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An investigation into the likely causes of spurious rain in
anticyclones in the fine mesh model.

by

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An investigation into the likely causes of spurious rain in anticyclones in the fine mesh model.

1. Introduction

The occurrence of spurious, mainly dynamic precipitation close to the centre of anticyclones has been a recurring problem with fine mesh rainfall forecasts. An example of this is illustrated in figure (1) which shows a T+36 rainfall forecast from data valid at 0000 GMT 9/2/84. The forecast shows an area of dynamic precipitation in the SW approaches inside an area enclosed by a 1040 mb isobar. There was no precipitation forecast in this area at T+30 and the rain at T+36 did not appear to be connected with a front or a similar meteorological feature. Surface land and ship observations shown in figure (2) indicated that there were likely to be scattered light showers in the area falling from shallow cumulus and stratocumulus clouds but no organised precipitation. The rainfall forecast in this area was therefore unrepresentative. Since the forecast over other areas was good, it was decided that a detailed investigation of this case might provide reasons for the spurious rainfall. This note describes the investigation, provides conclusions and offers suggestions for future work.

2. Investigation

The first stage of the investigation was to examine the vertical profiles from the model in the rain area near SW England at T+36. Figure (3) shows an ascent from the model near 48.75°N 8.5°W, which is the position marked E in figure (1). The Camborne ascent made at 1200 GMT on

10/2/84 is shown in figure (4) for comparison. The model profile is stable but has a saturated, almost isothermal, layer between 970 and 900 mb. Above 900 mb the model was fairly dry.

The Camborne sounding shows an anticyclonic subsidence inversion down to 800 mb with a rather moist, unstable, and well mixed layer between the surface and 910 mb. This profile was consistent with the cloud observations over the sea to the southwest of Camborne. There are clearly large differences between the model and observed temperature and humidity profiles. The model does not have the subsidence inversion and was too moist, particularly below 900 mb and between 600 and 800 mb.

2.1 Discussion

The model will produce dynamic precipitation if there is sufficient moisture and upward motion. In this case sufficient moisture was available below 900 mb and the vertical velocity chart at T+36 shown in figure (5) shows that in the region near SW England air was ascending at rates between 0 and 10 mb/hr at sigma level $3\frac{1}{2}$ (approximately 950 mb). Clearly, the model produced the spurious rain because it was too moist between 900 and 970 mb and this moist air was being lifted. At this stage two questions may be asked. Why was the model saturated below 900 mb, and was the vertical velocity field realistic? These questions of moisture and vertical motion are addressed in the next two sections.

2.2 Moisture

The air at 900 mb at point E in figure (1) was traced backwards in time through the forecast along the 900 mb pressure surface neglecting vertical motion. The locations of the air at 6 hourly intervals from T+36 to T+0 are plotted on the chart shown in figure (6). At each of these locations tephigrams were produced and these are shown in figure (7).

The most curious thing one notices about figure (7) is that the near isothermal layer between 900 and 970 mb is evident at T+0 and is maintained throughout the forecast with varying amounts of moisture. The decrease in humidity in this layer between T+6 and T+12 can be explained by the fact that at T+6 the model was raining with a dynamic precipitation rate of 0.2 mm/hr and by T+12 all of the excess moisture had been "rained" out. During the next 12 hours to T+24 the layer gradually moistened up and by T+24 the model was again producing rain. This process of drying out and becoming moister was repeated between T+24 and T+36. The reason why the model became saturated after losing excess moisture through rainfall is not clear. However, between T+6 and T+24 the layer between the surface and 1000 mb was absolutely unstable and it is possible that moisture was transported upwards from near the surface. This unstable layer was consistent with the Camborne sounding. However, the sounding indicates that in reality the air would have been mixed through a greater depth than it was in the model. This suggests that the incorrect forecast temperature and humidity profiles at T+36 were largely due to the

model being too warm between 900 mb and 970 mb. This had the effect of limiting the vertical mixing layer in the model near the surface to 950 mb.

2.3 Discussion

The T+0 mean sea level pressure analysis is shown in figure (8) with the CFO frontal analysis superimposed. The figure shows that between 50N and 55N the warm front in the model was too slow. A vertical cross-section of humidity and temperature from the analysis was taken across the front along latitude 53N, the section is shown in figure (9). The kink in the isotherms and the area of 100% relative humidity near 15W suggest that the surface position of the model's warm front was around 17°W with a very shallow gradient to 900 mb at 10°W. This estimated surface position was consistent with the mean sea level pressure field shown in figure (8). The vertical profile from the model at 51.75°N, 15°W at T+0 and shown in figure (7) also indicates a surface warm front to the west of 15°W. From this evidence we can conclude that the error in the position of the warm front was the reason for the moist isothermal layer in the model at T+0.

2.4 Vertical velocities

Figures (10) to (13) show a sequence of vertical velocity fields from the model at sigma level 3.5 (approximately 950 mb) at T+3, T+12, T+21 and T+30 respectively. The main areas of interest are outlined boldly in black. It can be seen from these figures and figure (5) that the area of rising air near SW England at T+36 had

been advected steadily eastwards as a coherent feature from T+3. This area could not be associated with an observed frontal system. The largest vertical velocity at T+3 was 20 mb/hr at 45N 30W. The 850 mb relative humidity field shown in figure (14) shows that in this region the model was saturated at T+0. Surface observations at 1800 GMT 8/2/84 and 0000 GMT 9/2/84 did not support the large scale ascent and cloud structure implied by the model at low levels in this area. However, satellite pictures did indicate some organised cloud at medium levels in the area. The satellite pictures were consistent with the analysed 500 mb height and 1000-500 mb thickness shown in figure (15), which shows a relaxing trough just to the west of the area with very slight warm advection on the eastern side of the trough.

A more complete picture of the model's analysis can be gained by examining the vertical cross-sections of wind, temperature and relative humidity along 42°N shown in figure (16). Looking first at the wind analysis shown in the upper half of the figure it can be seen that at 31W there is a slight discontinuity in the vertical velocities. The rising air near and to the west of 31W was associated with a layer of saturated air below 850 mb as shown in the lower half of figure (16). The isotherms together with the wind vectors and humidity information indicate that the model had a weak warm front near the surface around 31W.

2.5 Discussion

As mentioned earlier, surface observations did not confirm the suggestion of a weak, warm front near 31W. It was felt, therefore, that a comparison with the ECMWF analysis would help to resolve this difference. Since the ECMWF analysis uses a later data cut-off time than the analysis from which the fine mesh start field is derived, it was considered more appropriate to compare the Met Office update analysis, which has a cut-off time closer to ECMWF, with the ECMWF analysis. The update analysis vertical cross-sections are shown in figure (17). This analysis was broadly similar to the fine mesh initial conditions with only small differences in the relative humidity and temperature structures. The warm front structure is more pronounced in the update run with increased wind speeds and a greater rate of ascent west of 31W.

2.6 Comparison with ECMWF

The vertical cross-sections from the ECMWF analysis are shown in figure (18). Comparing figures (17) and (18) it is obvious that there are large differences between the UK and ECMWF analyses.

The ECMWF relative humidity analysis is much smoother, and below 700 mb it is a lot drier than the UK analysis. West of 30W and below 850 mb the UK analysis is warmer than ECMWF. The low level warm front structure is not evident in the ECMWF temperature and relative humidity fields. The main difference between the wind fields is that the vertical velocities in the ECMWF analysis are less intense (allowing for the change in scale). Moreover, between 31W and 37W there is slight downward motion in the ECMWF analysis, whereas in the

UK analysis there is quite vigorous upward motion. It is the opinion of the author that the ECMWF wind and temperature analyses were probably closer to the truth than the Met Office update analyses. The presence of cloud at medium levels and the slight warm advection at 500 mb probably justifies the structure of the Met Office humidity analysis, particularly at medium levels. The ECMWF humidity analysis, however, was probably too dry at lower levels. To understand why the Met Office vertical velocities were more intense than ECMWF, the background fields used for the two analyses were examined. These fields are shown in figures (19) and (20). Like the analyses there are large differences between the background fields.

The ECMWF background cross-sections shown in figure (19) are very similar to the ECMWF analysis cross-sections shown in figure (18). However, the Met Office background cross-section in figure (20) has quite unrealistic vertical velocities. For example, at 33W there is convergence at 950 mb with strong ascent to 500 mb where there is a light westerly. Further east at 25W there is convergence at 400 mb with strong descent to 950 mb with a returning easterly flow at low levels to 33W. This unrealistic background field certainly made a contribution to the generation of the low level warm front structure evident in the fine mesh initial field in figure (16).

3. Conclusions

The spurious rain near SW England at T+36 appeared to have a variety of causes. The trajectory calculation showed that the source of humidity for the rainfall was from a poor positioning of a warm front in the analysis to the west of Ireland near 15W. The large

scale uplift required to produce dynamic rain in the model originated from the analysis of a spurious warm front at low levels over the mid-Atlantic. The Met Office analysis in this area was compared with the ECMWF analysis and there were large differences in all fields.

The two main problems that have arisen from the study of this case are as follows:

(1) In all of the model tephigrams shown in figure (7) it can be seen that the moist isothermal layer between sigma levels 3 and 4 is maintained throughout the forecast. Sigma levels 3 and 4 are the highest full levels in the model boundary layer [1], and questions may be asked regarding the accuracy of the model's representation of the boundary layer in this case.

(2) The vertical velocities in the Met Office background field for 0000 GMT 9/2/84 were large and unrealistic. Since the mid-Atlantic is not a "data rich" region, the background field had an appreciable effect on the final analysis. The final analysis showed a frontal structure at low levels which was inconsistent with observations and the ECMWF analysis. It has been shown that the area of rising air associated with the spurious front was advected eastwards during the forecast, and that this area of upward motion was a contributing factor for the rain at T+36. It is conceivable that improvements to the vertical velocities in the model may reduce the incidence of small amounts of spurious rain. It may also be beneficial to

examine fine mesh rainfall forecasts run from an ECMWF analysis, since this case has shown that there can be large differences between the analyses from the two systems.

References

- [1] Dickinson A and Temperton C. 1984. The operational numerical weather prediction model. Met O 11 Technical Note number 183.

FIGURE LEGENDS

1. T+36 forecast of dynamic and convective rainfall rate with mean sea level pressure superimposed. DT 0000 GMT 9/2/84.
2. Surface observations at 1200 GMT on 10/2/84.
3. Forecast tephigram near Camborne at T+36. VT 1200 GMT 10/2/84.
4. Camborne upper air sounding at 1200 GMT on 10/2/84.
5. T+36 forecast vertical velocity at sigma level $3\frac{1}{2}$. Rising air is shaded, quickly rising air is heavily shaded.
6. Backward trajectory locations from T+36 every 6 hours to T+0.
7. Model tephigrams at points shown in figure (6) from T+0 to T+36. The dynamic rainfall rates in tenths of a millimetre per hour are shown in DYNC at the top of the tephigrams.
8. T+0 fine mesh mean sea level pressure.
9. Fine mesh initial field. Vertical cross-sections of relative humidity, temperature and wind along latitude 53N from 21W to 9W.
10. T+3 forecast vertical velocity at sigma level $3\frac{1}{2}$. Rising air is shaded, quickly rising air is heavily shaded.
11. T+12 forecast vertical velocity at sigma level $3\frac{1}{2}$.
12. T+21 forecast vertical velocity at sigma level $3\frac{1}{2}$.
13. T+30 forecast vertical velocity at sigma level $3\frac{1}{2}$.
14. Coarse mesh 850 MB relative humidity analysis at 0000 GMT on 9/2/84.
15. Coarse mesh analysis of 500 MB height, 1000-500 MB thickness at 0000 GMT on 9/2/84.
16. Fine mesh start field at 0000 GMT on 9/2/84. Vertical cross-sections of relative humidity, temperature and wind along latitude 42N from 40W to 20W.
17. Coarse mesh update analysis at 0000 GMT on 9/2/84. Vertical cross-sections of relative humidity, temperature and wind along latitude 42N from 40W to 20W.
18. ECMWF analysis at 0000 GMT on 9/2/84. Vertical cross-sections of relative humidity, temperature and wind along latitude 42N from 40W to 20W.

19. ECMWF background field. Vertical cross-sections of relative humidity, temperature and wind along latitude 42N from 40W to 20W.
20. Met Office background field valid at 0000 GMT on 9/2/84, DT 1800 GMT 8/2/84. Vertical cross-sections of relative humidity, temperature and wind along latitude 42N from 40W to 20W.

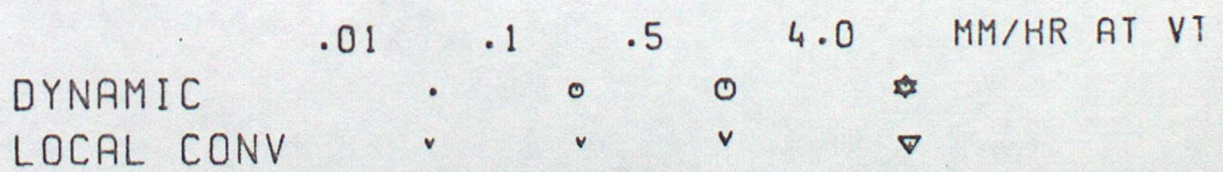
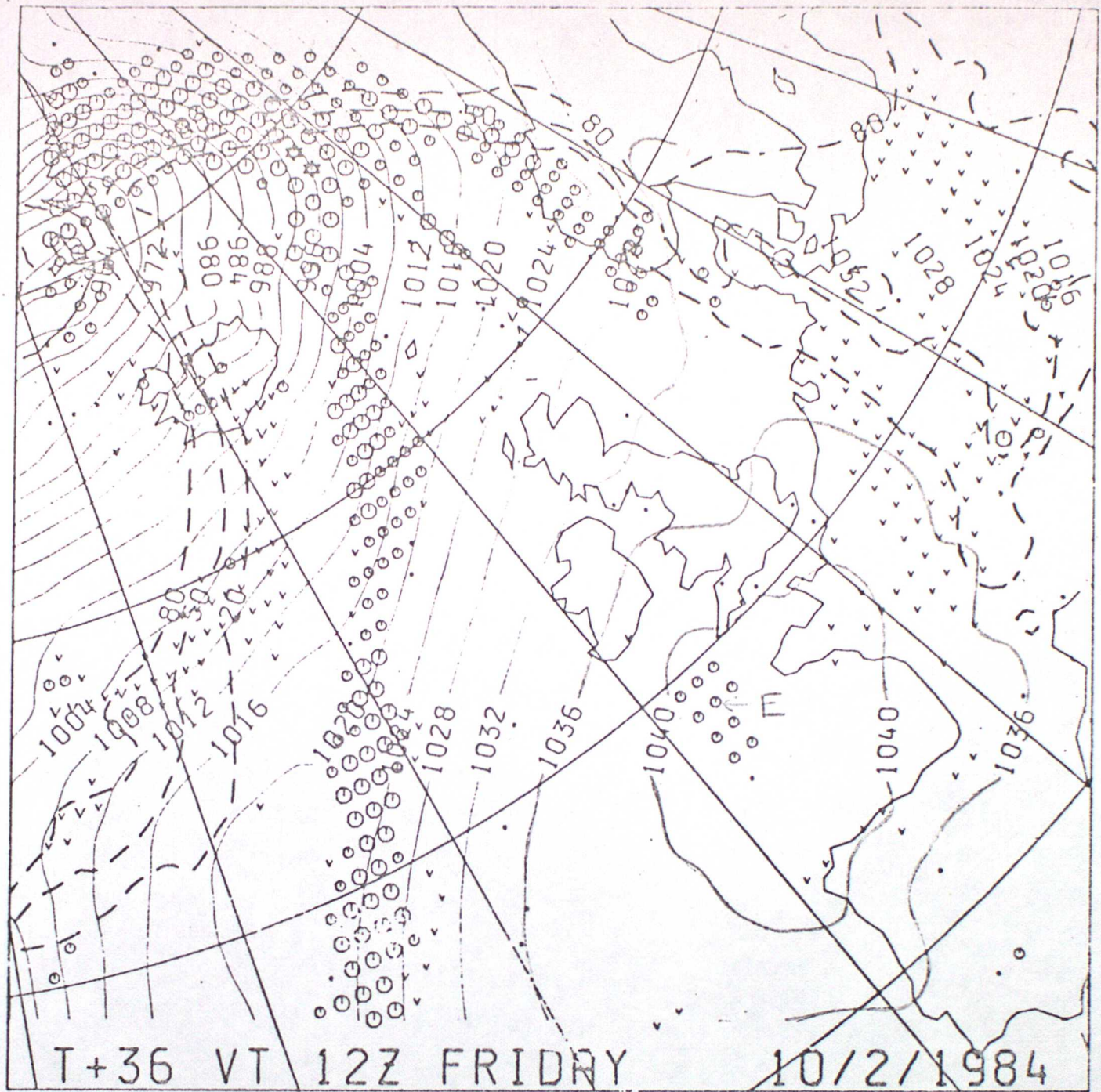
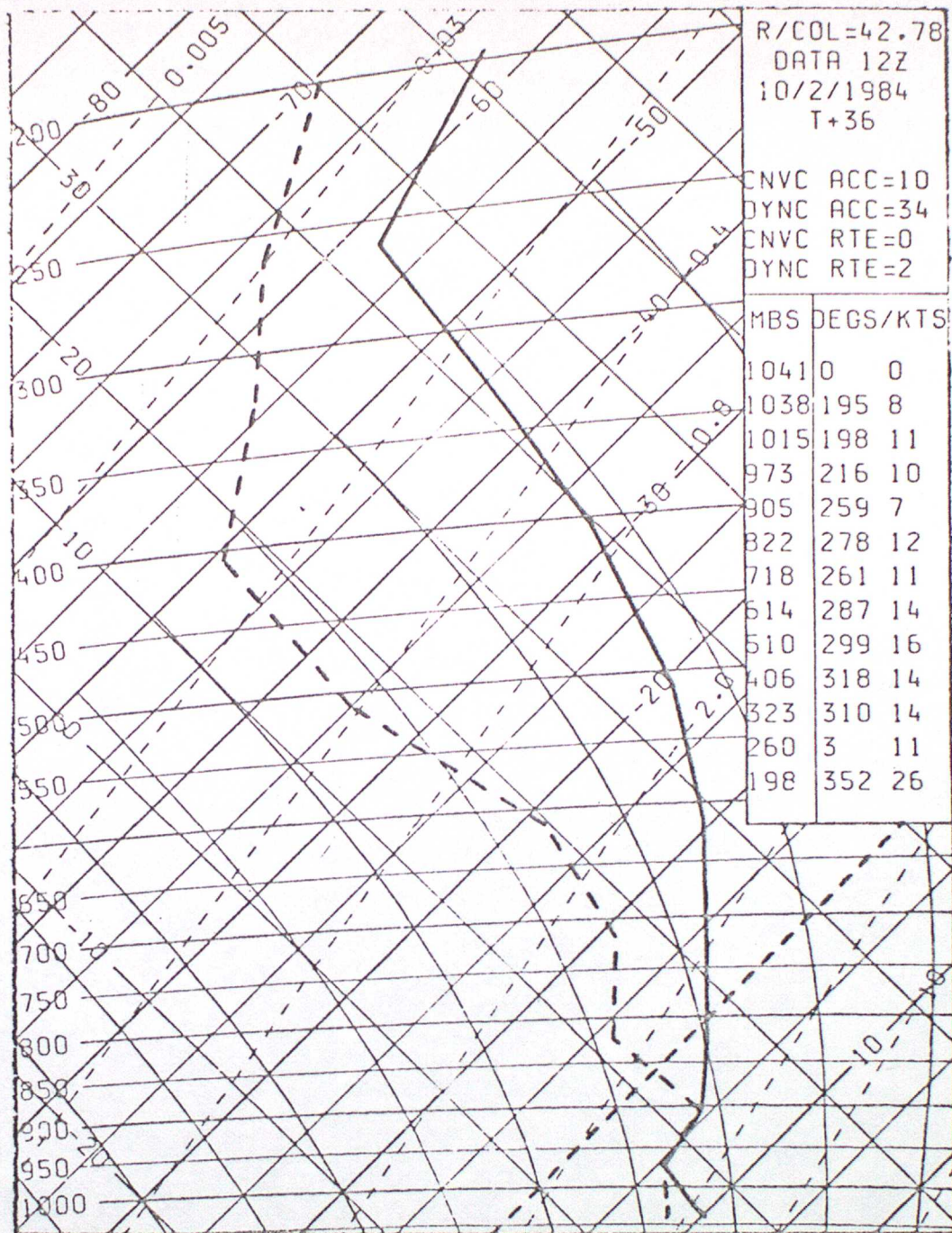


FIGURE 1



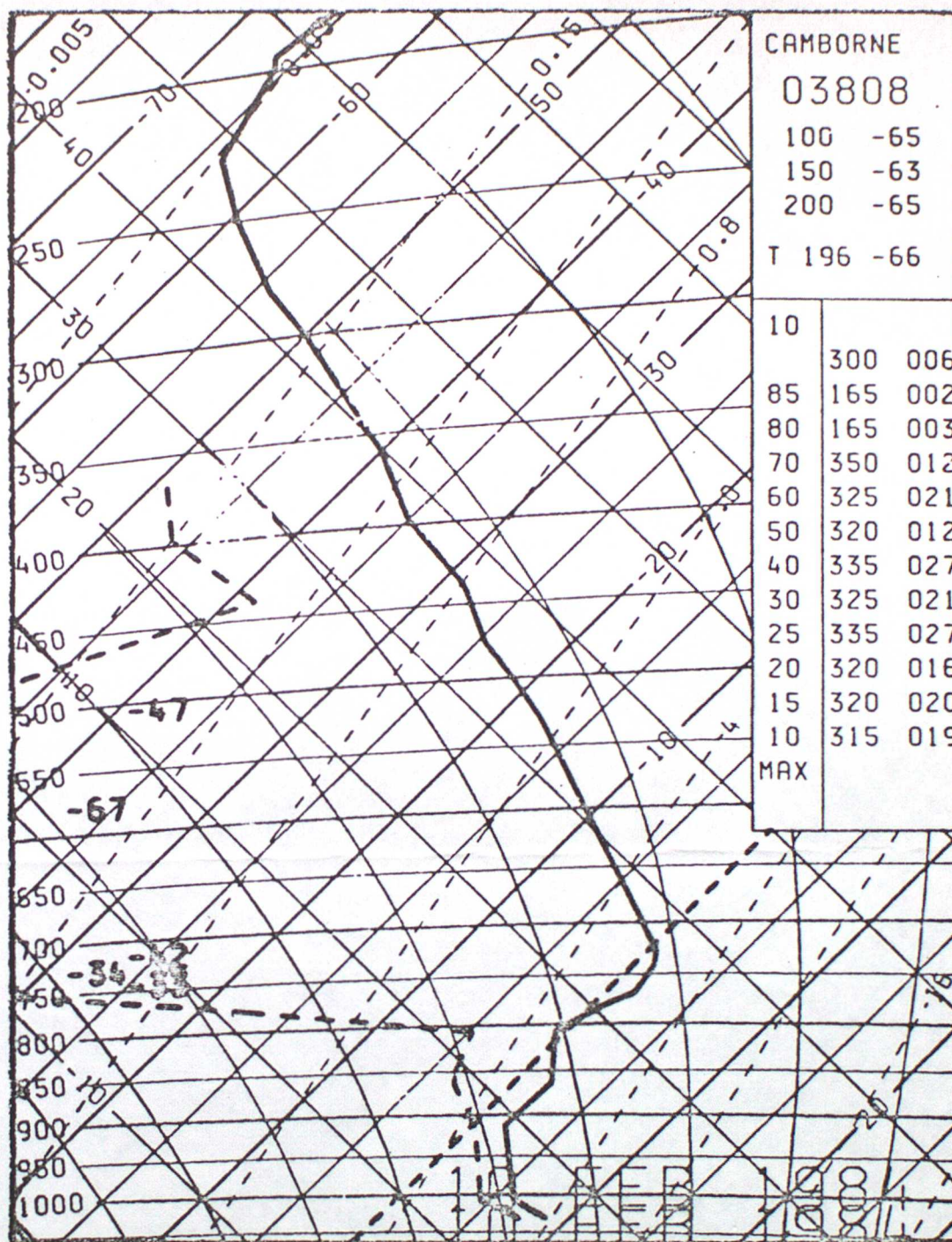


FIGURE 4

OPERATIONAL 09FEB DT00Z

VT 12Z 10/2/1984

FINE-MESH F/C MAIN RUN

OMEGA (MB/HR) AT SIGMA-LEVEL $3\frac{1}{2}$ DT 0Z 9/2/1984

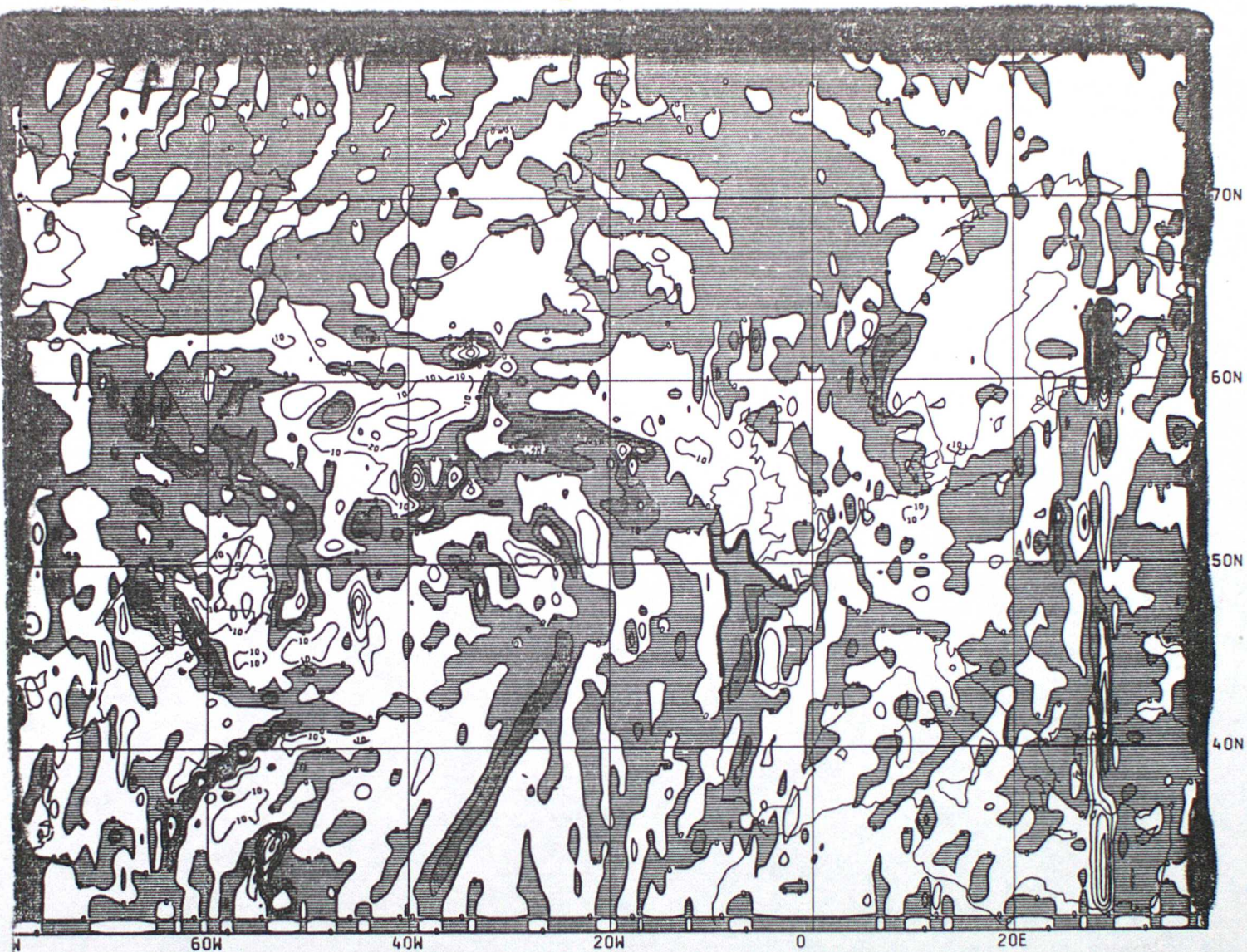


FIGURE 5

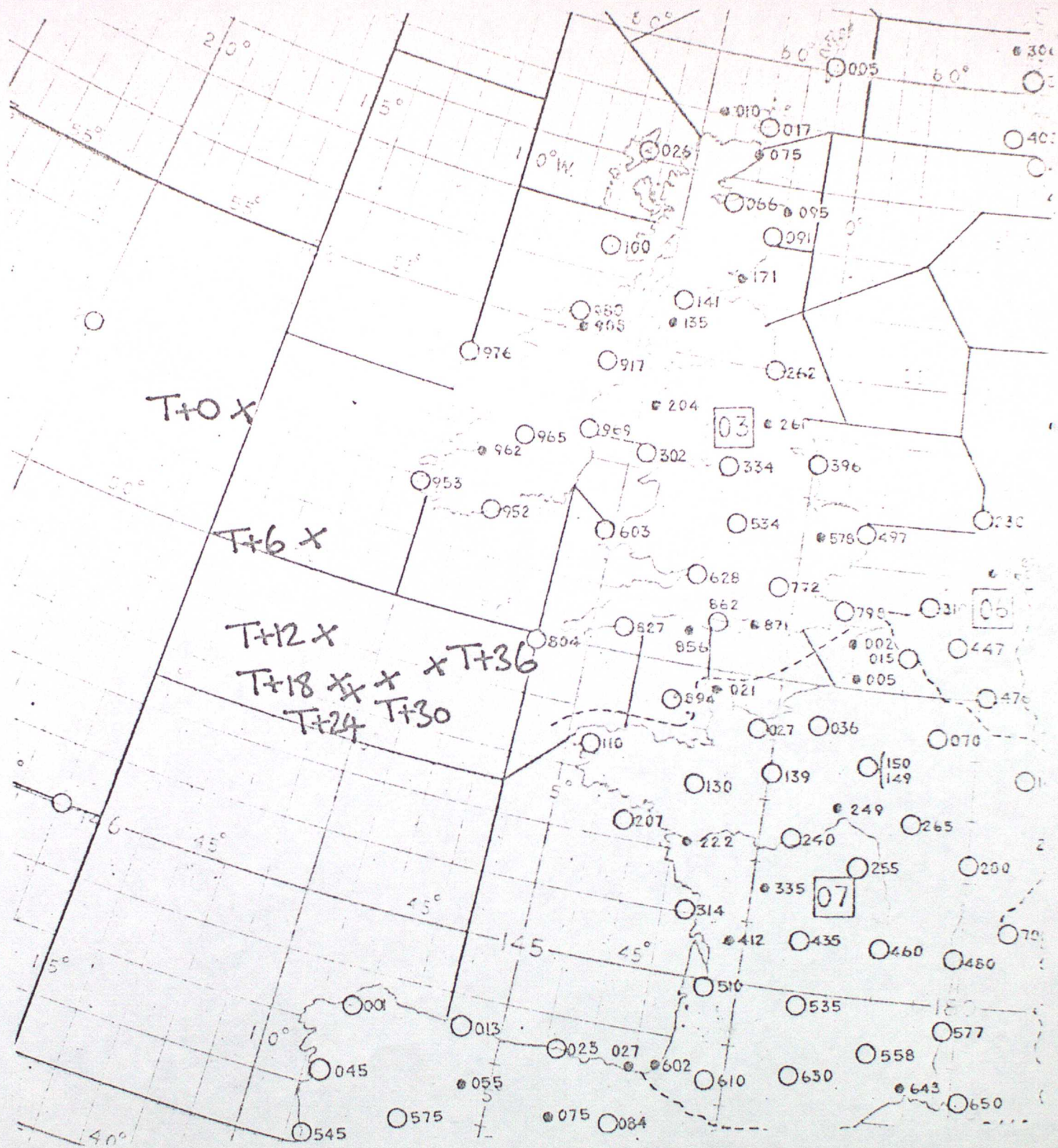


FIGURE 6

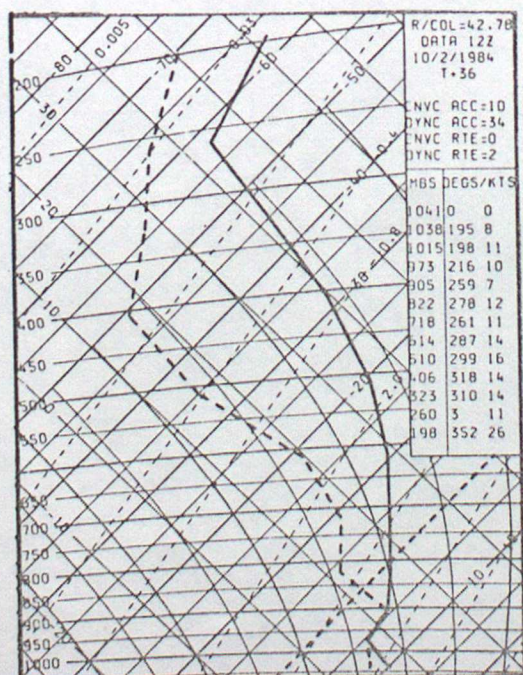
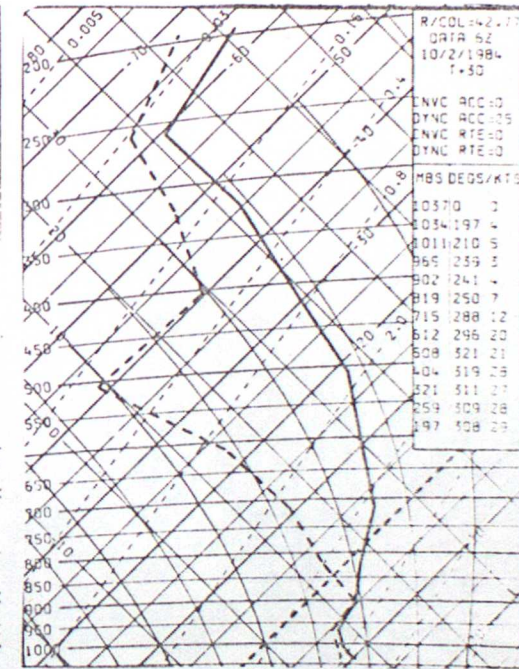
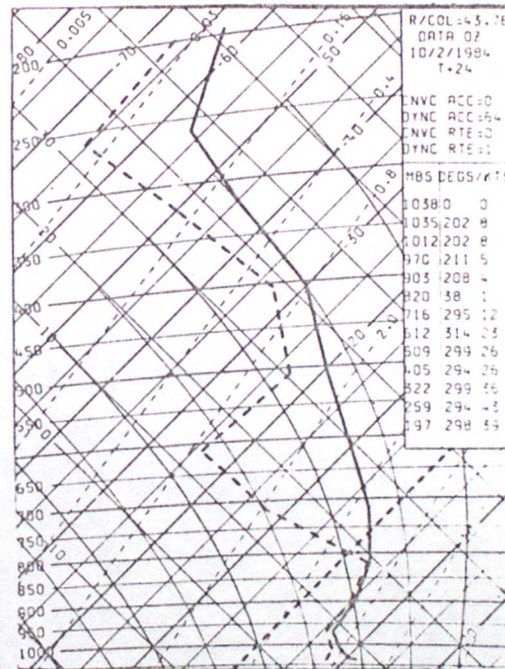
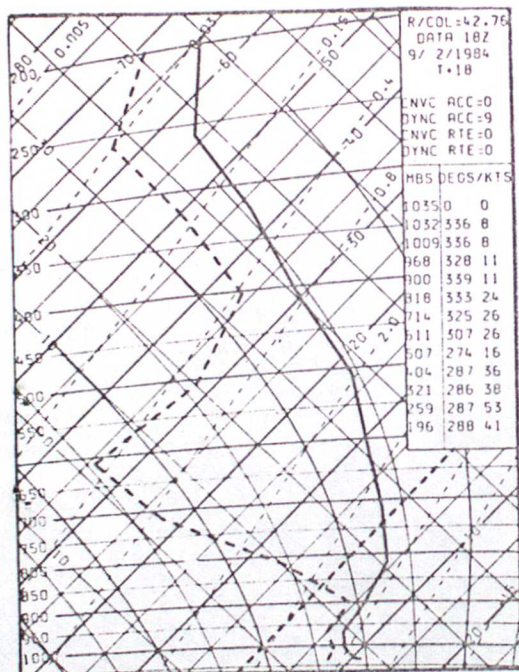
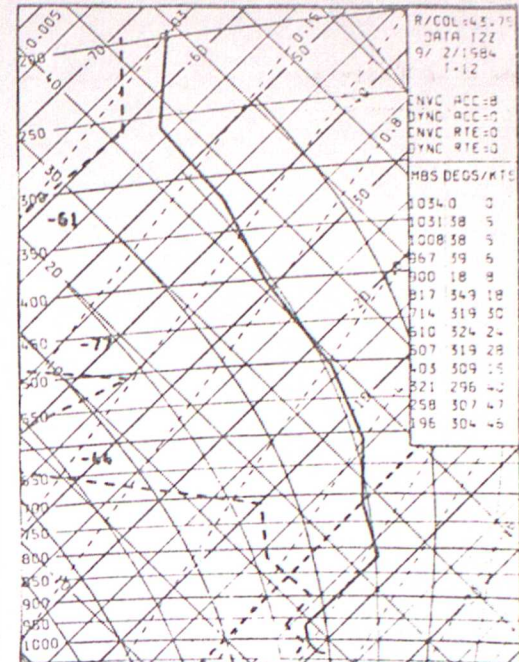
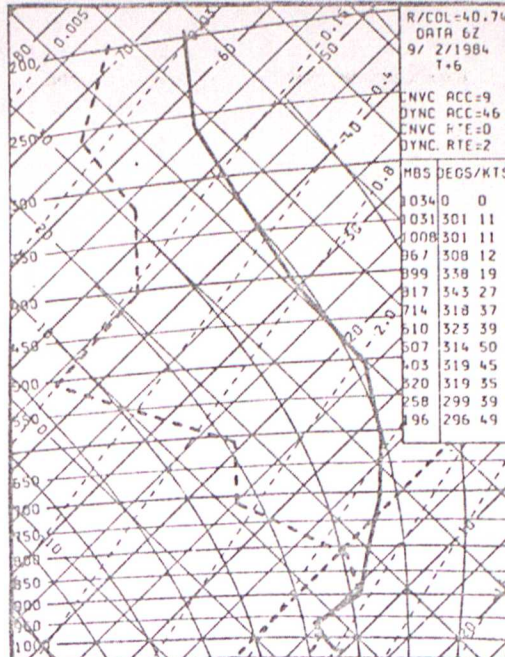
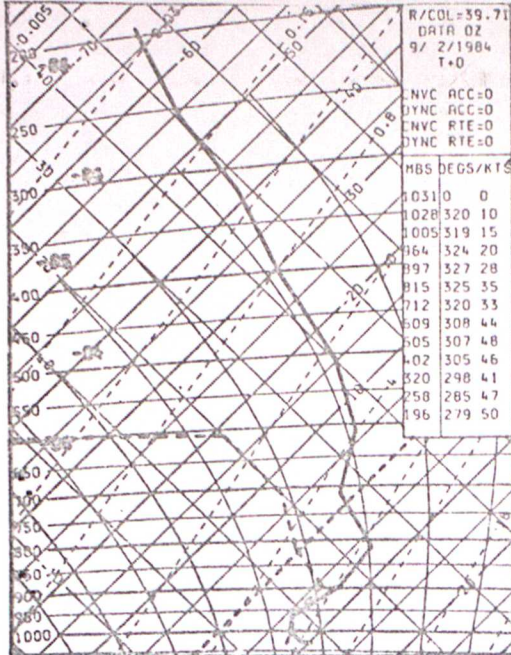
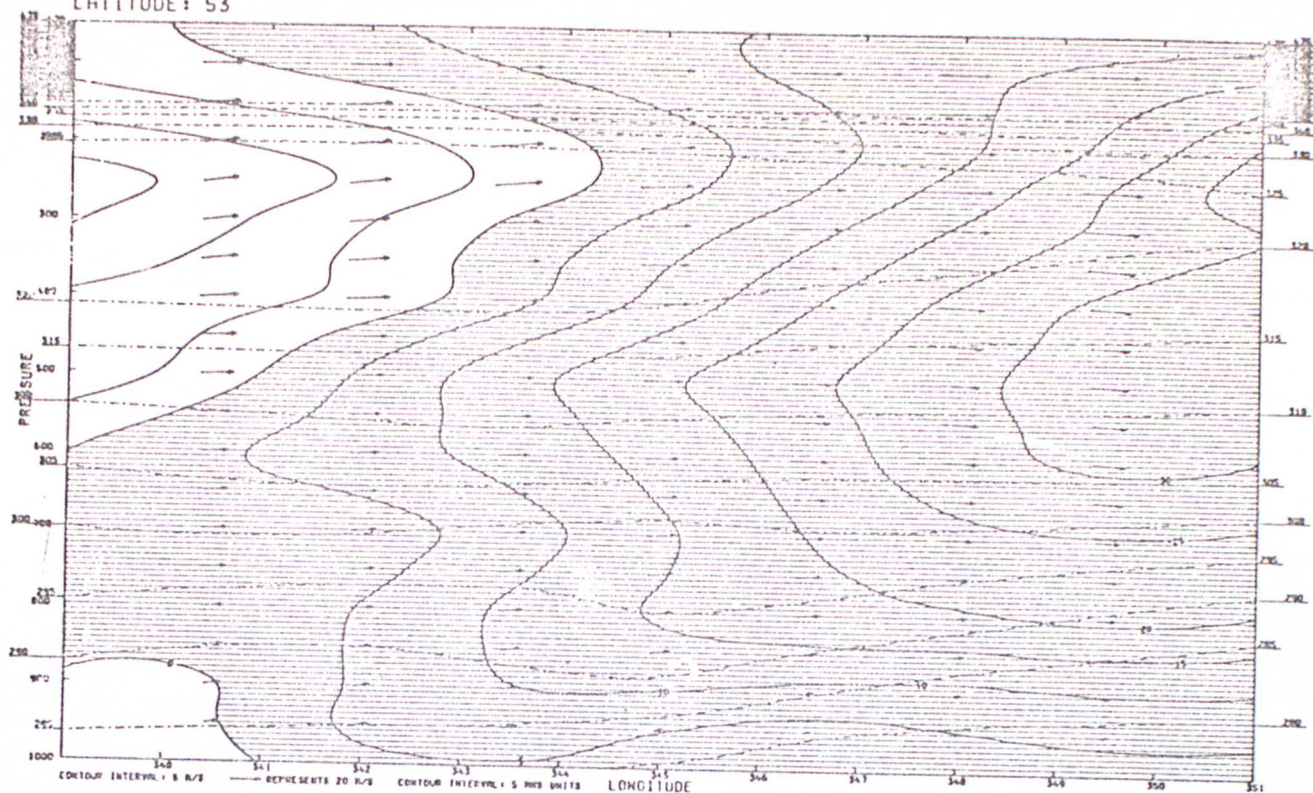


FIGURE 7

1

OPERATIONAL UPDATE ANALYSIS
 E-W X-SECTION. V-SOLID CONTOURS -VE SHADED. U&W-ARROWS. POT.TEMP=PECKED CONTOURS
 VALID AT 0Z ON 9/2/1984 DAY 40
 LATITUDE: 53



OPERATIONAL UPDATE ANALYSIS
 E-W X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
 VALID AT 0Z ON 9/2/1984 DAY 40
 LATITUDE: 53

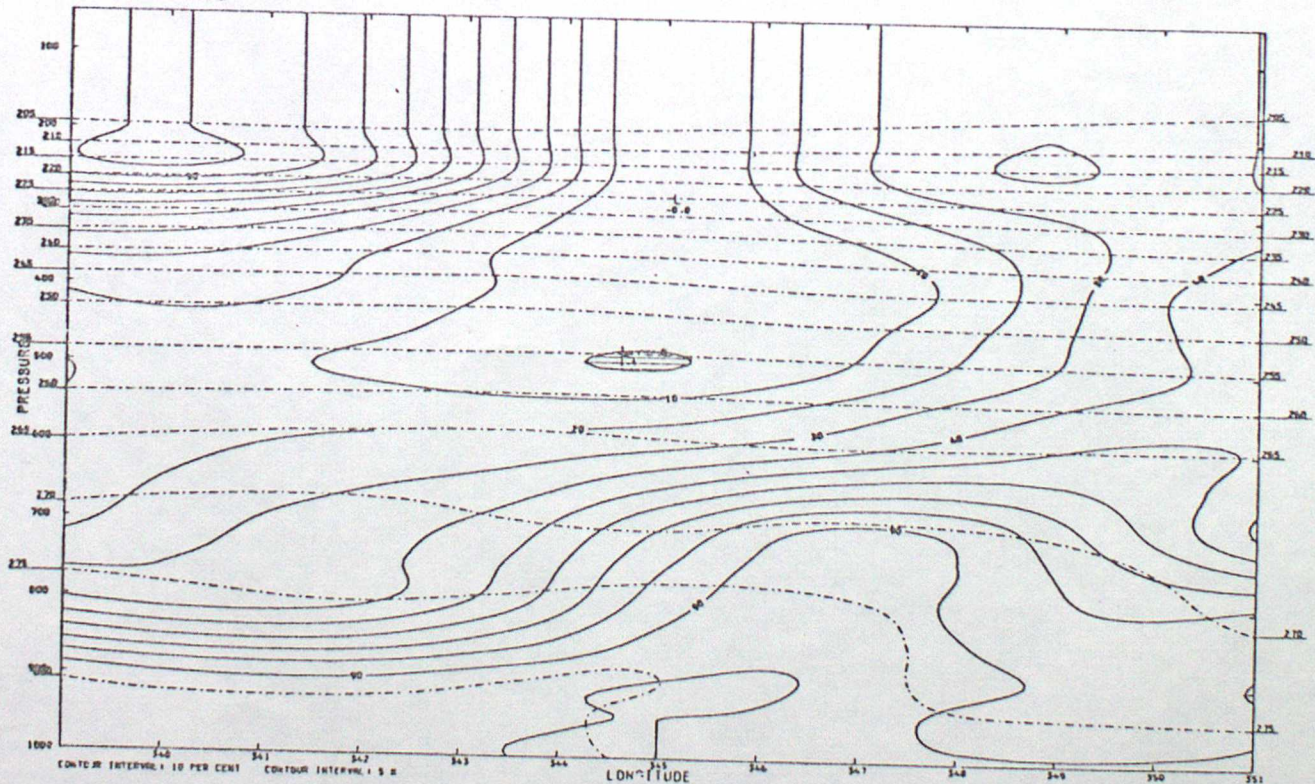


FIGURE 9

OPERATIONAL 09FED DT00Z

VT 3Z 9/2/1984

FINE-MESH F/C MAIN RUN

OMEGA (MB/HR) AT SIGMA-LEVEL $3\frac{1}{2}$ DT 0Z 9/2/1984

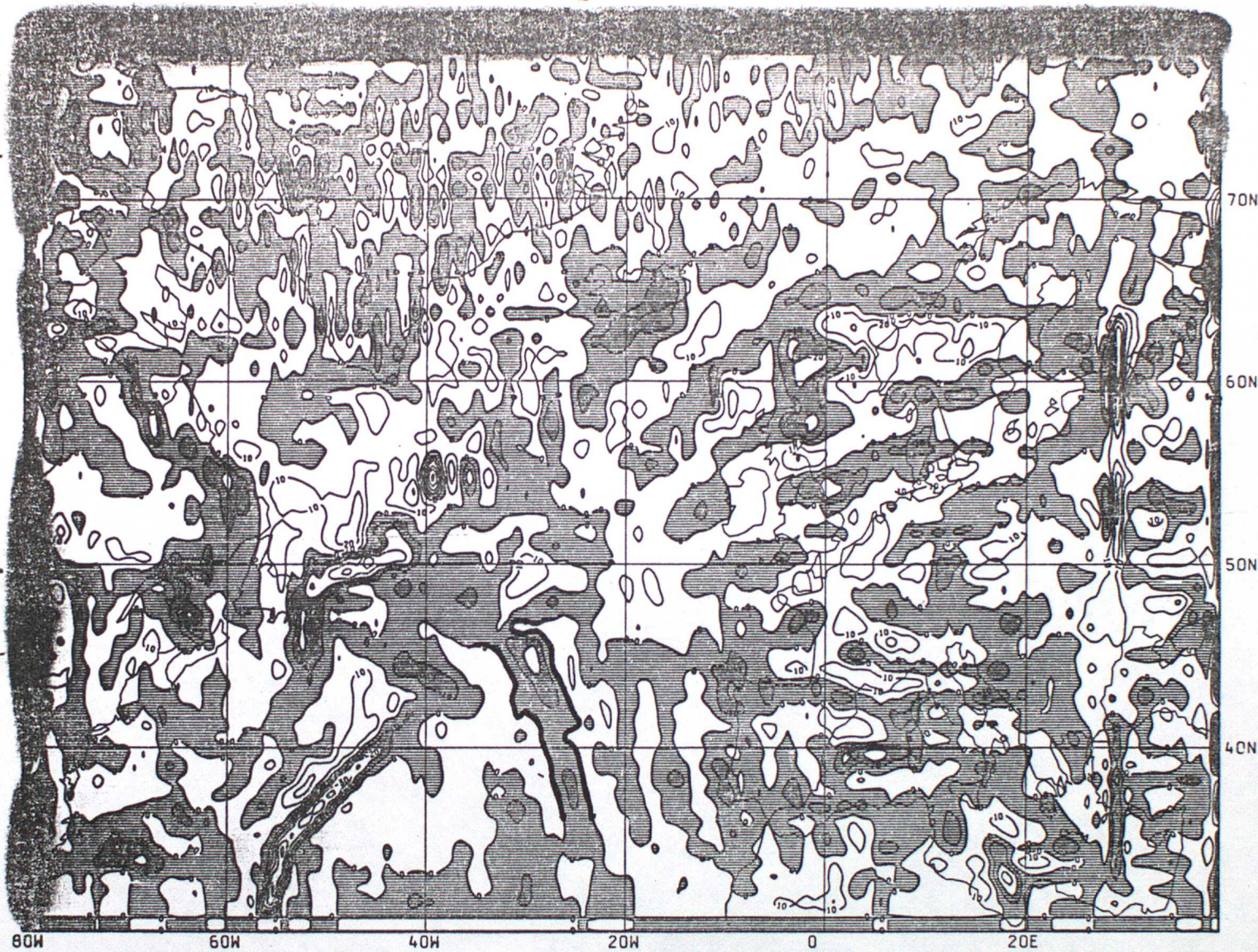


FIGURE 10

OPERATIONAL 09FEB DT00Z

VT 12Z 9/2/1984

FINE-MESH F/C MAIN RUN

OMEGA (MB/HR) AT SIGMA-LEVEL $3\frac{1}{2}$ DT 0Z 9/2/1984



FIGURE 11

OPERATIONAL 09FEB DT00Z

VT 21Z 9/2/1984

FINE-MESH F/C MAIN RUN

OMEGA (MB/HR) AT SIGMA-LEVEL $3\frac{1}{2}$ DT 0Z 9/2/1984

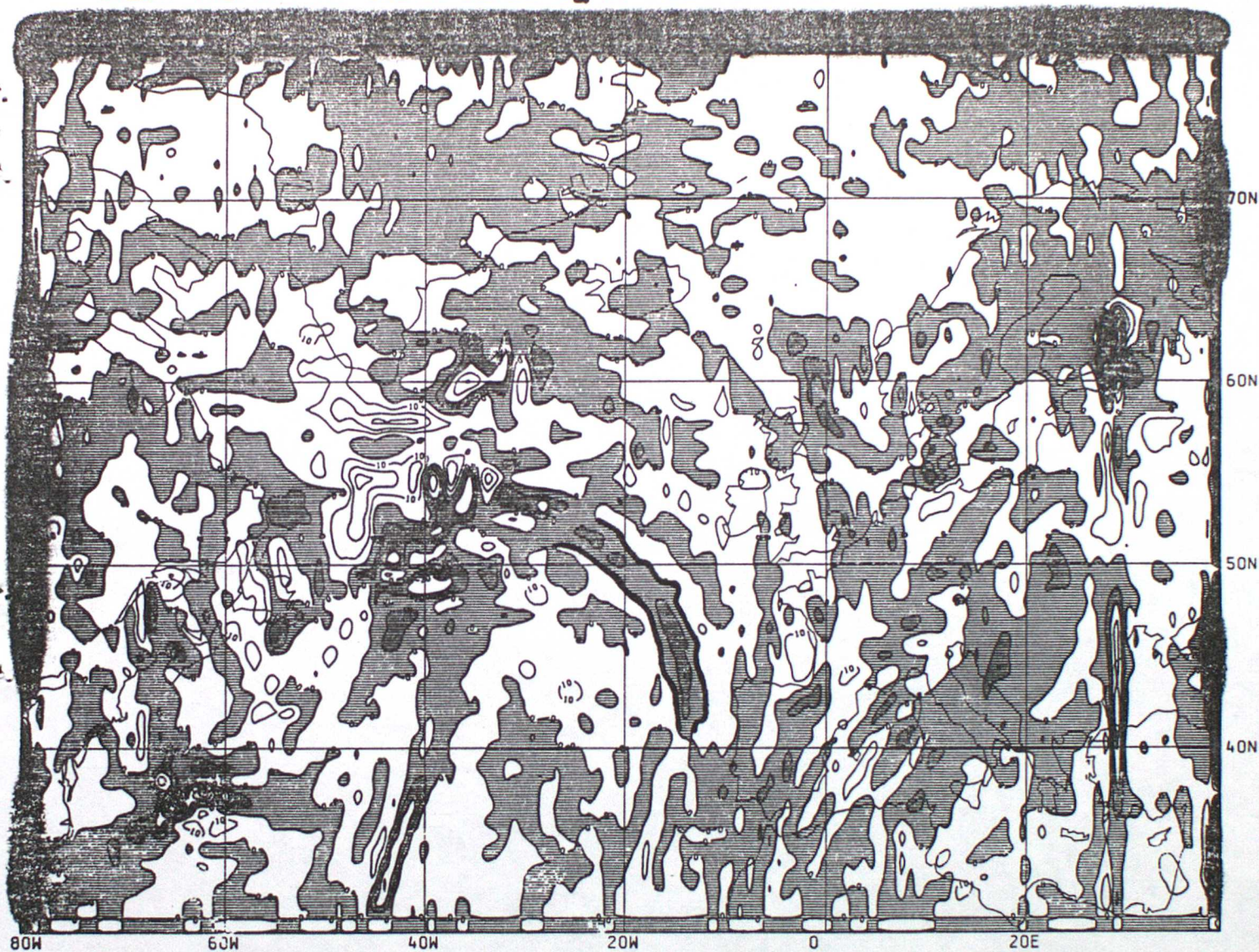


FIGURE 12

OPERATIONAL 09FEB DT00Z

VT 6Z 10/2/1984

OMEGA (MB/HR) AT SIGMA-LEVEL $3\frac{1}{2}$ DT 0Z 9/2/1984

FINE-MESH F/C MAIN RUN



FIGURE 13

UK ANALYSIS
RELATIVE HUMIDITY
VALID AT 0Z ON 9/2/1984 DAY 40
LEVEL: 850 MB

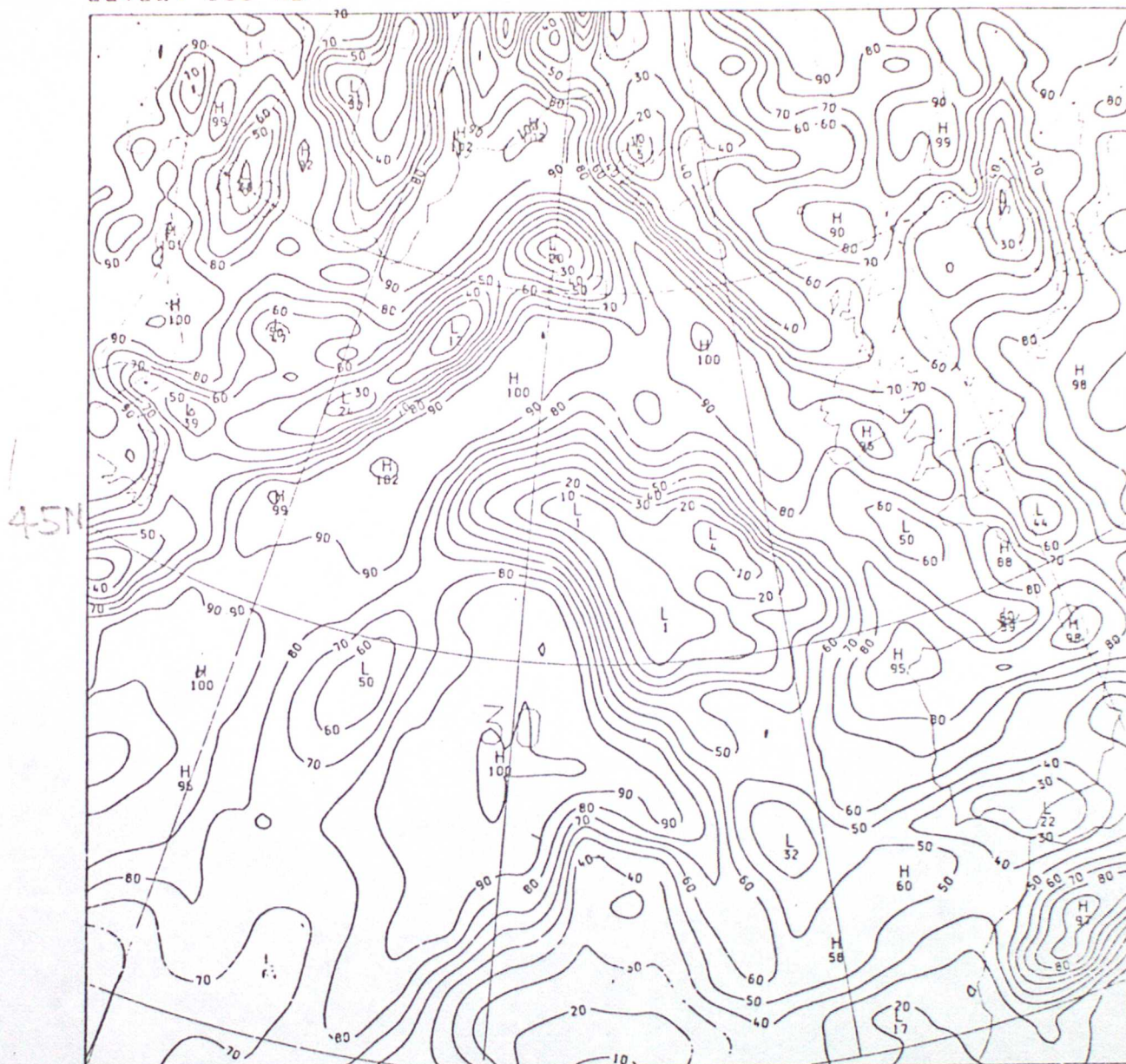


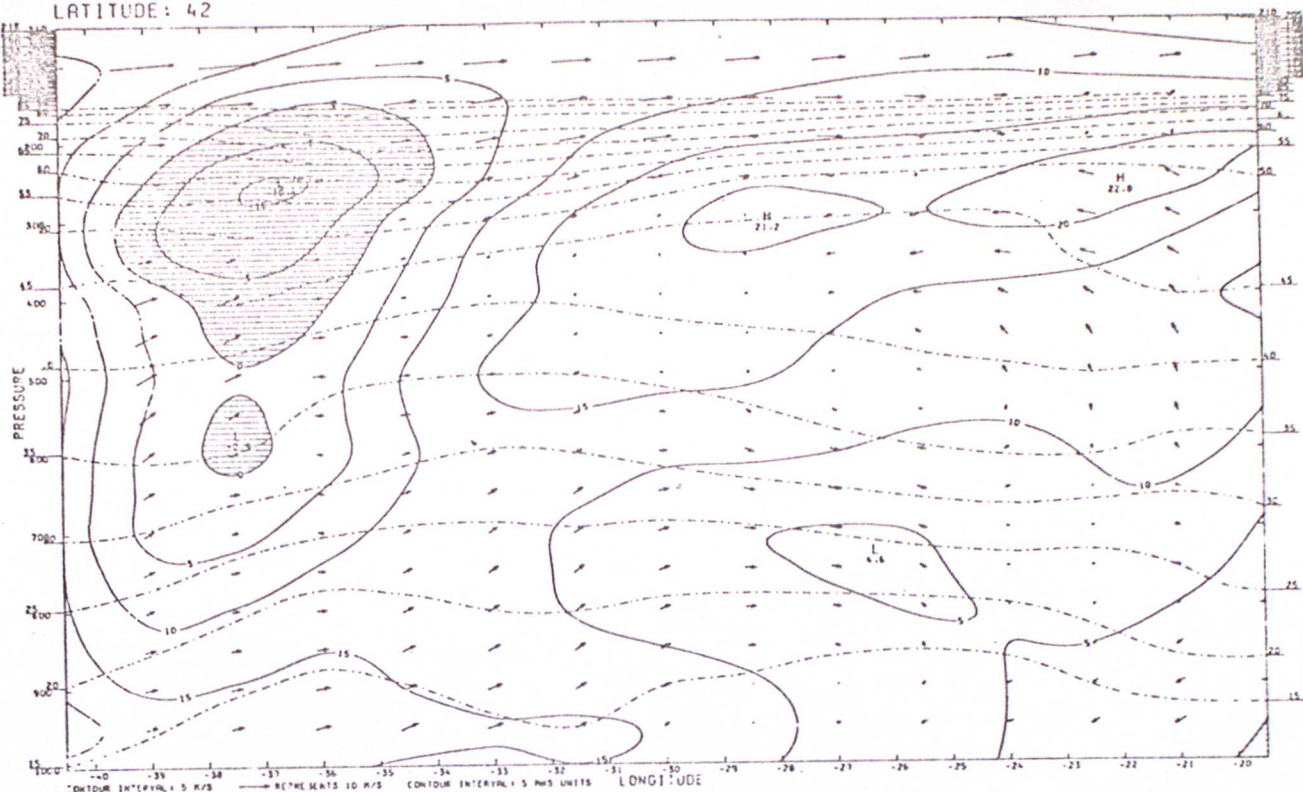
FIGURE 14

DT 0Z THUR 9/2/84 VT 0Z THUR 9/2/84 MAIN T+0 HEIGHT DM. 500 MB
 DT 0Z THUR 9/2/84 VT 0Z THUR 9/2/84 MAIN T+0 THICKNESS DM. 500-1000MB



FIGURE 15

FINE MESH ANALYSIS
 E-W X-SECTION. V=SOLID CONTOURS -VE SHADED. U&W=ARROWS. POT.TEMP=PECKED CONTOURS
 VALID AT 0Z ON 9/2/1984 DAY 40
 LATITUDE: 42



FINE MESH ANALYSIS
 E-W X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
 VALID AT 0Z ON 9/2/1984 DAY 40
 LATITUDE: 42

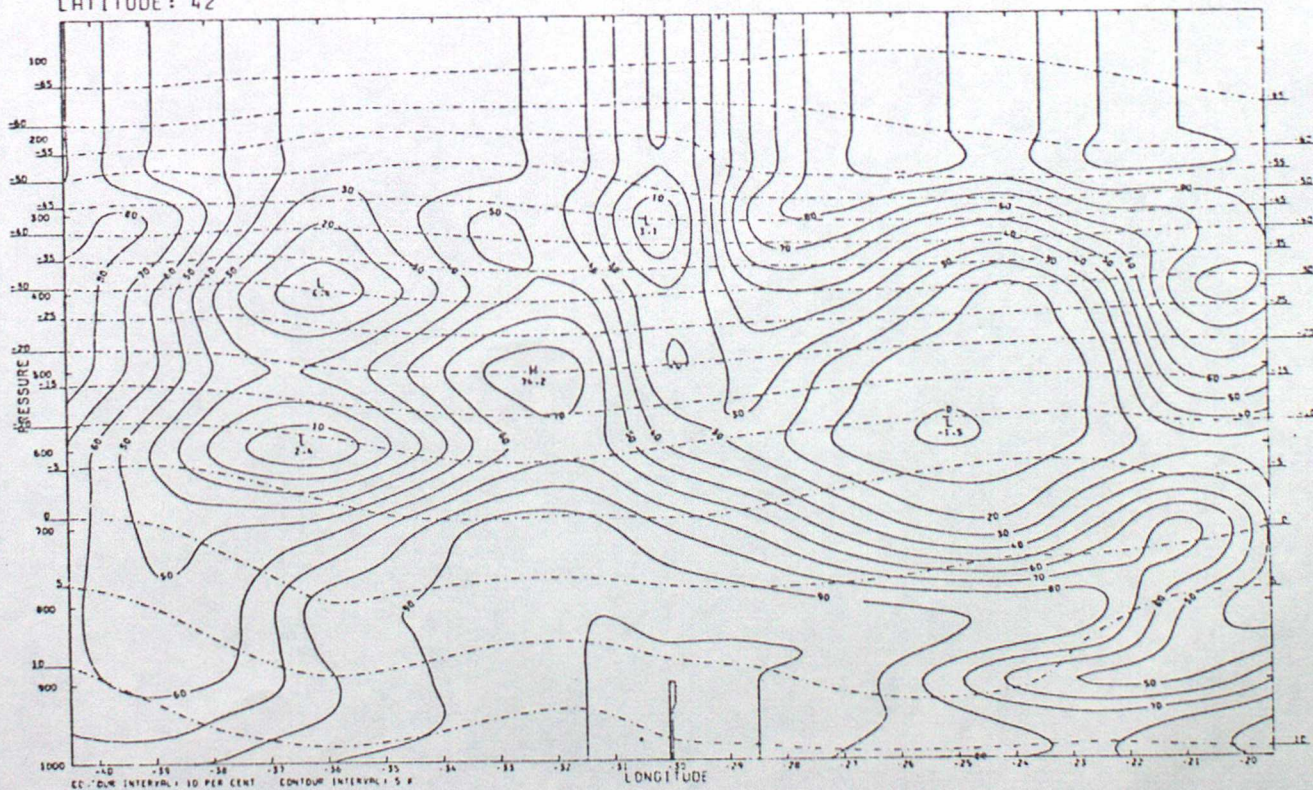
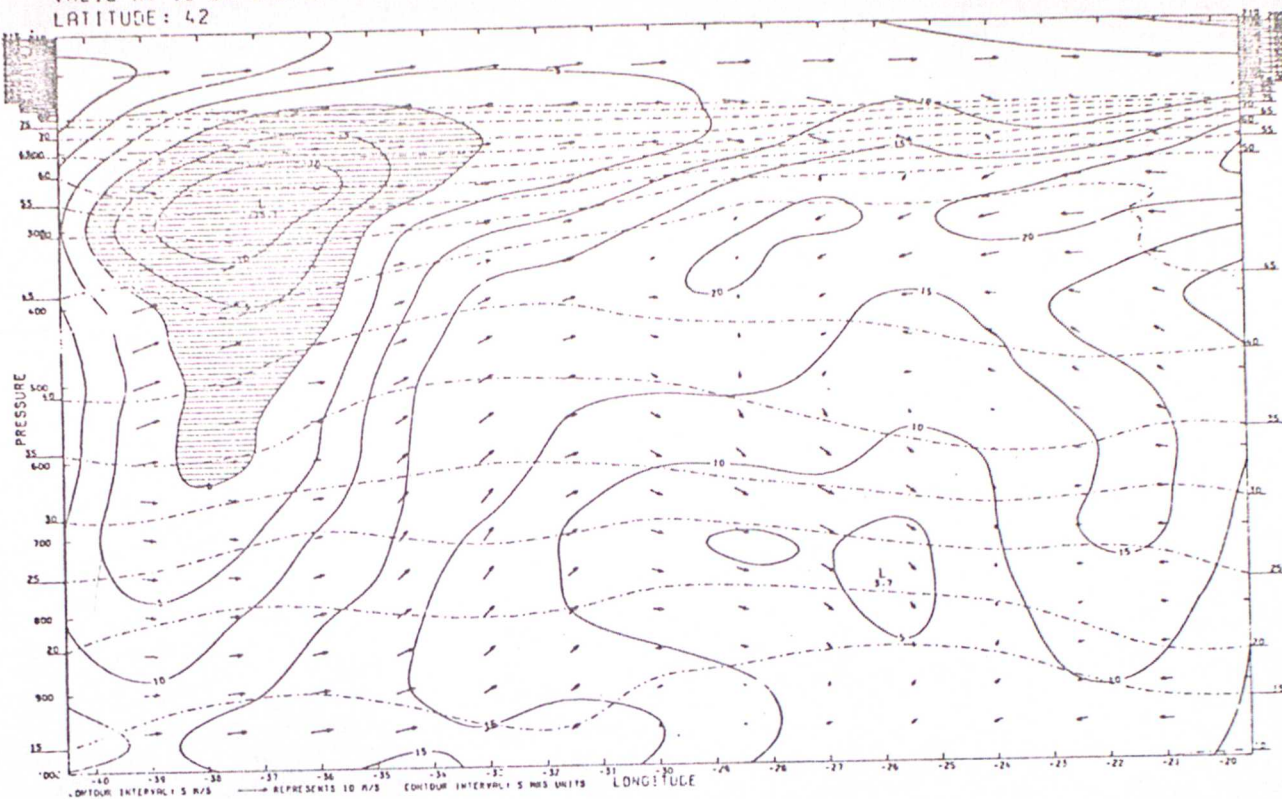


FIGURE 16

COARSE MESH ANALYSIS (UPDATE RUN)
 E-W X-SECTION. V=SOLID CONTOURS -VE SHADED. U&W=ARROWS. POT.TEMP=PECKED CONTOURS
 VALID AT 0Z ON 9/2/1984 DAY 40
 LATITUDE: 42



COARSE MESH ANALYSIS (UPDATE RUN)
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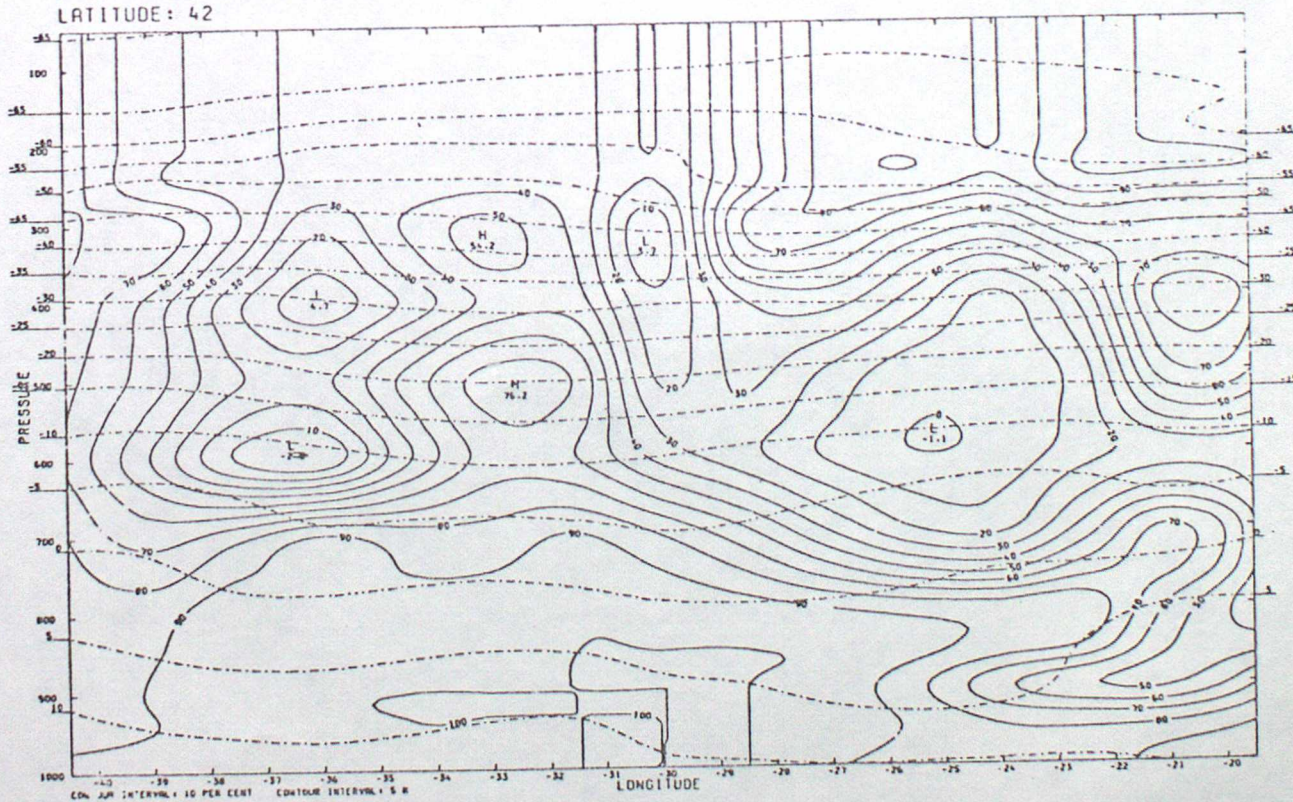
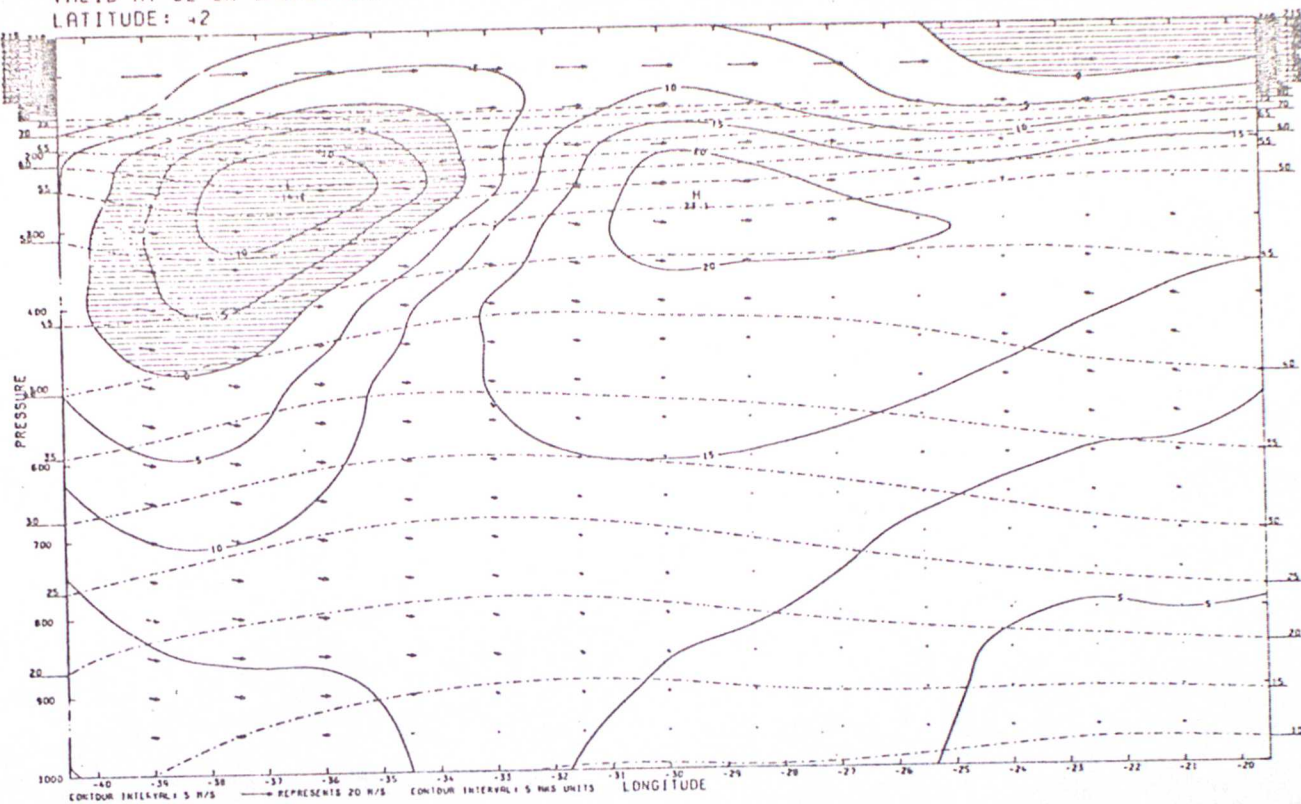


FIGURE 17

ECMWF ANALYSIS
 E-W X-SECTION. V=SOLID CONTOURS -VE SHADED. U&W=ARROWS. POT.TEMP=PECKED CONTOURS
 VALID AT 0Z ON 9/2/84 DAY 40
 LATITUDE: 42



ECMWF ANALYSIS
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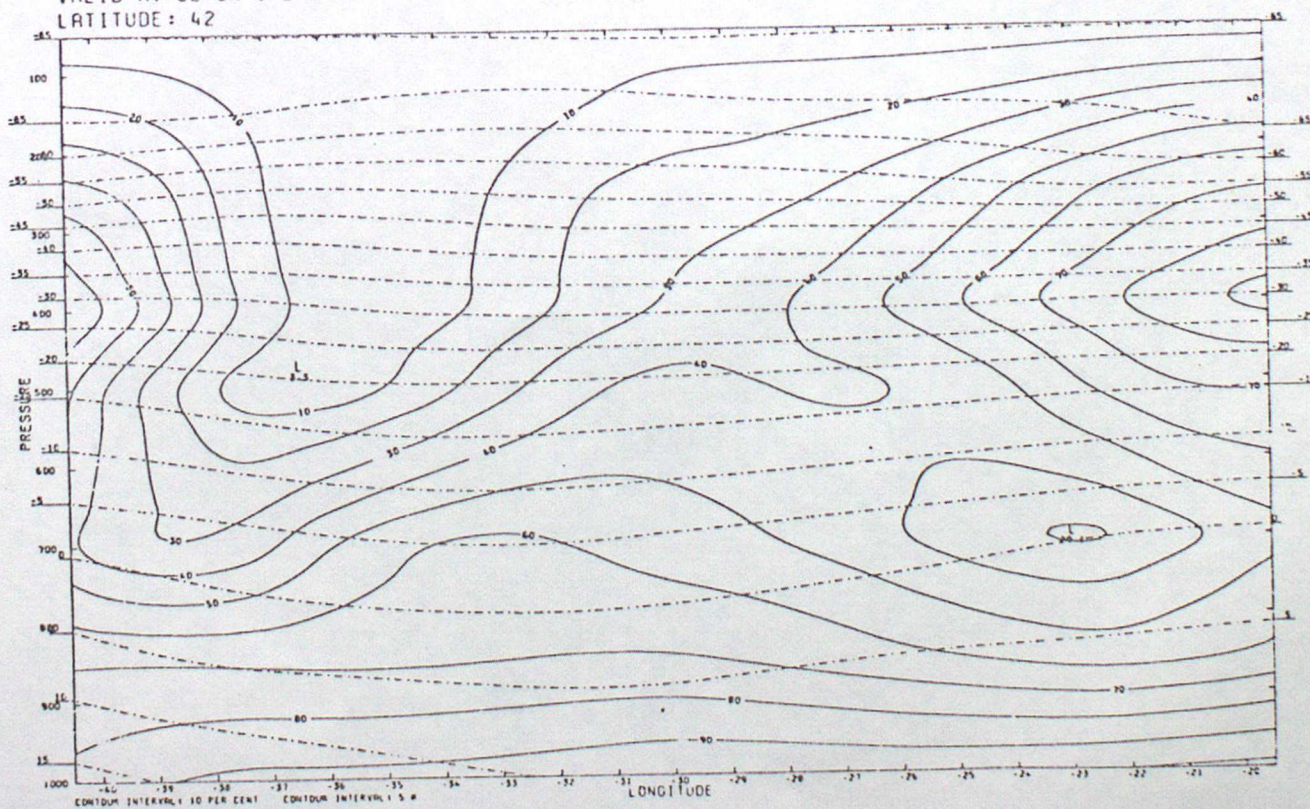


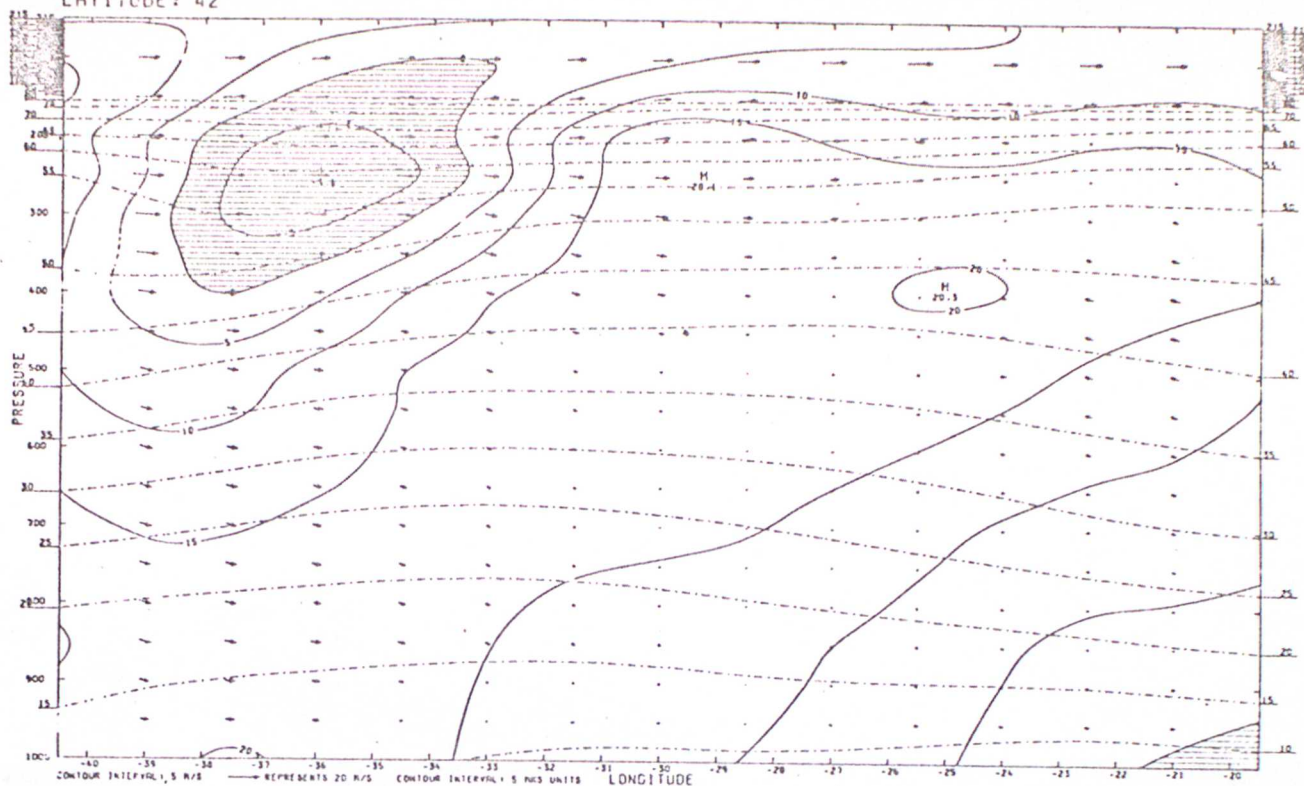
FIGURE 18

ECMWF BACKGROUND

E-W X-SECTION. V=SOLID CONTOURS -VE SHADED. U&W=ARROWS. POT.TEMP=PECKED CONTOURS

VALID AT 18Z ON 8/2/84 DAY 39

LATITUDE: 42



ECMWF BACKGROUND

E-W X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.

VALID AT 18Z ON 8/2/84 DAY 39

LATITUDE: 42

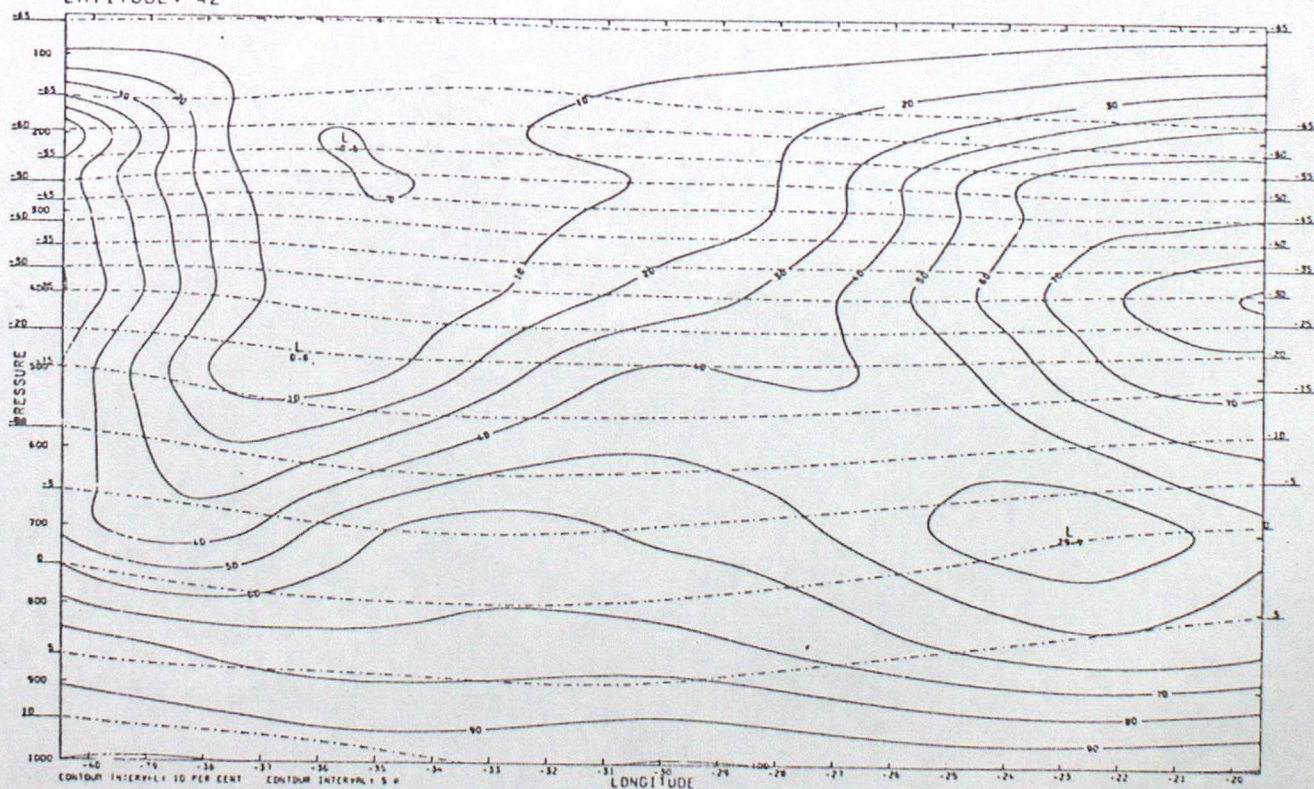
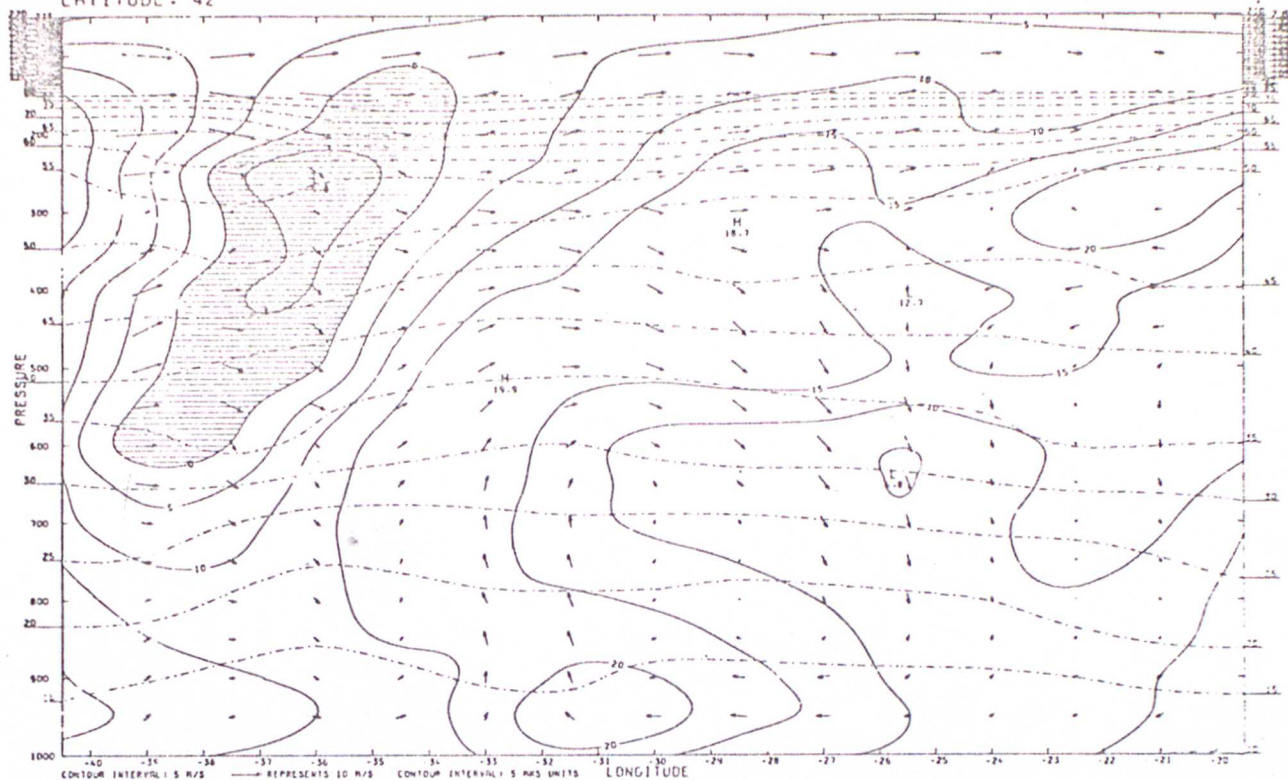


FIGURE 19

MET OFFICE BACKGROUND

E-W X-SECTION. V=SOLID CONTOURS -VE SHADED. U&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 0Z ON 9/2/1984 DAY 40 DATA TIME 18Z ON 8/2/1984 DAY 39
LATITUDE: 42



MET OFFICE BACKGROUND

E-W X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 0Z ON 9/2/1984 DAY 40 DATA TIME 18Z ON 8/2/1984 DAY 39
LATITUDE: 42

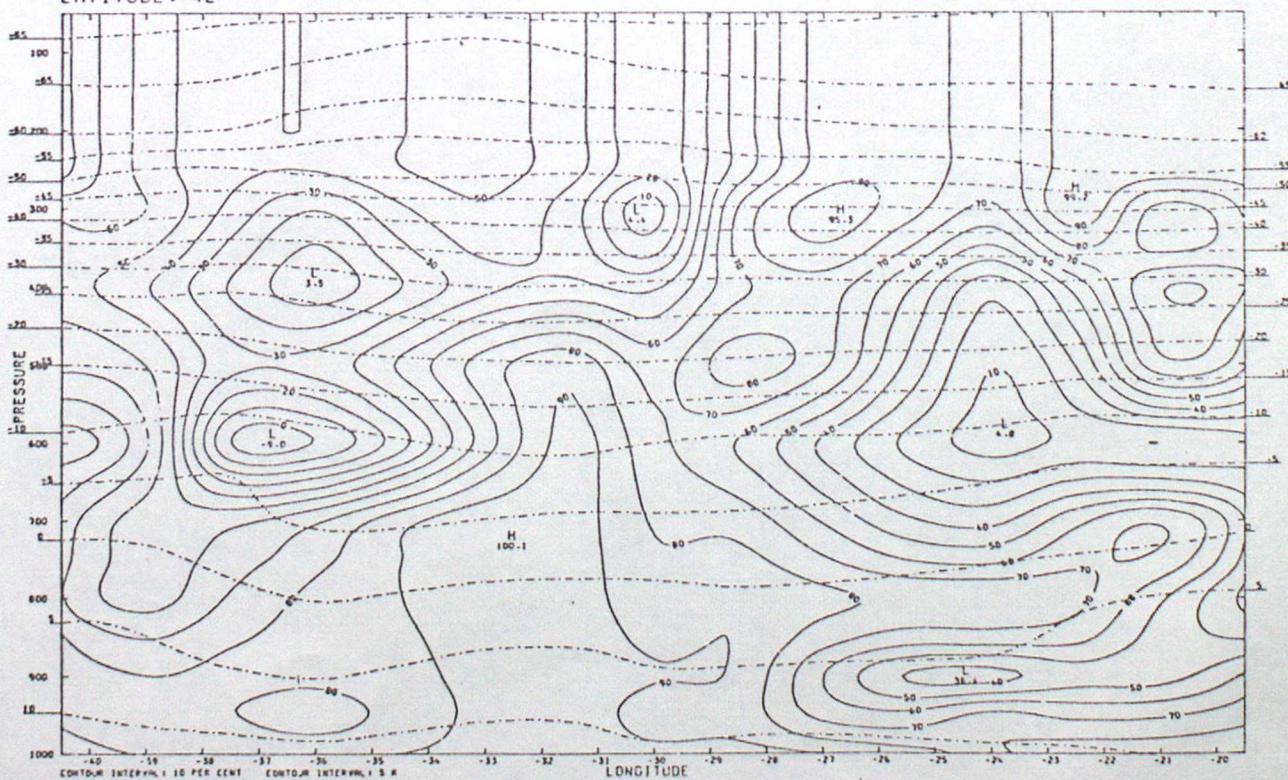


FIGURE 20