperature lines in such a way that the areas of the two triangles bounded by the sounding and the base of the scale on the two sides of each and the isobars 755 and 700mb. on the third, are equal. Then measure the distance between the two isobars 755—700 mb. by a divider (as so many degrees centigrade) at the base of the Tephigram, correct to first decimal place. δT is the actual difference in temperature of the two levels, measured in degrees centigrade. δT_m is measured like δT_d, here of course measuring the horizontal distance between the points of the intersection of the top and bottom isobars with the mean wet adiabat.

Then applying the equation (8) or (9) according as the layer is wet or dry, $\dot{C}$ is evaluated for each layer. 0·2 is the value of M′/M used.

6. Summary of the analysis.

In all the calculations the value of M′/M has been taken as 0·2 throughout. The results of analysis by both the methods are given in table A. Only those cases have been entered there in which the analysis of the sounding by parcel method indicated a possibility of thunderstorm.

Leaving aside the days on which thunderstorm was actually occuring when the ascent was taken, it would be seen, that thunderstorms occurred on other five days. From Table A it may be noted that :

(1) except the thunderstorm on 9-6-1947 which could not be forecasted from the radiosonde data of 8-6-1947 on the basis of the slice method, the probability of thunderstorm was shown by the slice method on the other four occassions. Even the thunderstorm on 9-6-1947 could have been visualised by taking account of the possible changes in the structure of the atmosphere due to penetration of monsoon current at higher levels ;

(2) no thunderstorm occurred on the days when $\dot{C}$ was either negative or less than $+1{\cdot}3$, even though the parcel method indicated the possibility of a thunderstorm.

It was also seen that thunderstorm was actually occuring over the station, when a large positive value of $\Sigma\dot{C}$ of the order of $+3{\cdot}0$ or more was obtained.

To be able to interpret correctly the result of analysis of Tephigram by slice method it is very necessary to bear in mind, the time factor and the possible changes in the synoptic situation that may take place, particularly so in India as the soundings are made at 1900 hrs. I. S. T. *i.e.* 20 hours before the time they are to be made use of. Another great handicap is there in making a correct evaluation of humidity upto 500 mbs. above the freezing level as the wet bulb freezes.

The following facts are an useful guide in the slice method of analysis.

(1) The time factor may be considered qualitatively. Thus perturbations persisting for several hours in layers where $\dot{C}$ is positive will result in velocities large enough to penetrate the stabler layers above.

(2) The magnitude of the initial perturbations may be considered qualitatively. Thus impulses from a thick turbulent surface layer in which the wind is strong will be greater than if light winds were present in a thin surface layer.

(3) When $\dot{C}$ is positive for all layers separately, the instability will certainly result in thunderstorms, cumulonimbus and hail.

(4) When $\dot{C}$ is negative for all layers separately, the stability present will prevent any cumulus formation.

(5) When $\dot{C}$ summed over all layers is positive and greater than a critical value cumulus activity is certain.

7. *Detailed discussion of some interesting cases.*

(*i*) *8th June, 1947 at 1900 hrs. I.S.T.* (*vide Fig. 1*).

Humidity values were not obtainable above 600 mb. The Upper air analysis showed that the layers above 15,000 ft. (nearly 600 mb) were dry, since the wind at 15,000 ft. was from 70° which formed a part of the dry northwesterly feed to the anticyclone over Central parts of India. The synoptic situation indicated that a depression was forming in the North Bay of Bengal and that monsoon was strengthening over the peninsula. The parcel method forecasted slight possibility of thunderstorm next evening. $\Sigma \dot{C}$ was —1·2 ; obviously no convective phenomena could be expected. The actual obtained on the evening of the 9th June, 1947 was 5/10 Sc, Cu (large) at 1600 hrs. developing to 7/10 Sc, Cu and Cb (base 3000′) at 1750 with thunder showers which continued intermittently till 0130 hrs. next morning. It may be pointed out that in view of the synoptic situation, if the effect of the penetration of the moist current to higher levels was taken into account for calculating $\dot{C}$ for higher layers, possibility of a thunderstorm could have been indicated.

(*ii*) *9th May, 1947 at 1900 hrs. I.S.T.* (*vide Fig. 2*).

A shallow low formed over the Chota Nagpur causing influx of the SEly, Tm drawn in the circulation in the lower layers upto 4000′ a.s.l. being overrun by the NWly Tc aloft. Maximum temperature next day was expected to reach 106°F and skies were expected to be lightly clouded with Ac mainly, on the morning of 10th May. No change of this pattern in the upper air was expected. Parcel method forecasted thunderstorm. To $\Sigma \dot{C}$ were contributed positive values from the mean CCL (730 mb) to 700 mb and 600—500 mb, and negative value for 700—600 mb, though $\Sigma \dot{C}$ was +1·4 *i.e.* above the critical value of $\Sigma \dot{C}$ which is +1·3. It may be noticed that the layer 700—600 mb. contributing —1·2 to $\Sigma \dot{C}$ would normally damp all convective phenomena unless of course the perturbation from lower levels are carried over the barrier by insolation for which a maximum temperature of 100°F was necessary. A perusal of the current weather diary revealed that the day was partly cloudy with 3/10 to 5/10 Ac. Maximum temperature of 10th was 108°F. ScCu 5/10 at 1330 hrs. developed to 5/10 Sc, Cb at 1700 hrs. and thundershowers started ; thunderstorm subsided within half an hour and rain within 45 minutes.

(*iii*) *14th June, 1947 at 1900 hrs. I.S.T.* (*vide Fig. 3*).

On this day monsoon currents, the Em had penetrated the upper air up to 13,000 ft. overrun by the dry NWly, Tc aloft. As there was no depression in the Bay, no change in the upper air structure was expected. The maximum temperature expected for the next day was 103°F, the surface layers needing a temperature of 100°F only for reaching the CCL. The sky was expected to be partly to lightly clouded with Cu, Ac clouds in the morning. An isothermal existed between 570-530 mb which was expected to be swept away by turbulent layers from below. Parcel method forecasted thunderstorm with certainty. $\Sigma \dot{C} = 0{\cdot}3$, the contribution to it being a large positive value from the adiabatic wet layer between 700-600 mb, and a similar large negative value from the isothermal layer 570-530 mb and even above upto 5.0 mb. Since a large negative value is obtained near and above the freezing level no thunderstorm can even be expected and in fact fair weather could be forecasted on the basis of the slice method of analysis. As the current weather diary revealed, weather was actually fine upto 1330 hrs after which 3-5/10 Cu with isolated patches of large Cu developed at 1800 hrs dissipating to 1/10 Ac at night. Maximum temperature was 104°F. No thunderstorm was reported even within 200 miles radius.

(*iv*) *16th June, 1947 at 1900 hrs. I.S.T.* (*vide Fig 4*).

Monsoon was strong in the upper air and it was causing rain on the western coast of India with skies 3/4th to overcast there. Parcel method showed beyond doubt that thunderstorm was a certainty, since actual instability was obtainable between the surface (960 mb) and 700 mb.

Slice method on the other hand proved beyond doubt that there can be no thunderstorm since $\Sigma\dot{C} = -0{\cdot}4$. Though a large positive value of $\dot{C}$ was contributed by layers between CCL and 560 mb, the value of $\dot{C}$ for the inversion layer between 560-500 mb was all that mattered most. The actual obtained from the synoptic chart showed skies generally less than 6/10 clouded with Sc, Cu with a few places clouded with 7/10th Sc, Cu without any thunderstorm report within 200 miles of Nagpur on the 16th June, 1947. There was no noticeable change in the synoptic situation or the weather on the 17th June, 1947 as well.

8. *Conclusion.*

In concluding it may be said that so far as the forecasting of heat thunderstorms of the inland stations is concerned, based on the analysis of Tephigram, slice method of analysis appears to be a more suitable method. Where the possible changes in the synoptic situation likely to change the structure of the atmosphere have been taken into consideration, the results obtained by the slice method of analysis of Tephigram were by far much better than those obtained by the parcel method. A further advantage gained in the slice method of analysis is that the magnitude of the value of $\dot{C}$ gives an idea of the intensity of the convective phenomena *e.g.* large positive values of $\dot{C}$ above the 0°C isotherm for a considerable height (say 5,000 ft.) can foretell thunderstorms of more than moderate intensity or even hail if the height be higher than 5,000 ft.. In any case Cb, thunderstorm and the allied convective phenomena can be forecasted with greater confidence by the slice method of the analysis of the Tephigram.

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REFERENCES:

1. Bjerkenes, J. *Quart Jour. Roy Met. Soc.*, LXV, 325-30, (1938).
2. Petterssen, S., *Geoph Pub.*, XII, 9, (1939).
3. Beers, N. R, *Handbook of Met*, (1941).

TABLE A

Comparison of the inferences based on the analysis of the Tephigram by the parcel method and the slice method with that of the weather realised.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hrs. (2) Within 24 hrs.
		APRIL 1947.	
4th	Real latent instability ground (970) to 630 mb: CCL 650 mb: Fz. level 600 mb: Max. temp. necessary 104°F, reached 107°F: layers adiabatic 970-640 mb: +ve areas greater than −ve areas considerably for layers upto 700 mb. Thunderstorm quite likely.	Mean CCL 660 mb: 660-600 mb Wet $\dot{C}$, +2·9: 600-560 mb wet $\dot{C}$, +0.1: 560-500 mb int. $\dot{C}$, -2·4: $\Sigma\dot{C} = +0·6$.	(1) Fine weather. (2) 4/10 Cu between 1300 and 1600 hours. No thunderstorm reported within 200 miles.
7th	Actual instability ground (970) to 670 mb: layer being super-adiabatic between 970-700 mb for which large +ve areas obtainable: CCL 780 mb: Fz. level 675 mb: Thunderstorm sure.	Mean CCL 775 mb: 775-700 mb wet $\dot{C}$, +7·6: 700-645 mb wet $\dot{C}$, +1·2: 645-600 mb Int. $\dot{C}$, −3·1: 600-500 mb dry $\dot{C}$, −7·3: $\Sigma\dot{C} = -1·6$ Note the large −ve values of $\dot{C}$ above 0°C isotherm	(1) Fine weather. (2) 4/10 Sc., Cu between 1230 and 1600 hours. No Cb reported within 200 miles on 7th and 8th.
27th	Actual instability ground (970) to 600 mb (θ ground =311°A & θ 600=305°A) layer being super-adiabatic: Layer 700-600 mb. humid 75-100%: $\gamma < \gamma_m$ between 600-500 mb but still +ve areas were quite large between 970-670 mb: Thunderstorm most likely.	Mean CCL. 725-600 mb: 725-600 mb wet $\dot{C}$+9·6: 600−570 mb wet $\dot{C}$, −2·0: 570-500 mb wet or Int. $\dot{C}$, −4·9 or −7·9 Upper wind chart shows layers dry above 600 mb. $\Sigma\dot{C} = -0·3$	(1) Fine weather. (2) Fine weather. No Cb reported within 200 miles on 27th and 28th.
		MAY 1947.	
9th	Actual instability ground (970) to 600mb with large +ve areas for layers 970−700 mb: Layers adiabatic 970−850 mb	Mean CCL. 730 mb: 730−700 wet $\dot{C}$, +2·2: 700−600 mb wet $\dot{C}$, -1·2: 600−500 mb wet $\dot{C}$, +0·4: $\Sigma\dot{C} = +1.4$	(1) 3/10 Sc base 7000 ft. (2) 3/10 Sc, Cu at 1930 hrs. developing to 6/10 Sc, Cb at 1630 hrs. with thunderstorm at 1702 hrs.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hrs. (2) Within 24 hrs.
	($\theta = 314°$A) and super-adiabatic 850 – 700 mb : θ 700 = 310°A. From 700 – 600 mb $\gamma = \gamma_m$ but humidity 95-100% : Fz. Level 590 mb. Thunderstorm most likely.	Notes : The layers 600--500 mb which are taken wet were so on the 10th afternoon only. Surface perturbations reached 600 mb due to isolation.	Thunderstorm stopped at 1730 hrs., but Cb continued till 0200 hrs. of 11th.
10th	Real latent instability between 970 – 600 mb : + ve areas in large excess of – ve areas between 970—850 mb a super-adiabatic between 850 – 600 mb : CCL. 770 mb : Fz. Level 650 mb : Max. temp. necessary 96°F reached 108°F. Layers 670 – 600 mb 70 – 90% humid : Thunderstorm sure.	Mean CCL. 720 mb : 720 – 600 mb. wet $\dot{C}$, +8·9. 600 – 500 mb wet Int. C+ 2·4 or-4·0 : $\Sigma \dot{C} = -4·9$. (This is a case where storm was actually occurring at the time of ascent).	(1) 3/10 Sc base 700 ft. (2) 3/10 Sc, Cu at 1330 hrs. developing to 6/10 Sc, Cb at 1630 hrs. with thunderstorm at 1702 hrs. Thunderstorm stopped at 1730 hrs., but Cb continued till 2hrs of 11th.
11th	About the time of max. temp. actual instability from 970 – 600 mb ; large + ve areas being obtained for surface layers upto 730mb. CCL 710 mb. Max. temp. necessary 103°F reached 106°F : Thunderstorm sure.	Mean CCL. 700 mb : 700 – 600 mb wet $\dot{C}$, + 6·6: 600 – 580 mb wet $\dot{C}$, +0·3 : 580 – 560 mb dry $\dot{C}$, – 3·1: 560 – 500 mb dry $\dot{C}$, – 5·6 : $\Sigma \dot{C} = -1·8$ (Note the large – ve value of $\dot{C}$ above 580 mb in 1500 ft. above 0° isotherm)	(1) Fine. (2) 3—5/10 Sc, Cu between 1200 and 1700 hrs. of 12th. No Cb reported within 200 miles.
17th	CCL 600 mb : Max. temp. necessary 112°F : max. temp. reached 112°F; Lower layers very dry : Layer of latent instability 970 – 480 mb : positive areas being slightly greater than negative areas for layer 970 – 700 mb : Fz. level 550 mb : Slight chance Thunderstorm.	Mean CCL 560 mb : 560 – 545 mb. wet $\dot{C}$, + 0·5 : 545 – 500 mb. Int. $\dot{C}$, 0 : $\Sigma \dot{C} = +0·5$. Last humidity reported nearly 60% for 600 mb. upper winds not available above 10000 ft. *i.e.* 700 mb.	(1) Fine Weather. (2) Fair at Nagpur. Thunderstorm occurred only about 100 miles from Nagpur.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hrs. (2) Within 24 hrs.
18th	Actual instability 970-640 mb : $\gamma > \gamma_d$ for 825-700 mb. and $\gamma = \gamma_d$ for 700-660 mb : positive areas considerably large for layers 970-660 mb : Fz. level 610 mb : Thunderstorm practically sure.	Mean CCL 660 mb : 660-600 mb. Int. $\dot{C}$, 0 : 600-500 mb. dry $\dot{C}$, $-5{\cdot}1$: $\Sigma\ \dot{C} = -5{\cdot}1$. Last humidity reported 60% for 700 mb : upper winds Nly above 10000 feet.	(1) 2-3/10 Cu, Sc. (2) 2-3/10 Sc, Cu. No thunderstorm occurred within 200 miles.
27th	Layer of real latent instability 970-600 mb : $\gamma = \gamma_d$ for 970-600 mb: γ slightly less than γ_d between 600-540 mb: and isothermal layer 540-500 mb : Humidity 70-100% between 660-540 mb : CCL 660 mb. Max. temp. necessary 102°F : Max. temp. reached 110°F. Fz. level 605 mb : Thunderstorm certain.	Mean CCL 660 mb : 660-600 mb. wet $\dot{C}$, $+3{\cdot}5$: 600-540 mb. wet $\dot{C}$, $+2{\cdot}0$: 540-500 mb. wet $\dot{C}$, $-5{\cdot}0$: 540-500 mb : Int. $\dot{C}$, $-6{\cdot}1$. Even if layers 540-500 mb. be taken wet $\Sigma\ \dot{C} = +0{\cdot}5$ otherwise $\Sigma\ \dot{C} = -0{\cdot}5$.	(1) 1-3/10 Sc for two hours. (2) Fine to fair weather. No thunderstorm was reported within 200 miles.
29th	Real latent instability 970-600 mb : CCL 700 mb : max. temp. necessary 103°F : max. temp. reached 109°F : positive areas considerably in excess of negative areas for surface layers : humidity 65-75% for layers 700-600 mb: Fz. level 590 mb: Fair chance of thunderstorm.	Mean CCL 610 mb. wet $\dot{C}$, 0·0 : 610-590 mb. wet $\dot{C}$, $+3{\cdot}1$: 590-500 mb. dry $\dot{C}$, $-3{\cdot}9$: $\Sigma\ \dot{C} = -0{\cdot}8$. Note large negative values of $\dot{C}$ above 0° isotherm.	(1) 7-8/10 Sc, Cb for two hours, later 5-7/10 Sc with slight precipitation. (2) 3-5/10 Sc for practically the whole day. No thunderstorm reported within 50 miles.
	JUNE 1947.		
1st	Actual latent instability 970-690mb: $\gamma = \gamma_d$ for 970-800 mb : and $\gamma > \gamma_d$ for 800-690 mb : though layers are quite dry except those	Except between 720-670 mb all layers dry. Mean CCL 680 mb. and above this no layer $\gamma > \gamma_d$.	(1) Fine. (2) 4/10 Cu between 1200 to 1700 hours. No thunderstorm within 200 miles.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hours. (2) Within 24 hours.
	between 700-650 mb which are 55% humid, the positive area for lower layers is sufficient to expect slight possibility of thunderstorm.	Hence $\Sigma\dot{C}$ is a large negative value.	
5th	Real latent instability 970-600 mb : Positive areas in large excess for layers 970-660 mb : CCL 710 mb: Max. temp. necessary 102°F Max. temp. reached 106°F. Fz. level 570 mb: Thunderstorm most likely.	Mean CCL 690 mb : 690-565 mb. wet. $\dot{C}$, +2 6 : 565-500 mb. dry $\dot{C}$, − 3·4 : 565-500 mb. wet $\dot{C}$, + 1·0 : Average $\dot{C}$ for 565-500 mb. − 1·2: $\Sigma\dot{C} = +1.4$ Note since C is -ve above freezing level even if $\Sigma\dot{C}$ is > + 1·3, even if thunderstorm occurs it should be very mild and short-lived.	(1) 5-6/10 Sc.Cu developing to Sc. Cb at 2300 hours becoming occasionally overcast till (800 hours. (2) 3/10 Sc, Cu at 1300 hours developed to 7/10 Sc, Cb at 1500 hours with thunderstorm 1530 to 1730 hrs. Cb becoming St at 2100 hours.
6th	Since the ascent was taken just after a thunderstorm, the sounding is not useful for forecasting.	...	...
7th	Real latent instability 965-565 mb: Layers 70-100 % humid from 750-570 mb : CCL 790 mb: Max. temp. necessary 102°F : Max. temp. reached 106°F : excessive positive areas for lower layers. Fz. level 610 mb. Thunderstorm sure.	Mean CCL 650 mb : 650-565 mb. wet $\dot{C}$, + 5 2 : 565-540 mb. wet $\dot{C}$, − 1·0 : 540-500 mb. wet $\dot{C}$, − 0·7 $\Sigma\dot{C} = +3{\cdot}2$.	(1) Thunderstorm was occuring even a few minutes before the ascent the skies being 5-7/10 covered with Sc, Cb occasionally overcast with Cb with occasional lightning and drizzle.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hrs. (2) Within 24 hrs.
8th	Layer of real latent instability 960-690 mb : CCL. 790 mb : max. temp. necessary 97°F : max, temp. reached 105°F : large excess of positive area over negative area for surface layers: Fz. level 580 mb : Thunderstorm quite likely.	Mean CCL. 750 mb : 750-700 mb. wet $\dot{C}$, +1·5 : 700-600 mb. wet $\dot{C}$, + 2·6 : 600-500 mb. dry/Int. $\dot{C}$, −5·3/−2·5. If the layer 600-500 mb. taken dry $\Sigma\dot{C}$ = −1·2 and if taken int. $\Sigma\dot{C}$ = +1·6. Since upper winds at 15000 ft. were 050° layer be taken dry and $\Sigma\dot{C}$ = −1·2.	(1) Skies nearly overcast with Ac, Sc clouds continuing all night and day till 1130 hrs. when low clouds dissipated. (2) 8/10 Sc, Cu developed again at 1230 hrs. becoming 7/10 Sc, Cb at 1600 hrs. and thunderstorm started at 1745 hrs. continuing till next ascent.
9th	Layer of real latent instability ground 960-660 mb : CCL 810 mb : Layers 820—600 mb 75-85% humid, Max. temp. necessary 94°F : Max. temp. reached 105°F : Very large positive area upto 730 mb. Thunderstorm sure. (Thunderstorm was actually taking place ½ hour before the ascent).	Mean CCL 800 mb : 800-700 mb wet $\dot{C}$, +4·6 : 700-600 mb wet $\dot{C}$, +3·2 : 600-500 Int./ $\dot{C}$, -6·2 wet -3·8. $\Sigma\dot{C}$ +4.0 or +1·6 According as 600—500 layer wet or less than 60% humid, upper winds indicate levels wet at least to 550 mb. $\therefore \Sigma\dot{C} = +4{\cdot}0$	Intermittent thunderstorms continued till 0300 hrs. when Cb clouds flattened into St. and Sc : widespread thundershowers occurred within 200 miles.
10th	Layer of real latent instability 960-700 mb: CCL 920 mb : Max. temp. necessary 89°F: Max. temp. reached 102°F : Layer 75%-100% humid upto 500 mb : Fz. level 580 mb : Thunderstorm definite. (Obviously the instrument was passing through clouds).	Mean CCL 820 mb : 820-700 mb : wet $\dot{C}$, +6·5 : 700-690 mb wet $\dot{C}$, +2·8 : 690-600 mb wet $\dot{C}$, -3·5 : 600-500 mb wet $\dot{C}$, −3 0 $\Sigma\dot{C}$ +2·8 (Note the large negative value of $\dot{C}$ above the freezing level. Even though $\Sigma\dot{C}$ is positive, the chance of cloud	(1) Skies were 6-8/10 clouded Ac, Sc and occasionally Cb with occasional showers but no thunderstorm occurred even within 100 miles.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hrs. (2) Within 24 hrs.
		development above 0°C is meagre and thunderstorm improbable but rain likely.	
13th	Real latent instability 970-570 mb : CCL 730 mb : Max. temp. necessary 101°F : Max. temp. reached 104°F : positive area considerably large for layers 970-670 mb : $\gamma=\gamma_d$ for 600-550 mb with isothermal layer 550-500 mb : humidity 70-80% between 730-550 mb: Fz. level 515 mb. Thunderstorm most likely.	Mean CCL 730 mb: 730-600 mb wet $\dot{C}$, $+3{\cdot}2$: 600-550 mb wet $\dot{C}$, $+3{\cdot}9$: 550-500 mb wet $\dot{C}$,-6.3 $\Sigma\dot{C}=+0.8$. (Humidity values not available above 600 mb. Note large negative $\dot{C}$ above 0°C isotherm).	(1) 4-6/10 Sc Cu with a light passing showe at 2100 hours, later 3-4/10 St. (2) Cloudy with 6/10 Sc, Cu between 1300 to 1600 hours of 14th. No thunderstorm within 200 miles.
14th	Real latent instability 970-620 mb: CCL 800 mb: Max. temp. necessary 101°F: Max. temp. reached 104°F: positive area much greater than yesterday for layers 970-770 mb: $\gamma=\gamma_d$ for 970-800 mb and 700-600 mb. with isothermal layer 570-530 mb: humidity $>$ 65% above CCL: it being 100% at 600 mb: Fz. level 600 mb: Thunderstorm most likely.	Mean CCL 755 mb. 755-700 mb wet $\dot{C}$, $+1{\cdot}9$: 700-600 mb wet $\dot{C}$,$+6{\cdot}2$: 600-570 mb wet $\dot{C}$,-0.3: 570-530 mb Int. $\dot{C}$, $-6{\cdot}5$: 530-500 mb dry $\dot{C}$, $-1{\cdot}1$: $\Sigma\dot{C}=+0{\cdot}3$ (See Fig. 3)	(1) 1-2/10 Sc dissipating in 2 to 3 hours. (2) 6/10 large Cu (not Cb) developed between 1400 to 2000 hours dissipating quickly afterwards. No thunderstorm within 200 miles.
16th	Actual instability 960—700 mb ($\gamma>\gamma_d$) with positive areas very large for layers upto 700 mb: real latent instability 700—600 mb : layers nearly saturated between 700—600 mb : Fz. level 630 mb. Thunderstorm a certainty.	Mean CCL 760 mb : 760—700 mb wet $\dot{C}$,$+3{\cdot}8$: 700—600 mb. wet $\dot{C}$,$+2{\cdot}1$: 600—555 mb wet $\dot{C}$,$+2{\cdot}0$: 555—535 mb Int. $\dot{C}$, -4.5: 535—500 mb Dry $\dot{C}$,$-3{\cdot}8$: $\Sigma\dot{C}=-0{\cdot}4$	(1) 2—3/10 Cu dissipating within 4 to 5 hours. (2) 3/10 Sc appeared at 0700 hours developing to 5/10 Sc, Cu at 1:00 hours, clearing at 2000 hours.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hrs. (2) Within 24hrs.
		Since winds above 7000 ft. not available, the inversion layer 555—535 has not been taken dry. (See Fig. No. 4).	No thunderstorm within 200 miles.
22nd	Layers of real latent instability 970 – 660 mb. positive areas in slight excess over negative areas. At times of max. temp. layers 960 – 700 mb. would become adiabatic : CCL. 700 mb. Fz. level 590 mb. Slight possibility of thunderstorm.	Mean CCL. 715 mb : 715—600 mb. wet $\dot{C}$, +3·9 : 600-500 mb. Int. $\dot{C}$, —2·0 : $\Sigma \dot{C} = +1{\cdot}9$ Winds not available above 7000 ft. where it was 310° and 11 knots with humidity 60%.	(1) 7/10 Cb with thunderstorm at 2200 hrs. continuing to 0120 hours. (2) 5/10 Cu developed to 8/10 Cb at 1600 hrs. with thunderstorm at 1640 to 1800 hours.
1th	At the time of max. temp. actual instability 960 – 850 mb. and real latent instability 800—560 mb : CCL. 800 mb. very large positive areas for layers upto 850 mb : humidity 75% between 800—700 mb. with lower layers nearly 60%: dry bulb practically a straight line between 800 mb. (temp. 20°C) to 500 mb. (temp – 6°C). Thunderstorm most likely.	Mean CCL. 770 mb : 770—700 mb. wet $\dot{C}$, +1·0 : 700—600 mb. wet $\dot{C}$, +1·9 : 600—500 mb. Int. wet $\dot{C}$, —3.6/0. Humidity values not available above 700 mb. and upper winds not available above 7000ft. If layers above 600 mb (15000ft.) taken 40—60 humid $\Sigma \dot{C} = +\ 0{\cdot}2$ and if taken 60% $\Sigma \dot{C} = +\ 3{\cdot}2$.	(1) 5-7/10 As, Ac. (2) 5/10 Sc, Cu at 1400 hours, developed to Sc, Cb at 1800 hours and thunderstorm was occurring 5 miles from the aerodrome (City observer reported).
25th	At the time of max. temp. real latent instability layers 960—560 mb. CCL. 690 mb : Max. temp. necessary 106°F : Max. temp. reached 106°F: the positive area sufficiently large for surface layers. Last humidity reported 600 mb.	Mean CCL 670 mb : 670 – 600 mb. wet $\dot{C}$, +3·7 : 600—500 mb. wet $\dot{C}$ +2·9 $\Sigma \dot{C} = +6{\cdot}6$.	Thunderstorm was occurring at the time of ascent not useful for forecast on 26-6-47.

Dates.	Inference by parcel method.	Inference by slice method.	Weather realised. (1) Within 8 hrs. (2) Within 24 hrs.
	sounding practically straight from 900 mb. (temp. 34°C) to 600 mb. (temp. 2°C) and again to 500 mb. (temp. – 8°C) Ground humidity 40% : Fz. level 575 mb. Thunderstorm certain.		
26th	At time of max. temp. actual instability would exist between ground to 700 mb : layers being super-adiabatic upto 700 mb: $\gamma = \gamma_m$ between 300 to 500 mb layers 75% to 100% humid 800 – 700 mb and later fully saturated. Fz. level 590 mb. Thunderstorm most likely.	Mean CCL 765 mb : 765 – 700 mb. wet $\dot{C}$, + 3·1 : 700 – 600 mb. wet $\dot{C}$, + 1·7: 600 – 500 mb. wet $\dot{C}$, – 0·9. $\Sigma \dot{C}$ + 3·9.	Skies were generally overcast with Sc, Cb, Ac night and day with occasional showers occurring. Thunderstorm rather heavy occurred at 2030 hrs. on 27th evening.

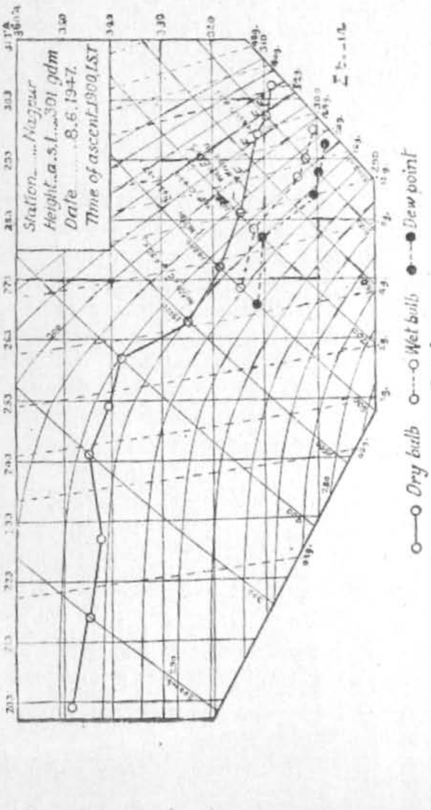

Fig. 1

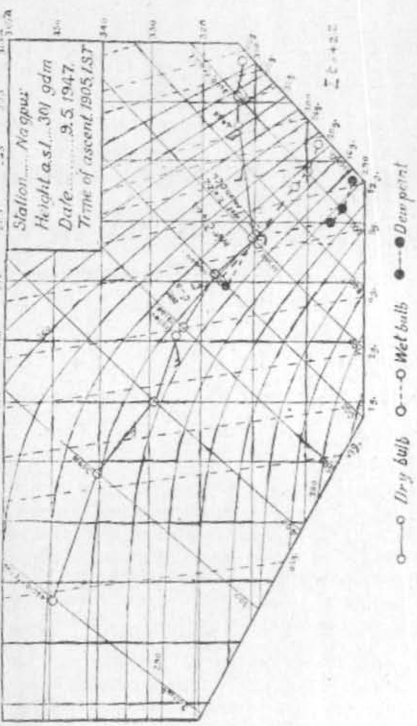

Fig. 2

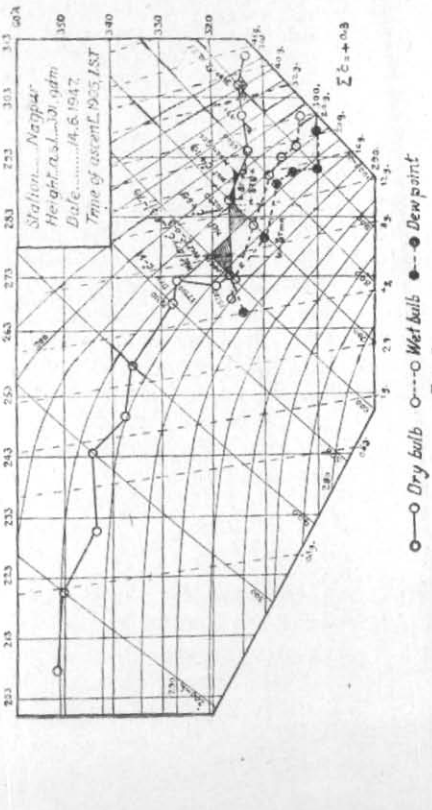

Fig. 3

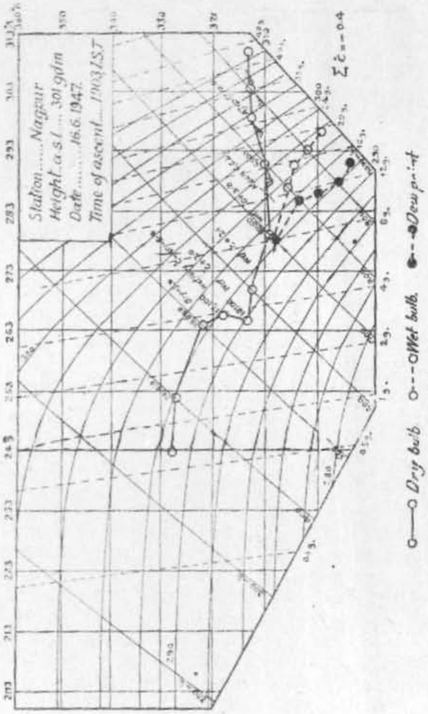

Fig. 4