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A MESOSCALE FORECAST FOR 14 AUGUST 1975 - THE HAMPSTEAD STORM

by

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ABSTRACT

A full numerical atmospheric model has been used to obtain a forecast for the afternoon of 14 August 1975, when an intense stationary multicell storm formed over London and produced extensive flooding. The forecast shows a well defined area of convergence at the right place, but about fours later than the actual storm. Shading by an observed bank of medium level cloud is included in the forecast model, and it is clear that this has an important effect on the forecast.

1. INTRODUCTION

On 14 August 1975, a stationary storm centred over northwest London caused extensive flooding. The natural history of this storm, the Hampstead Storm, has been well rehearsed (Keers and Westcott (1976), Grove (1978), Atkinson (1977)) and the dynamics of the storm itself have been studied using a numerical model (Miller (1978)). With this background, this date is a natural choice as a case study for testing a mesoscale forecast model. Such a model should provide detail that is not possible in a synoptic scale model and thus help to understand or forecast the environment in which strictly local events like the Hampstead Storm might occur. Tapp and White (1976) have described a model that is designed to give mesoscale weather forecasts for the British Isles, and this model has been used to attempt an experimental forecast for 14 August 1975.

A limited area atmospheric model needs initial conditions, which will describe the synoptic situation as well as any mesoscale detail that can be inferred from observations, and boundary conditions, through which information about synoptic changes can be supplied. In the present study, no attempt has been made to use observations to improve the initial conditions, which were interpolated from a synoptic scale model. In this respect, and many others, it is exactly like an earlier case study reported by Carpenter (1979). This simplification was made because we do not yet have the ability to calculate mesoscale initial conditions automatically, and it was not thought appropriate to go to the considerable effort of carrying out and digitising subjective analyses. The boundary conditions were also calculated from the synoptic scale forecast for the period in question.

The model is still being developed and does not include any treatment of clouds. Fortunately, the most obvious feature of the cloud was a bank of altocumulus spreading from the west. With the exception of small areas in the west of the country, once this cloud arrived at any place it remained cloudy there for the rest of the day. Thus it was possible to allow for the effect of this cloud on the surface heat fluxes by coding its time of arrival at each grid point. Two forecasts, with and without this cloud, were carried out and we shall argue that the effect of the cloud is so marked in the forecast that it must be relevant to the mesoscale dynamics of the storm, and that cloud shading is an important part of any reasonable local weather forecast model.

2. OBSERVATIONAL BACKGROUND

The synoptic surface pressure analysis for 1200 GMT on 14 August 1975 is shown in Figure 1, which also shows the positions of Hampstead and Crawley. The radiosonde ascent at 1200 GMT from Crawley is shown in Figure 2.

It is natural to ask why a storm developed in this environment, why it was stationary and why it was over London. The ascent is conditionally unstable and southeast England is in the confluence between air moving round the depression to the northwest of Ireland and southeasterlies circling the low pressure areas over France; the storm at Hampstead was not the only thunderstorm on this day. Miller (1978) has demonstrated that the storm was a multicell storm, in which each cell moved northwards in the ambient southerlies. The cold outflow from the succession of cells spread rapidly to the northwest, but the southern edge of the cold air was more or less stationary. Warm air from the south was forced over this cold air, triggering the release of latent heat and the growth of further cells. The initial development of the storm over Hampstead has been ascribed to Hampstead Hill, or to the urban heat island affect of central London (Atkinson (1977)). Miller's work does not resolve this problem, and it might be asking too much to expect to identify the precise perturbation amongst the many that could have precipitated a storm of this nature. The main reason for carrying out the mesoscale forecast reported here is to discover whether it would have been possible to warn that the London area might be a preferred location for severe thunderstorms.

As part of his study of London's urban heat island effect, Atkinson has produced mesoscale streamline analyses for the surface on 14 August 1975. These are reproduced in Figure 3 so that they can be compared with the present forecast.

3. THE MODEL

The model has been described in detail by Tapp and White (1976) and Carpenter (1979). It is based on a finite difference approximation of the non-hydrostatic compressible equations of motion on a three-dimensional grid. The horizontal grid has 61 X 62 points, a grid length of 10 km and covers England and Wales. There are ten levels and the top level is at 4 km. This grid is not a permanent feature of the model and it might have been natural to increase the model depth for this study. However, that could only be done at the expense of resolution and, in the event, the results suggest that there would be little benefit from using a deeper model.

Boundary layer turbulence is included in the model, using a K-theory approach, and there is a convective adjustment. However, the effects of moisture, cloud and radiation are only described in so far as they affect the exchanges of heat at the surface.

The calculation of surface fluxes of heat and momentum has been described by Carpenter (1977). Monin-Obukhov similarity theory is used, and the surface temperature is given be requiring heat balance at the surface.

$$S + R_{\downarrow} = H + L E + G + R_{\uparrow} \qquad (1)$$

where S is the solar heating of the surface

$R_{\downarrow}$ and $R_{\uparrow}$ are the thermal radiation fluxes at the surface.

H is the sensible heat flux into the atmosphere,

E is the flux of water vapour into the atmosphere,

L is the latent heat of vapourisation,

and G is the heat of flux into the ground.

The calculation of the evaporation E needs a value for humidity mixing ratio, which is otherwise absent from the model, at the bottom level; a constant value of 0.01 has been used. The solar radiation S is given by

$$S = 558 \cos (\quad t/12) + 72 \quad \text{watts/m}^2 \qquad (2)$$

before the arrival of the medium cloud, and

$$S = 279 \cos (\quad t/12) + 36 \quad \text{watts/m}^2 \qquad (3)$$

later in the day where t is measured in hours from midday. Thus the solar heating is halved following the arrival of the cloud. Equations (2) and (3) are intended to allow for atmospheric attenuation and reflection from the surface.

The fact that humidity was not a forecast variable and that the deck of altocumulus was not the only cloud observed during the day reduce the reliability of the sensible heat flux. Thus, it seemed inappropriate to consider the precise form of equations (2) and (3) too carefully, and the reduction of the solar beam by 50% was chosen for its simplicity. If we assume a transmissivity of 0.3 for medium level cloud (eg Kuo-Nan Liou (1976)), a solar beam S will be reduced to $(1-0.7C_m)$ S by a cloud amount C_m. The cloud was recognised by the British Isles forecaster in the Bracknell Central Forecast Office as a bank of more than 5/8 Ac, so about 55% of the solar beam should have penetrated the cloud. Thus equations (2) and (3) should give a qualitatively correct description of the shading effect of this altocumulus.

The leading edge of the cloud, as coded in the model, is shown in figure 4.

A synoptic scale model starting at 0001 GMT on 14 August 1975 was used to obtain initial and boundary conditions. The mass field forecast for 0600 GMT was interpolated to the mesoscale model grid, and the Eckmon layer equations were solved for the winds. The boundary conditions were updated throughout the mesoscale forecast using a second "initialisation" carried out for 1800 GMT.

4. RESULTS WITHOUT CLOUD

A forecast was made using only equation (2) to calculate the solar warming of the surface. This gave the winds and temperatures shown in Figures 5 and 6 for 1200 GMT and 1800 GMT respectively.

Given ascents resembling the Crawley ascent shown in figure 2, it is possible that the sea breezes apparent in figures 5 and 6 will trigger cumulus. Further, the convergence of breezes from the south and east coasts might indicate London as a preferred location for cumulonimbus. Never the less, it seems more likely that the results with cloud, shown below, are relevant to the special events on 14 August 1975.

5. RESULTS WITH CLOUD

Figures 7 and 8 show the forecast of low level winds and temperature for 1200 GMT and 1800 GMT, and are directly comparable with figures 5 and 6. The forecast for 1800 GMT encouraged us to continue the forecast to 2000 GMT, with the result shown in Figure 9. Figure 10, which shows forecast ascent and reports of thunder or cumulonimbus, shows Hampstead to be at the southern end of a line of ascent, and figure 9 shows a well defined vortex in the same place. Superficially, this is a remarkable success, but it must be born in mind that the storm started at 1600 GMT, so this forecast is 4 hours late.

Figure 11 shows a comparison between the forecast surface temperatures and the observed screen temperatures. Overall, the surface temperatures are about 1°C too high, which might be reasonable for the decrease in temperature from the surface to screen level. The sharp discontinuity across the cloud edge is not proved by the observations, but the drop in temperature from the eastern half to the western half of England seems correct.

6. DISCUSSION

When the forecast with cloud is compared with the analyses in figure 3 it can be seen that some details of the forecast are quite wrong. In the analysis, a line of divergence moves across the country in a way that is similar to the movement of the cloud edge and its associated convergence line in the forecast. The forecast shows divergence behind the convergence line and it is possible that a more realistic description of the cloud, with the amount increasing more gradually towards the west and the inclusion of some higher cloud further to the east, would lead to a forecast more like Atkinson's analysis. Atkinson's line of convergence is alligned along the east of the country far earlier than any similar feature in the forecast, and it seems unlikely to us that this has much to do with the advancing cloud parametrised in the forecast.

Nevertheless, the comparison between the forecasts is conclusive evidence that the effects of the cloud are important, and the location of all the thundery activity close to the leading edge of the cloud (see figure 10) cannot be dismissed as a coincidence. Figure 12 shows an east-west section through the model, and thus the cloud edge. It is clear that the cloud shading has induced a considerable temperature contrast throughout the boundary layer. This has in turn induced a thermally direct circulation in same ways similar to a sea breeze or gravity current. It is hoped that this response will be studied further, and a further case study in a similar situation is planned (The Skipton Storm, 13 June 1979).

It seems clear that any reasonable local forecast model must include calculations of the shading effect of clouds. The importance of calculating the latent heat release during cloud and rain formation is familiar, but it is possibly no more important than the radiative effects of cloud. This presents modellers with a substantial problem because it is not clear that it is easy to calculate cloud cover or cloud type with reasonable accuracy in a numerical model. In this forecast, we have, in effect, treated the cloud amount as a boundary condition that must and can be obtained from some external source. In operational practise, we would not have observations of clouds in advance, but it is possible that forecasts of cloud type and amount could be obtained using some objective extrapolation of satellite and surface observations. This suggests that an approach like, but more sophisticated than, that used in the present study might be more reliable than using model predicted cloud in the radiation calculations.

As for the Hampstead Storm, it is clear that no description of its mesoscale meteorology is complete unless it takes full account of the effects of cloud shading and the associated areas of ascent and descent. Our forecast cannot be considered a complete explanation because of the lack of mesoscale detail in the initial conditions, the timing error and the poor comparison with Atkinson's streamline analysis. However, Miller (informal contact) has pointed out that the strong low level convergence predicted in the forecast reported here is a useful addition to his work. (Miller (1978)). He found that the Crawley ascent (Figure 2) did not lead to a storm in his model unless he increased the low level heat and moisture, as shown in figure 2. His adjustment to the Crawley ascent is made more plausible by our forecast.

7. CONCLUSION

Two forecasts of the mesoscale developments on the day of the Hampstead Storm have been carried out, one with and one without cloud. The comparison of the two forecasts suggests that the calculation of cloud shading is essential to good numerical forecasts of local weather. The forecast with cloud showed marked low level convergence on the leading edge of the cloud, which moved across the country and eventually intersected with sea breeze fronts to suggest a preferred area for convection over London.

ACKNOWLEDGEMENT

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Kuo-Nan Liou (1976) 'On the absorption, reflection and transmission of solar radiation in cloudy atmospheres', JAS 33, 798 - 805.

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Figure Captions

Figure 1. The synoptic situation over the British Isles on 14 August 1975.

Figure 2. The radiosonde ascent from Crawley, S.E. England, at 1200 GMT on 14 August 1975. Modifications that Miller found necessary in order to simulate the Hampstead Storm are shown by the hatched lines.

Figure 3. Surface streamline analyses for 14 August 1975. This figure is a direct copy from Atkinson (1977).

Figure 4. The position at various times of the leading edge of a bank of cloud that moved across England on 14 August 1975.

Figure 5. Forecast 10m winds and potential temperatures for 1200 GMT on 14 August 1975 when cloud effects were excluded from the forecast model.

Figure 7. Forecast 10 m winds and potential temperature for 1200 GMT on 14 August 1975 when the effects of the bank of cloud shown in figure 4 were included in the forecast model.

Figure 8. As figure 7, but for 1800 GMT.

Figure 9. As figure 7, but for 2000 GMT.

Figure 10. Forecast vertical velocity at 190 m compared with significant weather reports, both for 1800 GMT on 14 August 1975.

Figure 11. Forecast surface isotherms compared with screen level temperatures reports, both for 1200 GMT on 14 August 1975.

Figure 12. A vertical east west section through the cloud edge showing the forecast potential temperature and components of wind velocity in the plane of the section for 1800 GMT on 14 August 1975. The section is restricted to the bottom 8 levels of the model and, approximately, the eastern half of the model.

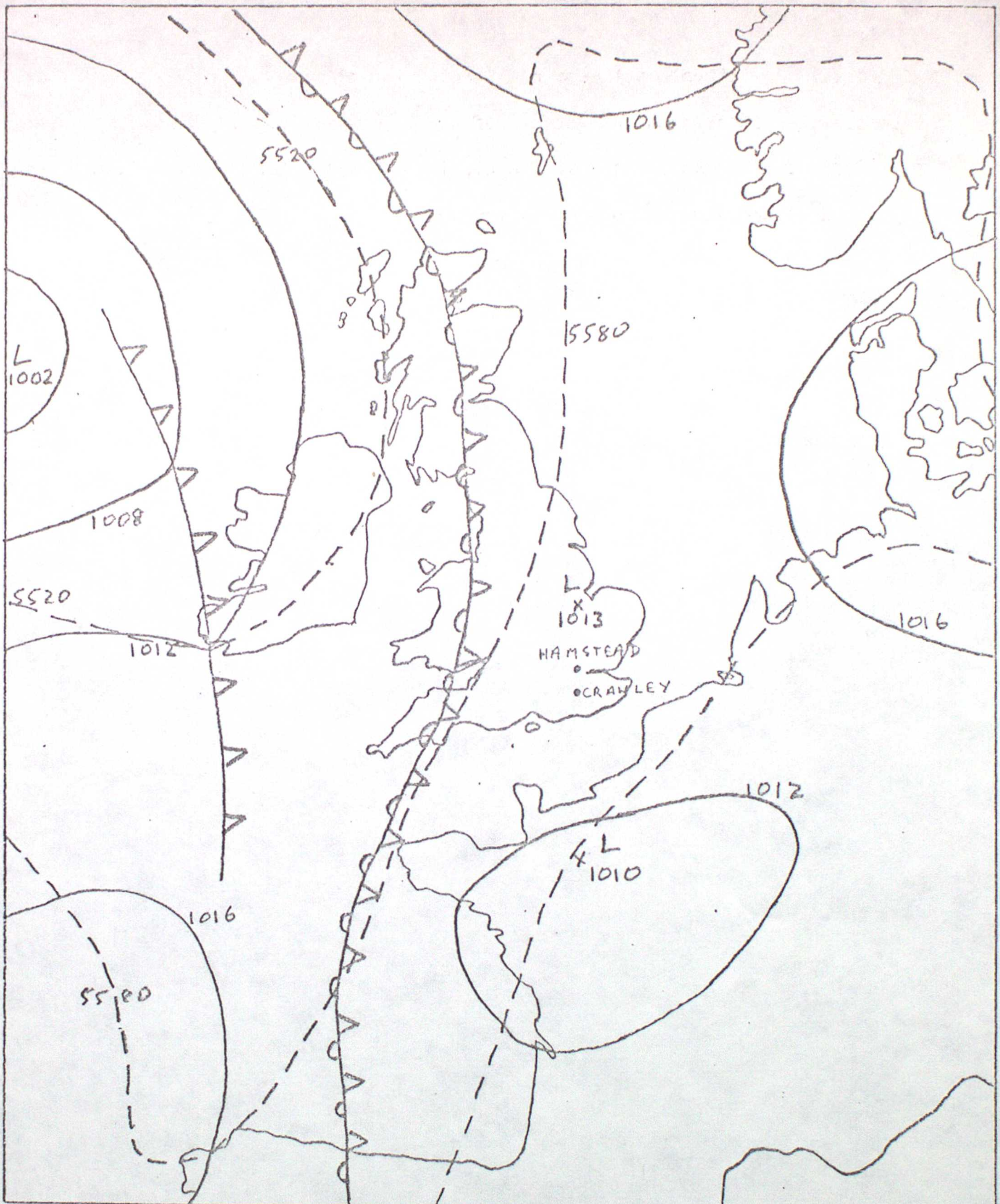
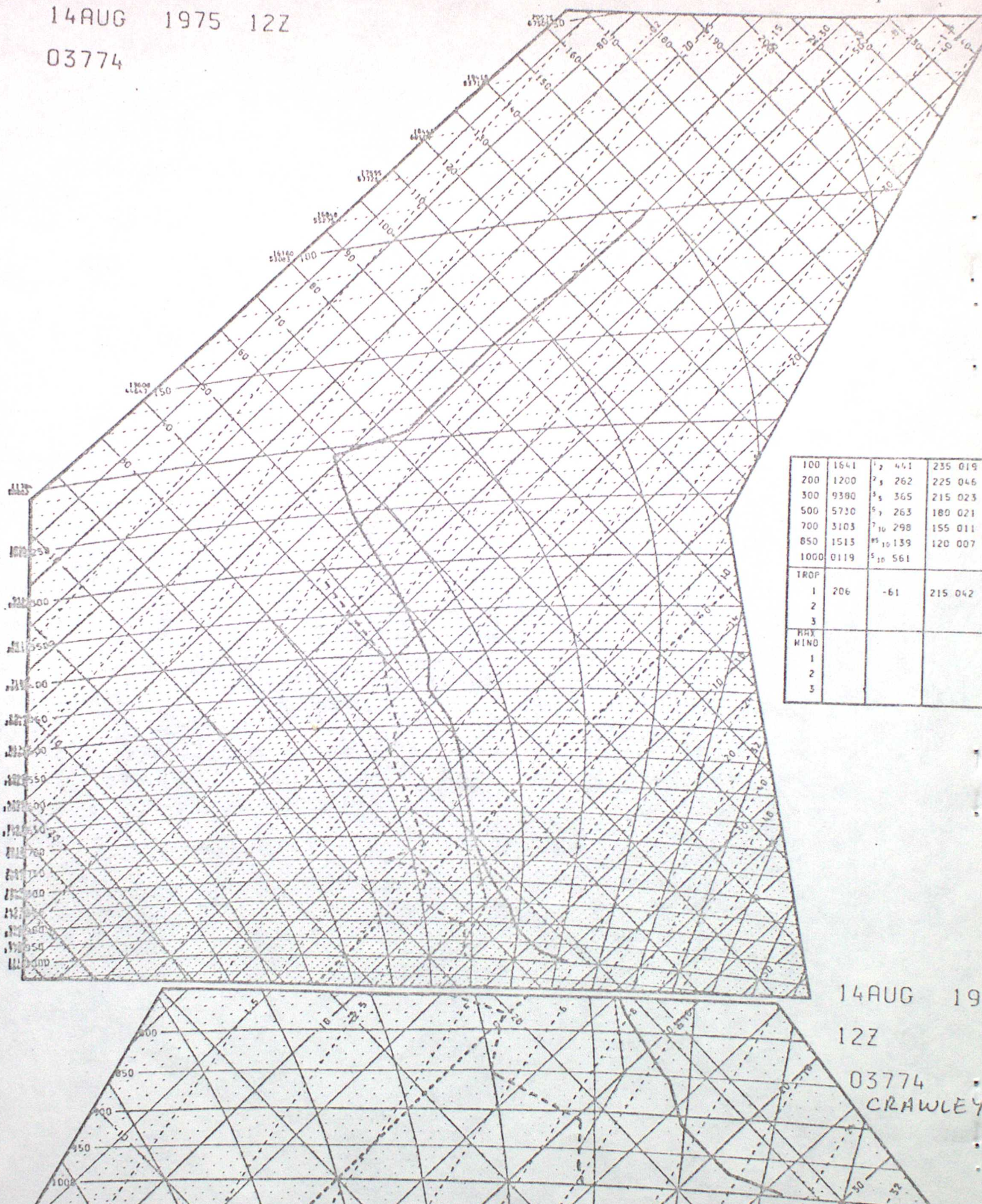

5520
L
1002
1008
5520
1012
1016
5580
L
1013
HAMSTEAD
CRAWLEY
1012
L
1010
1016
5580
1016

FIG. 1

14AUG 1975 12Z

03774



100	1641	$^{1}{}_{2}$ 441	235 019
200	1200	$^{2}{}_{3}$ 262	225 046
300	9380	$^{3}{}_{5}$ 365	215 023
500	5730	$^{5}{}_{7}$ 263	180 021
700	3103	$^{7}{}_{10}$ 298	155 011
850	1513	$^{85}{}_{10}$ 139	120 007
1000	0119	$^{5}{}_{10}$ 561	
TROP			
1	206	-61	215 042
2			
3			
MAX WIND			
1			
2			
3			

FIG. 2

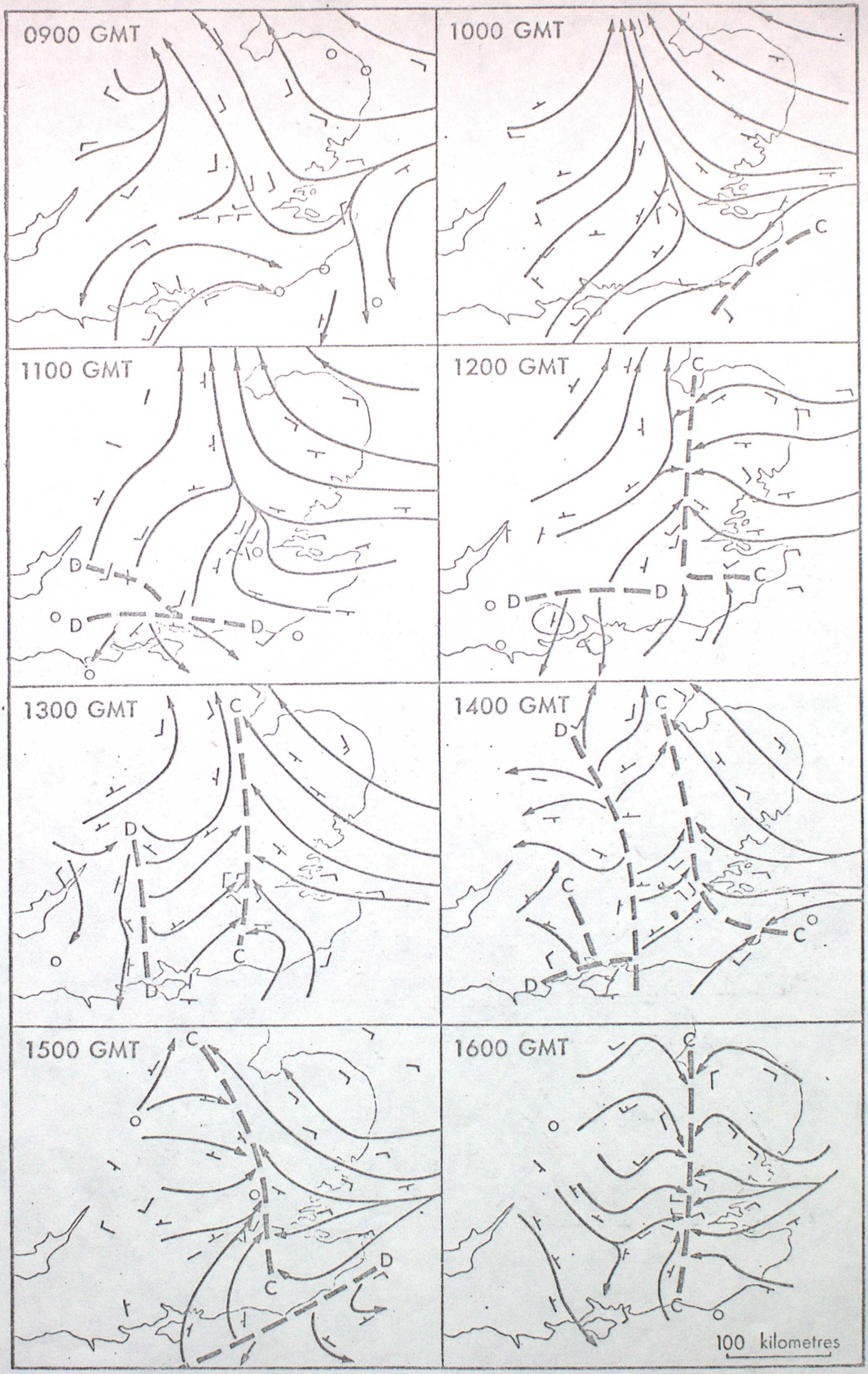

0900 GMT
1000 GMT
1100 GMT
1200 GMT
1300 GMT
1400 GMT
1500 GMT
1600 GMT
100 kilometres

FIG. 3

LEADING EDGE OF CLOUD

FIG 4

1200 GMT

POTENTIAL TEMP. & WINDS   ISOTHERM INTERVAL = 1 DEG C

FIG. 5

1800 GMT

POTENTIAL TEMP. & WINDS   ISOTHERM INTERVAL = 1 DEG C

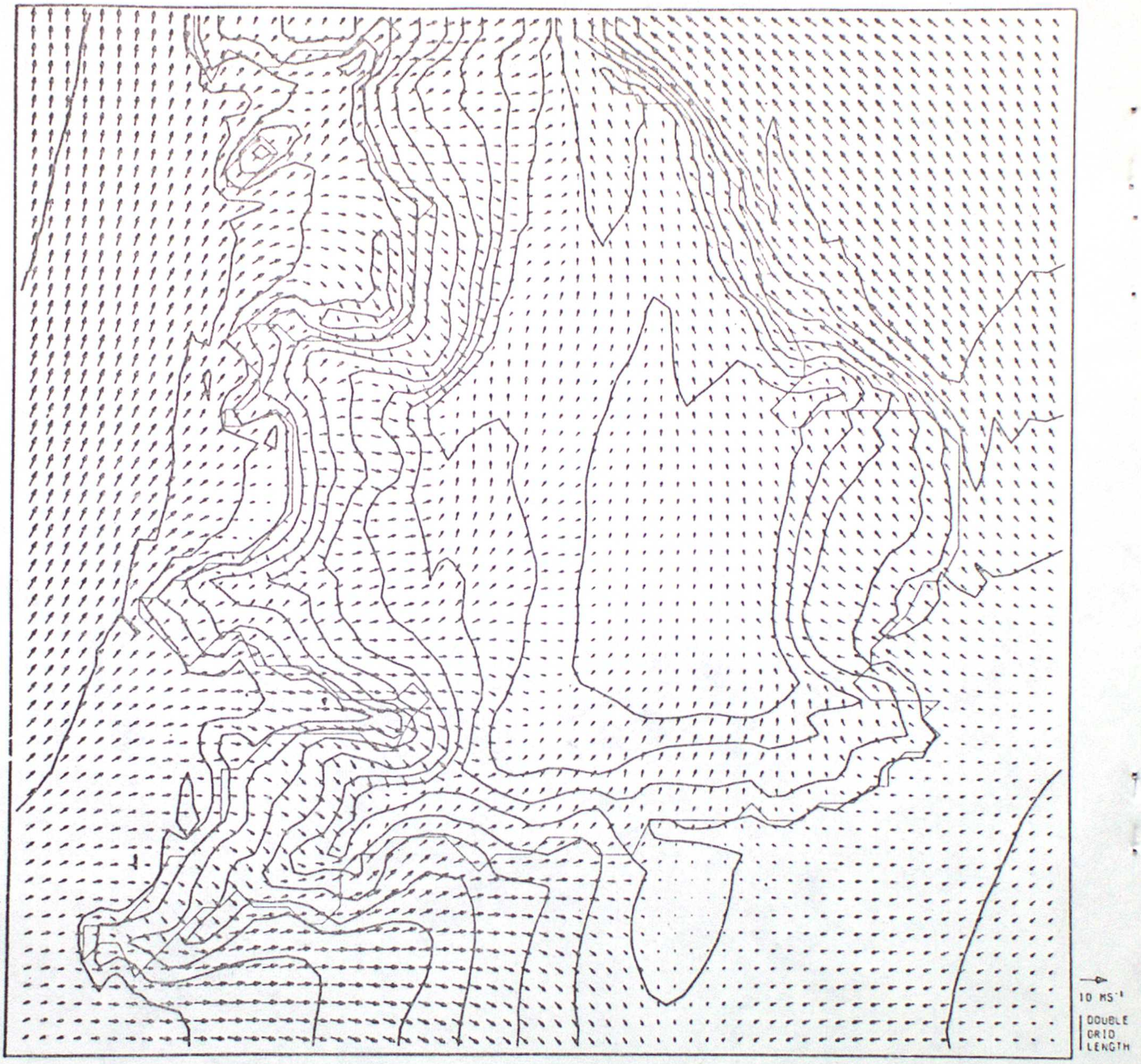


FIG. 6

1200 GMT

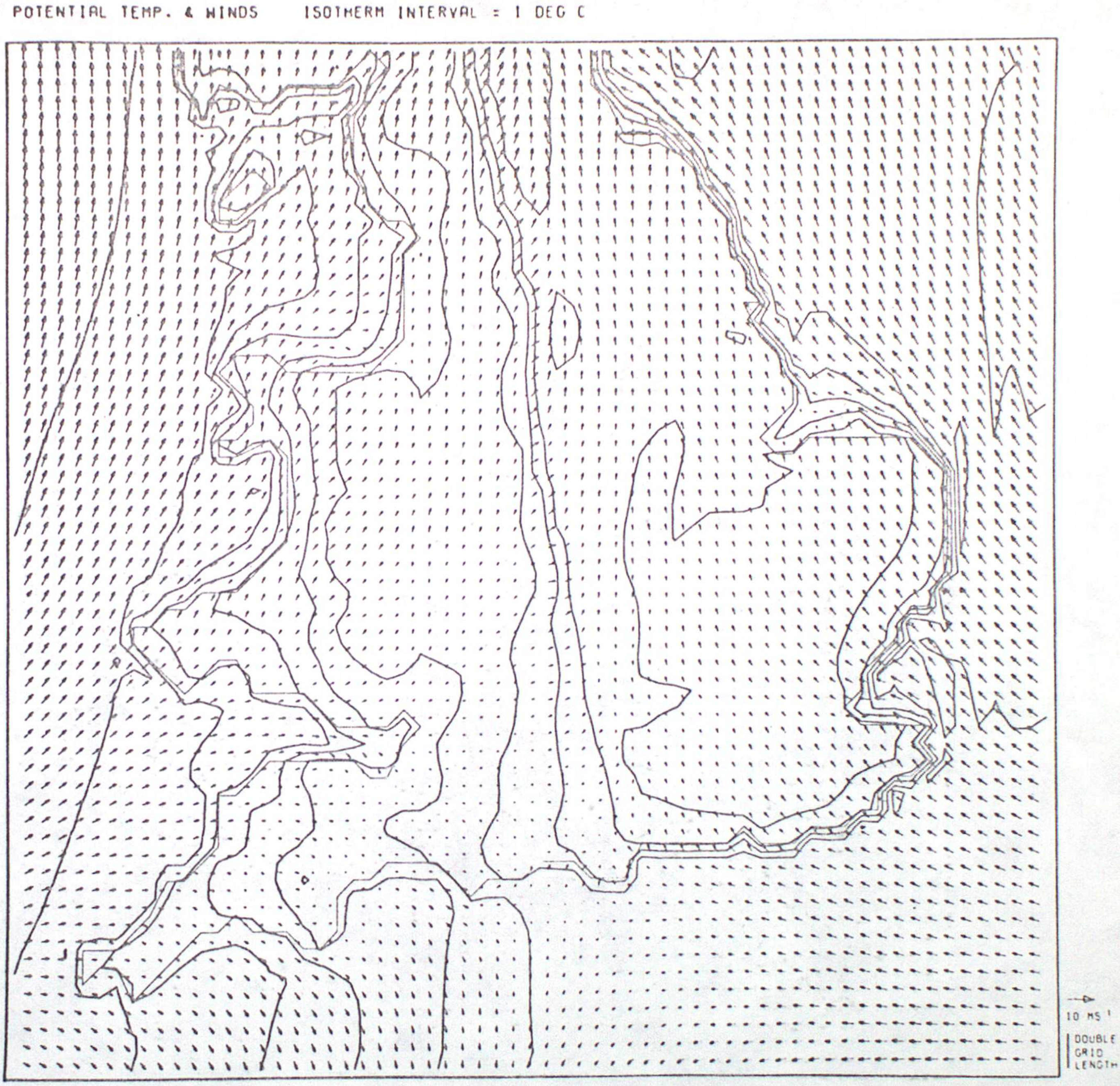


FIG. 7

1800 GMT

POTENTIAL TEMP. & WINDS   ISOTHERM INTERVAL : 1 DEG C

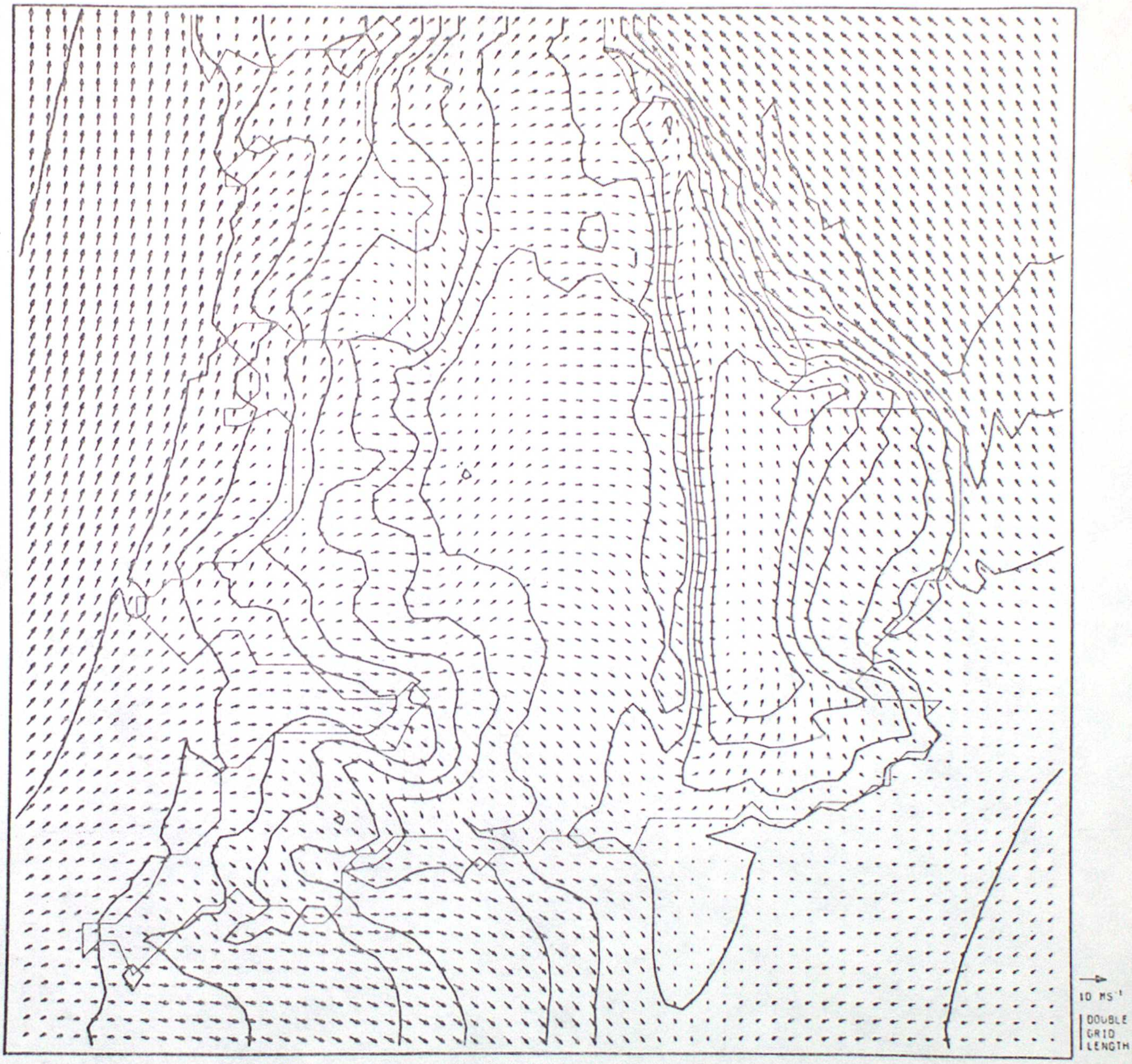


FIG 8

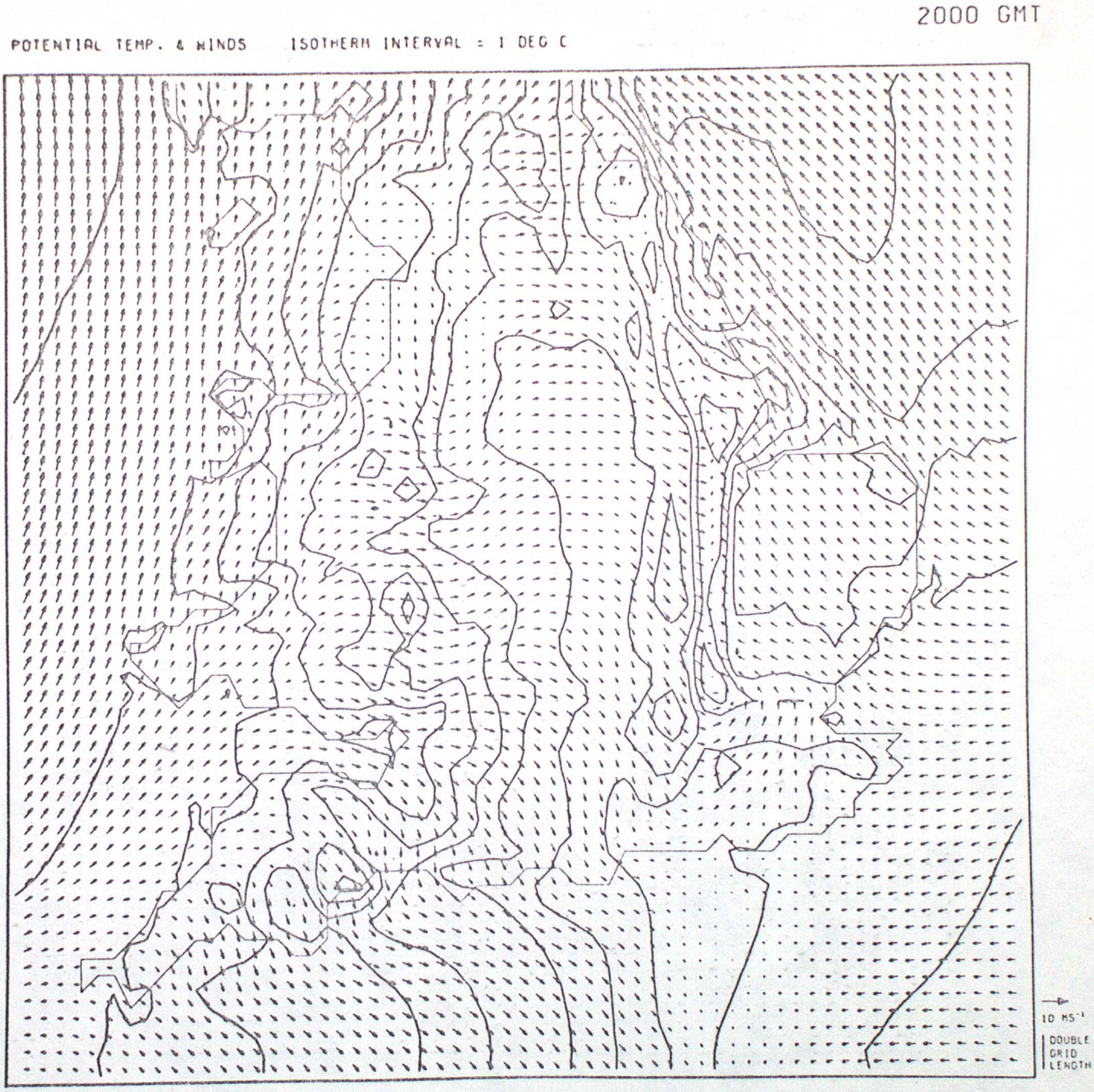

2000 GMT
POTENTIAL TEMP. & WINDS ISOTHERM INTERVAL = 1 DEG C
10 MS⁻¹
DOUBLE GRID LENGTH

FIG 9

1800 GMT

VERTICAL VELOCITY   ISOPLETH INTERVAL = 2 CM/SEC

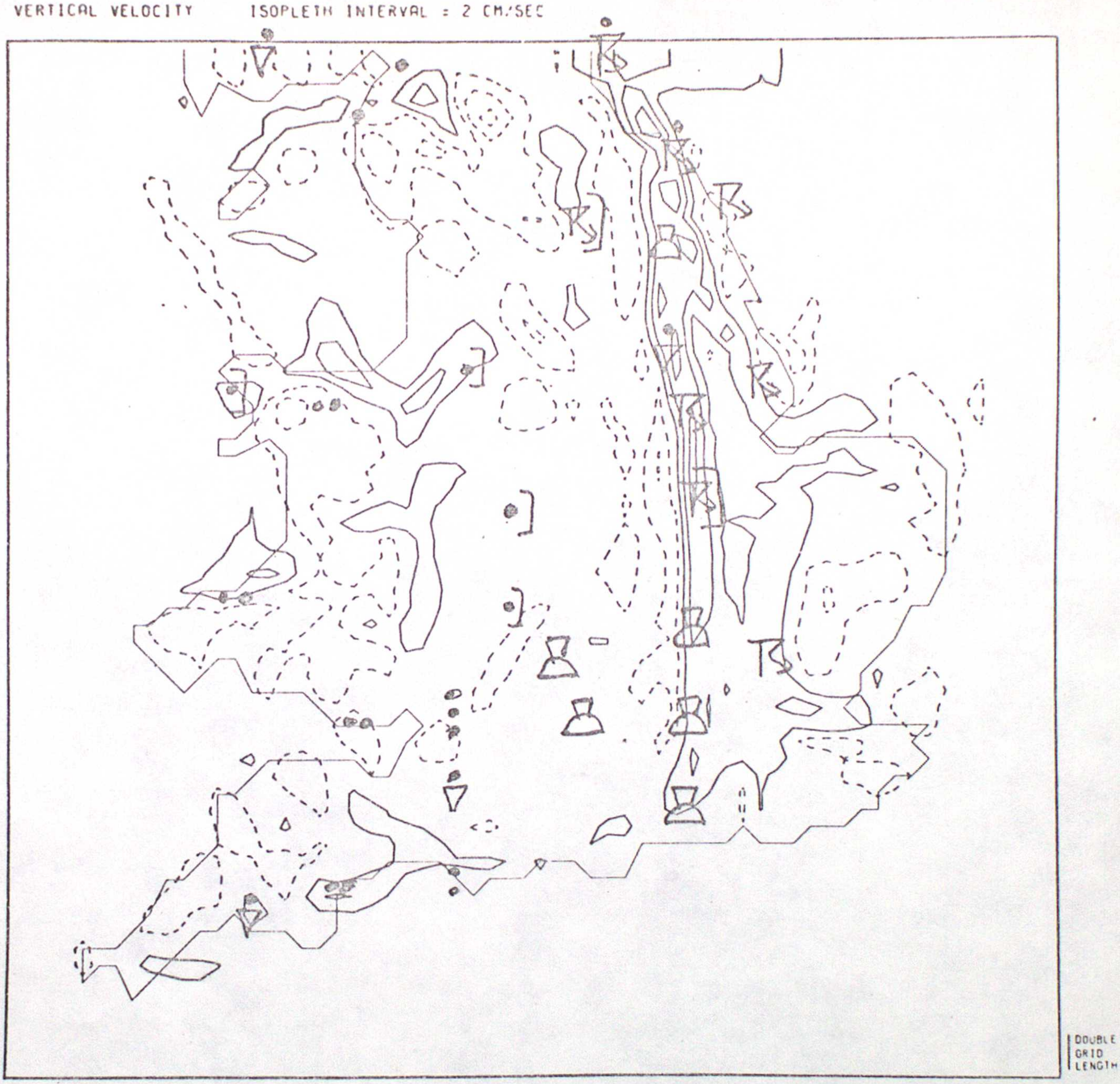
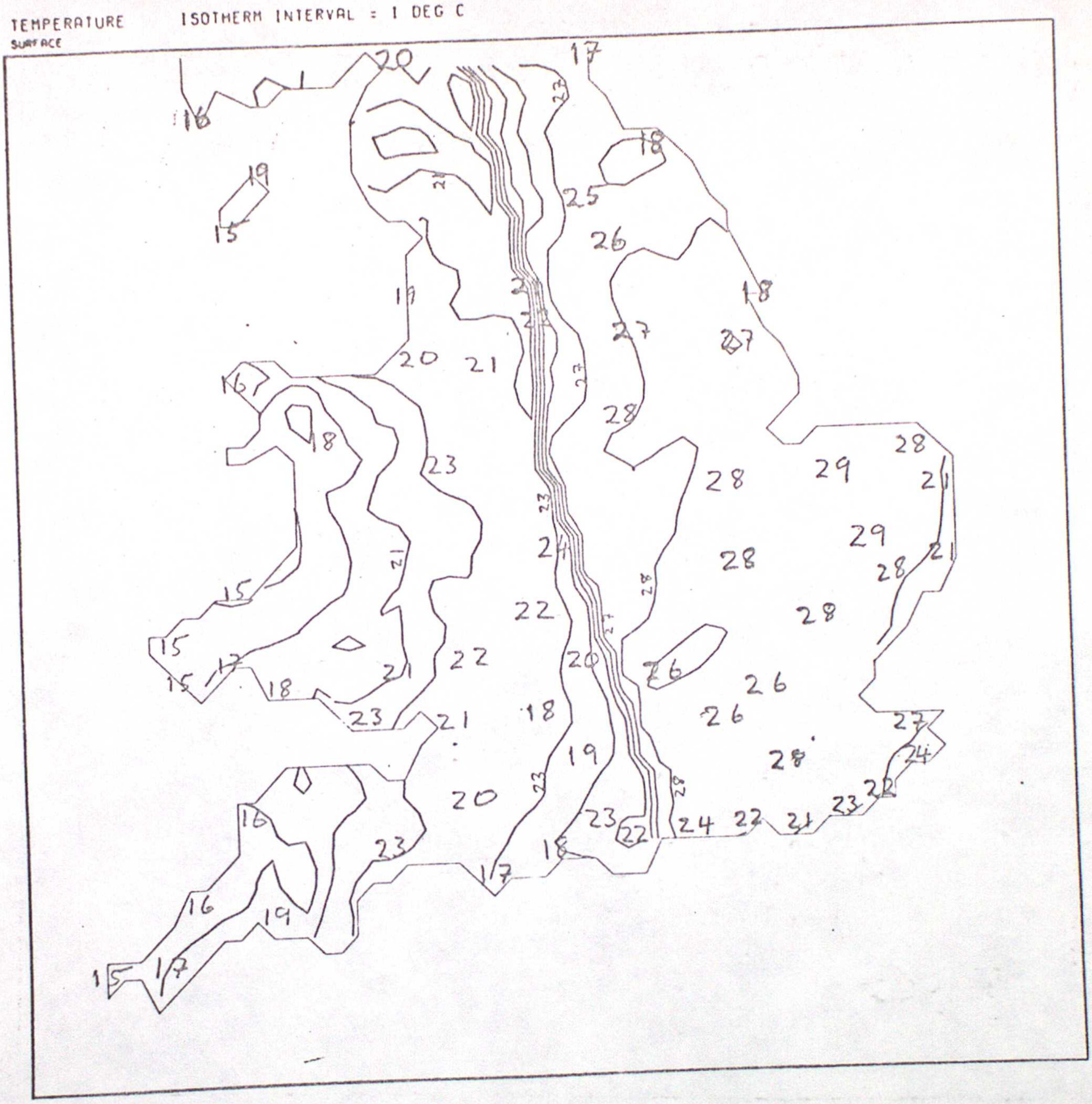


FIG 10

1200 GMT

TEMPERATURE ISOTHERM INTERVAL = 1 DEG C

SURFACE



DOUBLE GRID LENGTH

FIG 11

1800 GMT

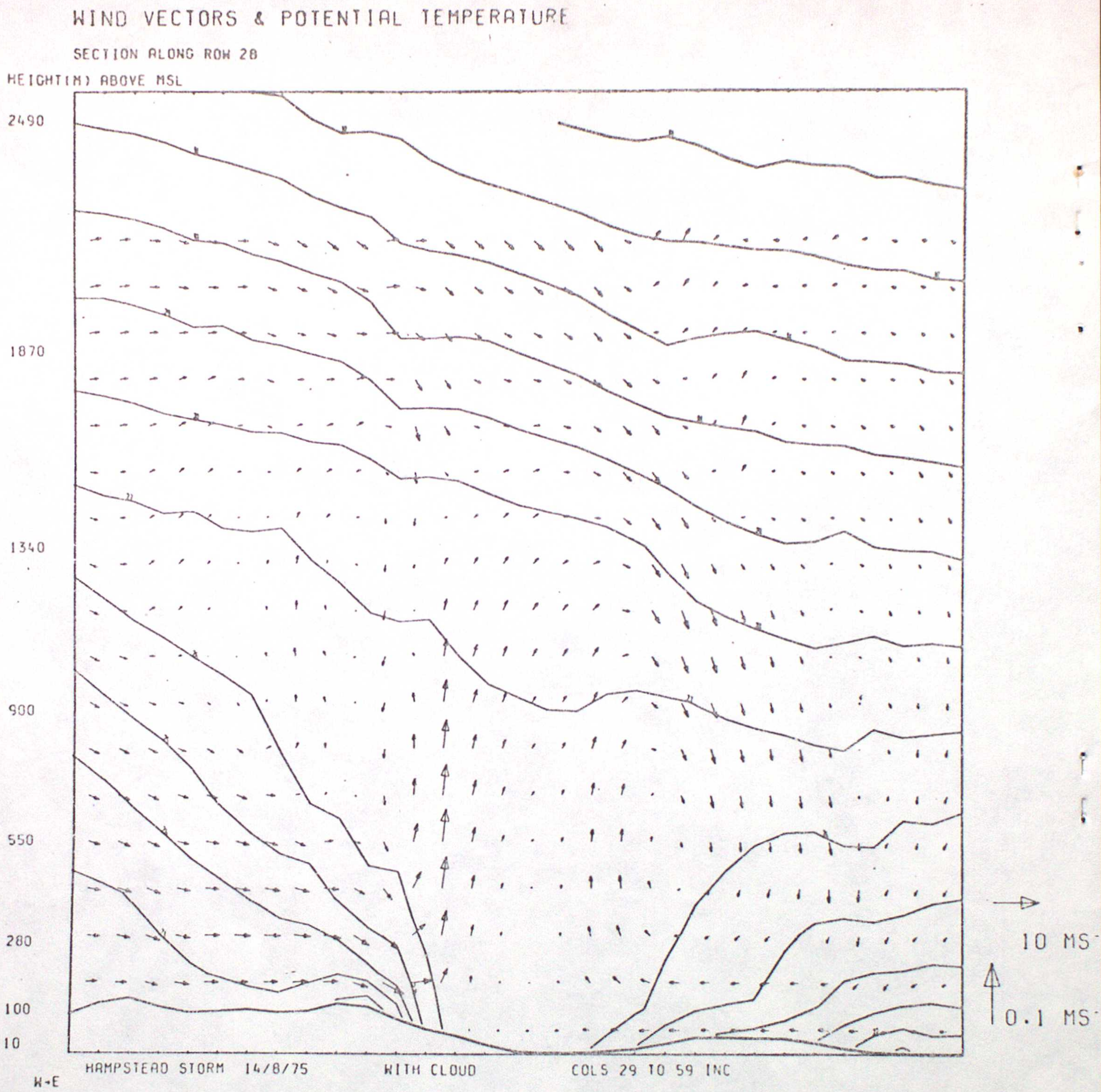


FIG 12