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A CASE STUDY OF COARSE MESH MODEL FIELDS FROM DATA ASSIMILATION EXPERIMENTS CARRIED OUT FOR 12Z 20 SEPTEMBER 1983

by

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Contents

1. Introduction

The 12Z 20/9/83 assimilation was selected as a case meriting further investigation following a criticism by CFO of the operational coarse and fine mesh sea level pressure (PMSL) analyses of low T at 45 N 20 W. The CFO surface analysis is shown in Figure 1a.

Preceding surface analyses suggested a history of a depression centre of less than 1000 mb and the 12Z surface data confirmed this giving sound evidence for a centre of 1000 mb or less. Indeed, when the depression centre crossed ship ROMEO (47 N, 17 W) between 15Z and 16Z on the 20/9/83 the reported pressures suggested a centre of 995 mb.

However, the operational coarse mesh analysed a central pressure of 1004 mb. This gave immediate grounds for doubt in the usefulness of the forecast product run from this assimilation, in terms of the subsequent development and motion of low T.

2. Aims

The aim of this report is to suggest possible causes for the poor fitting of pressure data in the anaysis of low T. There is an attempt to gain insight into the problem by looking at model diagnosed fields from the same case rerun with various changes to the model. It is necessary to establish whether failure to fit the pressure observations was indicative of misrepresentation of the dynamics of low T or whether it was merely a 'cosmetic' error.

An investigation is also carried out to see how the differences between the various initial fields affected the forecast development of the depression in question.

The experiments carried out on the analysis/assimilation for 12Z 20/9/83 in this investigation are listed in Appendix I. A list of the figures in this paper appears in Appendix II.

3. Discussion

Figure 2f shows the background PMSL field valid at 12Z 20/9/83. Low T has a central pressure of 1000 mb, and is in a very similar position to that shown in the 12Z operational analysis. One must therefore conclude that the assimilation of the 12Z observations was responsible for the problem in PMSL analysis.

For brevity, the background field will usually be referred to as 'BACK' in the text.

3.1 Description of surface fields for various model runs

In order to investigate further the fitting of the observations and the balance achieved by the model after a 6 hour assimilation, the following assimilations were carried out using the data for 12Z 20/9/83.

(a) Using the operational model current on 20/9/83. This will be referred to as OPASSM. Figures 2a, 3a, 5a.

(b) Using the same operational model but with normal mode initialisation (NMI). This will be referred to as OPINIT. Figures 2b, 3b, 5b.

(c) Using the operational model with a modified wind relaxation coefficient, henceforth referred to as DASSM. Figures 2c, 3c, 5c. In this case the effect of the wind increments is progressively reduced to zero near the end of the assimilation period.

(d) Using DASSM, but with divergence damping removed. This assimilation will be referred to as DNODD. Figures 2d, 3d, 5d.

(e) A univariate optimal interpolation analysis was carried out for 12Z 20/9/83. This will be referred to as UNOI. Figures 2e, 3e, 5e.

3.1.1 Figure 2a shows the operational PMSL and 1000 mb wind analysis with the verifying SDB observations.

It is immediately evident that ship observation 'A' with a pressure of 1000.9 mb has not been fitted. At this point the observation differs from the analysed pressure field by about 4 mb.

There also appear to be problems in fitting the reported wind directions, most notably at ship observation E. A considerable amount of ageostrophic motion is present in the analysis (Figure 2a) particularly on the southern side of low T. This takes the form of marked cross-isobar flow in the SW quadrant. In this area, we find at 42 N 28 W a separate high centre analysed in the PMSL field which is not present in the wind field. As a consequence of ageostrophy the centres of low T as defined by the pressure field and the wind field do not coincide. However, the displacement between the two is only of the order of a model gridlength. (Resolution of low T is discussed further in terms of model gridlength in section 3.8).

3.1.2 The operational assimilation run with NMI has an improved fit of the surface observation of 1000.9 mb near the depression centre. This is shown up well in Figure 4b a difference chart in PMSL for OPASSM-OPINIT. However, not all the wind directions have been fitted, again most notably at E. There is also less of a mismatch between the depression centre as defined by the wind and pressure fields than in the uninitialised version.

Ageostrophic motion is still present except that it is considerably less than in OPASSM in the southwest quadrant of the depression. The flow is in much better geostrophic balance around 42 N 20 W in OPINIT than OPASSM. (Figure 3b).

Marked troughing extending northeast from the depression centre (probably brought about by the right entrance area of a jet stream aloft) in OPASSM is much less pronounced in OPINIT where the main axis extends generally eastwards.

If one regards the NMI as representing one definition of a 'balanced' field, one can say that there was a rather unrealistic amount of imbalance being forced in OPASSM in the southwest quadrant of the depression. This was presumably brought about by the observations in that area.

3.1.3 In DASSM the central pressure of low T is analysed as about 1002 mb. This is a significant improvement over OPASSM and is much nearer the observation of 1000.9 mb. This shows up particularly well on the difference chart (Figure 4a).

As with the initialised and uninitialised operational analyses there have been problems in fitting the wind directions, most noticeably at 'E'.

The amount of ageostrophic motion analysed at 1000 mb (Figure 3c) on the south western quadrant of low T is rather less than in OPASSM. A significant improvement has been achieved around 42 N 28 W where OPASSM had analysed a high centre in the pressure field, not present whatsoever in the wind field. However, as in the two runs already examined the centres of low T as defined by the PMSL and wind fields do not coincide.

The shape of the troughing to the northeast of the depression centre is similar to that in OPASSM.

3.1.4 In the D assimilation with zero divergence damping the central pressure of low T is analysed as 1003 mb, 1 mb higher than in DASSM. There is a noticeable difference in the position of the troughing in the PMSL pattern on the forward side of the depression. The shape appears more like that of OPINIT than DASSM. (Figures 2b and 2c). A considerably greater amount of ageostrophic motion is present on the southern and eastern side of the depression than in DASSM.

Maximum 700 mb vertical velocities associated with low T (Figure 5d and Table 1) are much greater than in any of the other assimilations. The value of -2300 units on the figure corresponds to around 20 cm/s uplift.

3.1.5 In the analysis performed using univariate optimal interpolation, the central pressure of low T is analysed as 1000 mb (Figure 2e), which is very close to the hand analysed value. The general shape of the depression appears more like that of the background field (Figure 2f) than any of the assimilations. As in the assimilations there is marked troughing to the east of the depression.

There is generally greater ageostrophic motion around low T in UNOI (Figure 3e) than in any of the assimilations. The wind observation at ship E appears to have been fitted more closely than in the assimilations but at the expense of geostrophic balance in that area (Figure 3e). This is understandable since in UNOI the wind data has been analysed independently of the pressure data and there is no assimilation process attempting to achieve a balanced state.

3.2 Vertical motion fields associated with low T

The distribution of 700 mb vertical velocity around low T is similar in all of the assimilations, with uplift concentrated into three extensions from the low centre. (Figures 5a-5d). In the diagrams the isopleths are of omega (dp/dt) with -1000 units being approximately equivalent to 10 cm/s upward motion at 700 mb.

There is a tongue of upward motion extending to the east northeast of low T with an associated troughing in the PMSL pattern. This feature appears realistic with both surface based observations and satellite imagery (not shown in the test) showing extensive high and medium level cloud well ahead of low T, confirming the presence of large scale uplift. All of the runs agree on the position of the tongue of upward motion associated with the warm front (the CFO analysed position of the warm front is probably in error). A reanalysis of the 12Z chart is shown in Figure 1b. There is agreement too about an axis of upward motion to the west of the depression along 45 N. This is taking place just forward of the upper trough axis. What does distinguish between the assimilations is the magnitude of the vertical motions as Table 1 shows. The zero divergence damping case by far has the greatest values of omega. The reasons for the differences will become more apparent in the next section where the vertical cross-sections through low T are examined.

The vertical motion fields associated with low T in the optimal interpolation and background fields are both similar but significantly different from the other runs. In UNOI and BACK, vertical velocity fields, Figures 5e and 5f, indicate the warm frontal zone to the south of low T but the area of maximum ascent is to the north of the depression (rather than to the east as in the assimilations). Other features common to UNOI and BACK but different from other runs are the increased vertical motion along a cold frontal zone to the east of low T, the increased subsidence within the warm sector, and a tongue of vertical motion to the north of the depression associated with the upper trough.

Figures 5a-5f show that all of the runs seem to have captured the main synoptic features associated with low T reasonably well, producing a picture consistent with the hand analysis in Figure 1b.

3.3 Examination of the vertical structure of low T

Figures 6 and 8 are cross sections along 20 W running through the analysed centre of the surface depression. The sections are of (i) divergence; (ii) humidity and temperature; (iii) u-wind component with arrows of v and w; for

(a) BACK

(b) OPASSM

(c) OPINIT

(d) DASSM

(e) DNODD

(f) DASSM rerun without ships wind observations near low T.

This assimilation will be referred to as DASNS.

(g) UNOI

One feature common to all of the sections is the marked low level convergence around 45 N associated with the centre of low T. In all of the sections except for OPINIT, one finds increasing upper level divergence located above the depression centre, as one might expect. The pattern of divergence shown in Figure 6c, the assimilation with NMI, appears much less organised on a synoptic scale. However, it must be stressed that since one has no means of verifying a divergence field, one can only look for differences and relate these to analysed vertical velocity and moisture fields, and observable values such as surface pressure.

Figures 7a-7d show vertical divergence profiles over 45 N 20 W, the depression centre for the various runs.

Comparing the profiles it is apparent that there is significantly more convergence occuring in OPASSM below 700 mb than in DASSM. (Figure 7a). However, above this level there are only minor differences between the two profiles. The profile for DNODD shows much greater values at all levels than DASSM. (This is what one would expect since divergence damping is designed to suppress divergence). Therefore in DNODD greater convergence at low levels is being compensated for by greater divergence aloft. This is demonstrated by there being very little difference in central pressure of low T in DASSM and DNODD. However, if one again compares OPASSM and DASSM divergence profiles, this is probably not the case. OPASSM has greater convergence at low levels but little difference is present aloft between the two. As a consequence of greater mass accumulation at low levels and no compensating extra divergence aloft, the central pressure of low T is analysed 2 mb higher in OPASSM than DASSM. (See Figure 4a).

Comparing the operational assimilation and background field profiles for the same point (Figure 7b) thee again is appreciably more convergence in the operational assimilation below 700 mb, and little difference in integrated divergence between the two, above that level. Again this effect appears to be demonstrated by a higher central pressure in OPASSM than in the background field. It is interesting to note a sharp peak in divergence at jet stream level in the background field which is much less marked in the assimilations run including divergence damping.

In view of the central pressure of low T being analysed too high in OPASSM it seems probable that assimilation of 12Z observations was leading to excessive low level convergence. DASSM (in which the insertion of wind increments is gradually switched off at the end of the assimilation period) has reduced low level convergence and an improved PMSL value. One may conjecture therefore that assimilation of convergent wind data could be responsible for the erroneously high analysed central pressure. Divergence damping will have prevented there being compensating divergence aloft in response to forcing of convergence by the observations at lower levels.

There is an additional suggestion that the amount of divergence damping is too high. It appears in this investigation to be preventing the necessary column mass adjustment from taking place during the assimilation of observational data. Furthermore, it is evident from the divergence profiles and the cross sections that magnitudes of divergence are generally greater in the background field than in the assimilations. In the run without divergence damping the values are closer to those in the background field which is a 6 hour forecast. Since divergence damping is carried out in the assimilation and not in the forecast, this emphasises that the damping is probably too high. Comparison with ECMWF products also suggests this.

In terms of the vertical distribution of divergence (Figures 6a, 6g) UNOI and BACK appear very similar. The vertical profiles over 45 N 20 W, corresponding to the depression centre (Figure 7c) for UNOI and BACK have a similar shape although the magnitudes are different. This latter fact is not surprising in view of UNOI probably being in an unbalanced state immediately after the insertion of the OI increments.

3.4 Fitting of the observations by the model analysed fields

Table 2 shows root mean square (RMS) and mean errors between the synoptic data bank observations and the analysed field value at the observation points for the various model runs valid at 12Z 20/9/83 over the map area in, for example Figures 2a-2g.

OPASSM has achieved a better RMS fit to the wind data than DASSM at both the surface and 250 mb whilst DASSM has least overall bias than any of the runs for both levels. It appears in view of the RMS figures that DASSM whilst achieving a better fit to the pressure data than OPASSM has not fitted the wind data so precisely. It is also noticeable that although OPINIT has achieved the best fit of any of the assimilations to the central pressure of low T, the overall RMS error in PMSL is the worst.

UNOI has the best RMS fit to the pressure data (including the observation near the depression centre) but a worse fit to the surface wind data than any of the assimilations. At 250 mb the RMS fit to both the height and wind data is worse in UNOI than any of the assimilations.

All of the runs have achieved a better RMS fit to the wind, pressure, and height observations than the background field which indicates that the observations have had a positive impact over the area under consideration.

3.5 Rerun of D-assimilation without ships winds

To test the hypothesis that assimilation of ships wind data was leading to anomalous low level convergence hence poor surface pressure fitting, DASSM was rerun without ships' wind data in the region of the depression. The ships whose winds were omitted are indicated in Figure 2g. The resulting PMSL field Figure 2g shows low T with a central pressure of about 1001 mb. Figure 4d, the difference chart of PMSL between DASSM and DASNS highlights these differences.

A set of north south cross sections for DASNS through the centre of the surface depression were obtained similarly to the other runs and are shown in Figures 6f and 8f. Comparing the divergence sections for DASSM and DASNS the patterns are broadly similar but the values are smaller in the run without ships' winds. This shows up well in the divergence profile over 45 N 20 W (Figure 7d). The strong low level convergence is confined to a much shallower layer in DASNS (to what may be described as the friction layer). Above the 700 mb level both runs show divergence occurring, more so in DASSM, probably due to greater forcing from below. In response to the smaller divergence values in DASNS the vertical velocities over the depression centre are considerably less than in DASSM. (See Figures 5c, 5g and Table 1).

The quantity and distribution of ageostrophic motion around the depression are similar in DASSM and DASNS. (Figures 3c, 3g). However in DASNS there is marginally less ageostrophic motion in the southwest quadrant of low T. The centres of low T as defined by pressure and wind fields are closer together than in the other runs except perhaps BACK.

3.6 The significance of ageostrophic motion and normal mode initialisation

All of the assimilations show a similar area (in terms of direction and strength) of ageostrophic motion around 44 N 16 W in the southeastern quadrant of low T. This is probably realistic since the area was ahead of a marked surface front where ageostrophic motion and low level convergence would be expected to occur. A core of ageostrophic motion to the north of the depression is present in all of the assimilations and can partly be attributed to curvature effects. However the main cause is the non-coincidence of the depression centres as defined by the pressure and wind fields.

The area where differences between the assimilations are most marked is in the southwest quadrant of the depression. Largest cross contour ageostrophic motion appears to be occurring in OPASSM, with significantly less in DASSM, and less still in DASNS. The greatest differences are between the initialised and uninitialised runs of the operational assimilation.

This suggests that the strong cross contour flow (and hence low level convergence) is being forced by the assimilation of the three surface observations in that region. This is the region where the initialised assimilation is most different from the operational assimilation. Of all of the model runs, UNOI has produced the greatest imbalance in the southwest quadrant of low T, with a large area of over 18 m/s ageostrophic motion.

The model appears to have taken on a more 'balanced' and probably more meteorologically realistic state by modifying the wind relaxation coefficient as in DASSM, and also by omitting ships wind observations in the area near low T. The initialisation appears to have helped identify areas where meteorologically unrealistic motions are being forced by observations and therefore has potential use as diagnostic tool.

3.7 Discussion of humidity and temperature sections

The cross sections, Figure 8a-8g, show no apparent major differences in the temperature field between the various runs. Humidity differences present over the depression reflect the vertical velocity patters associated with the particular runs. For example DNODD has a much larger saturated area above the 500 mb level than, for example DASSM, and particularly DINIT owing to much stronger upward motion present in DNODD.

UNOI and BACK, Figures 8a and 8g, particularly are very similar, even down to the fine details of the temperature structure. The humidity distributions are essentially the same apart from minor differences at low levels where most of the new data will have been inserted.

3.8 Resolution of low T by the model

Low T was a relatively small circulation. The closed circulation as defined by, say, the 1008 mb isobar covers only 4 degrees of latitude and about 8 degrees of longitude. Therefore on the coarse mesh grid we have a north-south space scale of barely 3 grid lengths and an east-west scale of about 4 gridlengths. So failure to achieve the proper central pressure may be a problem of model resolution to some extent.

3.9 Problems in using the ship observations around low T with reference to quality control

None of the assimilations have been able to fit the reported wind direction of 190 /37 knots reported at ship E (call sign LGNR in Figure 1b). In view of the large difference between the reported wind and the background field, the quality control flagged the observation in the mode 1 check. However the observation was allowed through to be used in the assimilation since it did not disagree sufficiently with the surrounding data as laid down by the quality control criteria. In none of the runs has the pressure observation from this ship been fitted either.

The temperature and dewpoint indicate that this ship (henceforth referred to as LGNR) was undoubtedly in the warm sector of low T. From a synoptic point of view one would normally expect to see a reasonable agreement between wind directions within such a homogeneous air mass. On this basis the wind observation at LGNR seems meteorologically unrealistic when comapred with ship obs 3EDV, OZYY, PODZ in the analysed warm sector and should, arguably have been omitted from the assimilation. However, whereas a human analyst quality controls an observation not only by comparing it with its nearest neighbours but also by taking into account other observations which should agree with it in the context of the particular meteorological situation, this is not so in an automated quality control scheme. The scheme used operationally compares observations within a set radius ($5^1/_4$ degrees of latitude) irrespective of whether there is, for example, a change of airmass within that region. It follows that frequently data from airmass is used to quality control data from another. So in the case of ship LGNR the reported wind may appear too far backed in the context of other ships observations in the analysed warm sector but in terms of the observations within $5^1/_4$ degrees latitude of itself (as the operational quality control scheme sees the situation) the wind is acceptable.

3.10 Evolution of low T and the fine mesh forecasts run from the various start fields

The track of low T during the 36 hour period starting from 12Z 20/9/83 is shown in Figure 1b by its 6 hourly positions. The hand analysed estimated depths of the centre are shown in Table 3. Low T followed an east northeasterly track along the English Channel crossing Kent and ending up over the low countries by 00Z 22/9/83. After 12Z 20/9/83 it soon began to fill and continued filling slowly throughout the next 36 hours. (It did subsequently deepen again during 22/9/83).

36 hour fine mesh forecasts were run using as start fields the various coarse mesh assimilations interpolated onto a fine mesh grid. The forecast central pressures of low T are shown in Table 3 alongside the observed central pressure and forecasts from a start field from

06Z 20/9/83. The 6 hour fine mesh forecast value starting at 06Z 20/9/83 is different from the background field value (Figure 2f) since the background field is a coarse mesh forecast. The 24 hour forecasts are shown in Figures 9a-9g and the verifying analysis, Figure 10.

The most successful run in terms of central pressure of low T up to T+18 is the run based on data from 06Z 20/9/83. However there is a rapid deterioration thereafter. In terms of position, this run was about 6 hours too fast, and with marked overdeepening would have constituted misleading guidance.

The least successful forecast runs were those starting from the initialised and uninitialised operational assimilations. The forecasts run from D assimilation fields with and without divergence damping are similar and significantly better than the operational assimilation. The omission of ship winds near the depression has made very little difference to its evolution.

The forecast run from a univariate OI start field has produced the best overall result in terms of central pressure and position of low T. However, there are some marked pressure oscillations present during the second half of the forecast. Although UNOI produced the best representation of low T in the forecasts, the rise of pressure behind the depression in the latter stages of the forecast (T+30 and T+36) was very poorly handled in comparison with the other runs.

One must therefore consider how errors in the analysed fields contributed to subsequent errors in the forecasts.

In Table 3 it seems noticeable that a poor initial analysis of central pressure of low T has tended to lead to poor forecasts. OPASSM has led to a significantly worse forecast than DASSM indicating that the anomalous low level convergence induced by assimilation of wind data has contaminated the forecast product. However OPINIT, although starting with a better initial pressure field produced just as poor a forecast as OPASSM. Therefore in OPINIT the better representation of low T's central pressure was merely a cosmetic improvement concealing a misrepresentation of the dynamics of the feature. In this case removing the ships' winds near the depression has made a marginal improvement in both the analysis and forecasts, whereas removing divergence damping has had little effect on the forecasts.

The forecast made from the UNOI start field has produced a result, in terms of depth of low T, midway between BACK and OPASSM. The similarity between UNOI and BACK at T+0 has already been remarked upon. This is probably due to the absnece of divergence damping in UNOI and BACK. This hypothesis is supported by the similarity between these two runs and DNODD present in the shape of the divergence profile over 45 N, 20 W (Figs 7a, 7c). The PMSL field, having not been affected by assimilation of wind observations fits the pressure observation near the depression centre more precisely than the assimilation runs. From adjustment theory, it can be deduced that unless the flow is balanced, the divergent wind information leads to gravity waves which disperse during the forecast. Therefore in unbalanced flow, the divergent part of the wind information is lost during the forecast. In view of the large ageostrophic motion in UNOI (see section 3.6) it is conceivable that the influence of the divergent part of the wind data has been lost during the forecast to a greater degree than in the assimilation runs. In this case, the influence of the wind data appears to have been detrimental to the assimilations and forecasts in the region of low T and therefore its loss proved beneficial. It must therefore be emphasized that the success of the univariate optimal interpolation based forecast in its handling of low T is more by chance, especially in view of its failure to forecast the strength of the following ridge development.

PMSL is the main machine analysed quantity that the forecaster can use in judging whether a model has 'got hold of' a particular feature as it is the most easily verified against observations. This is because the observations are relatively plentiful, and have a smaller margin of error than for example wind data in which there may be errors of ± 10% frequently. A hand analysed PMSL field may often be the only means available of determining how well a model is handling a particular feature.

In this case study, apart from the case OPINIT, the versions which produced the best initial analysis of depth of low T led to the better forecasts suggesting that these versions did have the best representation of the depression's dynamics.

Further case studies would be necessary to establish whether this result is general rather than just specific to this case. One must always consider the possibility that improved fitting of pressure data may be accompanied by worse fitting of the wind data as has happened when comparing OPASSM and DASSM. In this respect DASSM has probably struck a compromise between the two conflicting requirements. It has achieved a good overall fit to the pressure field and has removed some of the excessive low level convergence that caused problems in OPASSM. This has also resulted in a better forecast, with only a slightly poorer fit to the wind data in the analysis. In addition there are no noticeable oscillations as are evident in the forecast run from optimal interpolation.

3.11 Rerun of 00Z 17/4/83

The operational assimilation from 00Z 17/4/83 data was rerun using the D assimilation. (Modified with relaxation coefficient).

On this occasion it had been noted that the PMSL analysis in the operational assimilation had not fitted the pressure observations over a large part of southern Britain and northern France, being analysed up to 2 mb too low in places. The D assimilation achieved a much closer fit to the pressure observations over the area in question.

4. Conclusions

Assimilation of ships wind observations was forcing an unrealistically large amount of convergence in the lower layers of the model during the operational assimilation. This was not entirely compensated for by divergence aloft and this led to PMSL being analysed too high in the depression studied. The D assimilation in which the wind increments are 'switched off' just before the end of the assimilation period shows an improved (but not perfect) PMSL analysis and this has been related to the upper level divergence field. In the limiting case, the D-assimilation run without ship winds near the depression, the PMSL analysis is further improved, a response to the reduced low level convergence. It has been suggested that divergence damping is probably too high and having the effect of suppressing the mass adjustment necessary to achieve balance in the model during the assimilation process.

One particular ship wind observation which appeared misleading when performing a hand analysis was accepted by the models quality control and may well have contributed to the excessive low level convergence present at the end of the assimilation period.

The univariate optimal interpolation analysis gave the best representation of low T in both its analysis and forecast development in terms of central pressure. However this has been shown to have occurred by chance. The influence of certain wind data which had a detrimental effect on the assimilation products and forecasts run using these as start fields, was probably lost during the forecast run from univariate optimal interpolation. This led to an improved forecast.

Poor fitting of PMSL in the assimilation fields for 12Z 20/9/83 appears symptomatic of a dynamical problem induced by the method of assimilation of wind data. This probable misrepresentation of the dynamics of low T then appears to contaminate the forecasts of the depression's development. Initialisation provides a 'cosmetic' change by improving the fit to certain pressure data but this merely conceals this basic error in the dynamics. However, initialisation may be a useful diagnostic tool to identify areas where meteorologically unrealistic motions are being forced by observations.

The D assimilation (modified wind relaxation coefficient) by removing the forcing of the wind data late in the assimilation period has improved the fitting of pressure data in the area studied, when compared with the operational assimilation. However, the opposite is true for the wind data both at the surface and upper levels. This highlights the major problem in assimilation of wind information; how to achieve the best fit to the wind data without sacrificing the fit to pressure data. The D-assimilation has been shown in this case to come up with a good compromise between the two conflicting requirements.

APPENDIX I

Experiments carried out on analysis/assimilation for 12Z 20/9/83

(a) OPASSM

A 6 hour analysis/assimilation cycle was carried out with the data for 12Z 20/9/83 using the version of the model operational on 20/9/83.

(b) OPINIT

As OPASSM but with normal mode initialisation. For further details see

Temperton, C., and Williamson, D.L., 1981

Normal mode initalisation for a multi-level gridpoint model, Part I: Linear aspects. Monthly Weather Review 109 pp 729-743.

Williamson, D.L., and Temperton, C., 1981.

Normal mode initialisation for a multi-level gridpoint model, Part II: Nonlinear aspects. Monthly Weather Review 109 pp 744-757.

(c) DASSM

As OPASSM but with a modified wind relaxation coefficient. In this case, the effect of the wind increments is progressively reduced to zero near the end of the assimilation period. For further details see

Lyne, W.H., Little, C.T., Dumelow, R.K., Bell, R.S., 1983.

The operational data assimilation scheme. Met O 11 Technical Note No. 168 Section 4.4.

(d) DNODD

As DASSM, but with divergence damping removed. A term is included in the model equations in order to suppress the amount of divergence occurring during the assimilation process. This is known as 'divergence damping' and is further described in

Dumelow, R.K., 1983.

Some experiments in the use of divergence damping in the operational assimilation model. Met O 11 Technical Note No. 171.

(e) DASNS

In this experiment DASSM was rerun but without ships' wind data in the vicinity of low T. The ships whose winds were omitted are indicated in Figure 2g.

(f) UNOI

A univariate optimal interpolation analysis was carried out for 12Z 20/9/83.

In optimal interpolation (OI) the observed quantities eg pressure, temperature, wind are analysed independently. Increments derived from the observational data are then added to the background field in one step to produce an OI field. For further details see

Lyne, W.H., Little, C.T., Dumelow, R.K., Bell, R.S., 1983.

The operational data assimilation scheme. Met O 11 Technical Note No. 168 Section 3.1.

(g) BACK

A 6 hour coarse mesh forecast was carried out from the assimilation field valid at 06Z 20/9/83 in order to generate the background field for 12Z 20/9/83. This acts as a 'control' to investigate model behaviour in the absence of 12Z data.

36 hour fine mesh forecasts were carried out from each of the fields (a-g) for 12Z 20/9/83.

Appendix II

Figures referred to by the text

1a CFO surface hand analysis for 12Z 20/9/83.

1b Reanalysis for 12Z 20/9/83.

Fig. 2 PMSL, 1000 mb wind (arrows and isotachs) and verying SDB observations for 12Z 20/9/83 for

(a) OPASSM

(b) OPINIT

(c) DASSM

(d) DNODD

(e) UNOI

(f) BACK

(g) DASNS - the circled observations had their winds omitted during this assimilation

Fig. 3 1000 mb height and ageostrophic wind (arrows and isotachs) for 12Z 20/9/83 for

(a) OPASSM

(b) OPINIT

(c) DASSM

(d) DNODD

(e) UNOI

(f) BACK

(g) DASNS

Figure 4a PMSL difference field OPASSM-DASSM

Figure 4b PMSL difference field OPASSM-OPINIT

Figure 4c PMSL difference field DASSM-DNODD

Figure 4d PMSL difference field DASSM-DASNS

Figure 5 PMSL (solid lines),

1000 mb wind (arrow)

700 mb vertical velocity (dotted line labelled in milli Pascals/sec)

1000-850 mb thickness (pecked line) for 12Z 20/9/83 for

(a) OPASSM

(b) OPINIT

(c) DASSM

(d) DNODD

(e) UNOI

(f) BACK

(g) DASNS

Figure 6 Cross sections of divergence along 20 W centred on 45 N (the centre of low T) at 12Z 20/9/83 for

(a) BACK

(b) OPASSM

(c) OPINIT

(d) DASSM

(e) DNODD

(f) DASNS

(g) UNOI

Figure 7 Vertical profiles of divergence at 45 N 20 W at 12Z 20/9/83 for

(a) DASSM, OPASSM, DNODD

(b) OPASSM, BACK

(c) UNOI, BACK

(d) DASNS, DASSM

Figure 8 Vertical cross sections of

(i) u-component, v and w (arrows) and potential temperature

(ii) relative humidity and temperature at 12Z 20/9/83 for

(a) BACK

(b) OPASSM

(c) OPINIT

(d) DASSM

(e) DNODD

(f) DASNS

(g) UNOI

Figure 9 24 hour fine mesh forecasts (valid at 12Z 21/9/83) run from 12Z 20/9/83 start fields for

(a) BACK

(b) OPASSM

(c) OPINIT

(d) DASSM

(e) DNODD

(f) DASNS

(g) UNOI

Figure 10 Surface hand analysis for 12Z 21/9/83.

LIST OF ABBREVIATIONS APPEARING IN THE TEXT

OPASSM	operational assimilation for 12Z 20/9/83.
OPINIT	operational assimilation for 12Z 20/9/83 with normal mode initialisation.
DASSM	'D'-assimilation - operational assimilationf or 12Z 20/9/83 but with a modified wind relaxation coefficient.
DNODD	'D'-assimilation run for 12Z 20/9/83 with zero divergence damping.
DASNS	'D'-assimilation for 12Z 20/9/83 rerun without ships' winds near low T.
UNOI	Univariate optimal interpolation analysis for 12Z 20/9/83.
BACK	Operational background field valid at 12Z 20/9/83.
CFO	Central Forecast Office.
NMI	Normal Mode Initialisation.
OI	Optimal Interpolation.
PMSL	Mean Sea Level Pressure.
RMS	Root Mean Square.

TABLE 1

VERTICAL VELOCITIES (MILLI-PASCALS/SEC) ASSOCIATED WITH LOW T IN THE VARIOUS MODEL RUNS AT 700MB AT 12Z 20/9/83

	BACK	OPASSM	OPINIT	DASSM	DNODD	DASNS	UNOI
Maximum value of omega around low T	-1900	-1300	-900	-1100	-2300	-700	-1500
Omega over centre of low T	-900	-1000	-300	-800	-1500	-400	-200

-1000 milli-pascals/sec is approximately equal to 10cm/sec upward motion

TABLE 2 MEAN AND RMS DIFFERENCES BETWEEN MODEL ANALYSES AND OBSERVATIONS

	39 PMSL OBS (MB)		WIND (MS^{-1})				4 250MB HEIGHT OBS (M)	
			41 SURFACE OBS		8 250MB OBS			
	MEAN	RMS	MEAN	RMS	MEAN	RMS	MEAN	RMS
BACK	0·9	1·8	−1·0	7·7	−4·1	9·1	25·6	38·1
OPASSM	−0·8	1·5	0·3	5·9	−0·8	5·4	23·3	32·2
OPINIT	0·2	1·6	1·1	6·4	−2·0	7·7	19·5	27·2
DASSM	−0·7	1·4	0·0	6·1	−0·3	6·2	24·2	32·4
DNODD	0·6	1·3	−0·1	6·5	−0·5	6·1	25·4	34·3
UNOI	−0·1	1·2	0·7	6·9	−3·2	8·6	26·5	33·7

In table 2

Mean refers to mean value of (observation -field value at observation point)

Mean wind refers to mean value of

(wind speed of observation-wind speed of field at observation point)

RMS wind refers to RMS of vector difference between observation and field at the observation point.

TABLE 3 CENTRAL PRESSURE (MB) OF LOW T AS FORECAST BY THE FINE-MESH, RUN FROM THE VARIOUS MODEL ANALYSES

	Start field for fine-mesh forecast							Fine mesh forecast up to T+42 data time 06Z 20/9
	ACTUAL	OPASSM	OPINIT	DASSM	DNODD	DASNS	UNOI	1000
12Z 20/9 T+0	999	1004	1002	1002	1003	1001	1000	999
18Z 20/9 T+6	995	1004	1003	1003	1002	1003	1000	997
00Z 21/9 T+12	997	1006	1006	1004	1004	1003	1001	997
06Z 21/9 T+18	998	1006	1006	1004	1004	1004	1000	995
12Z 21/9 T+24	1000	1007	1009	1005	1005	1005	1000	995
18Z 21/9 T+30	1001	1010	1010	1007	1006	1006	1003	991
00z 22/9 T+36	1002	1010	1010	1005	1003	1004	999	986

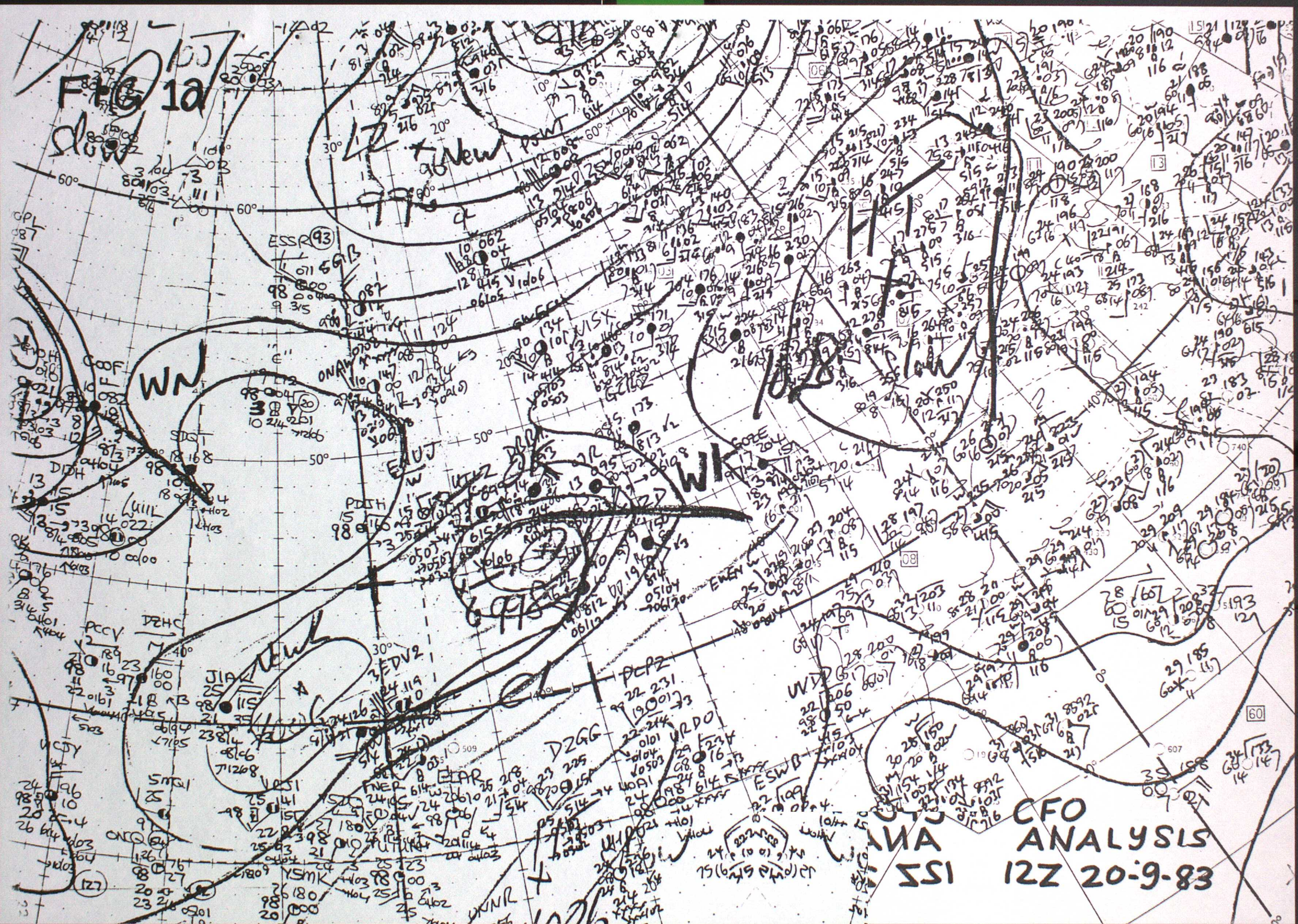


FIG 1a
CFO
ANALYSIS
12Z 20-9-83

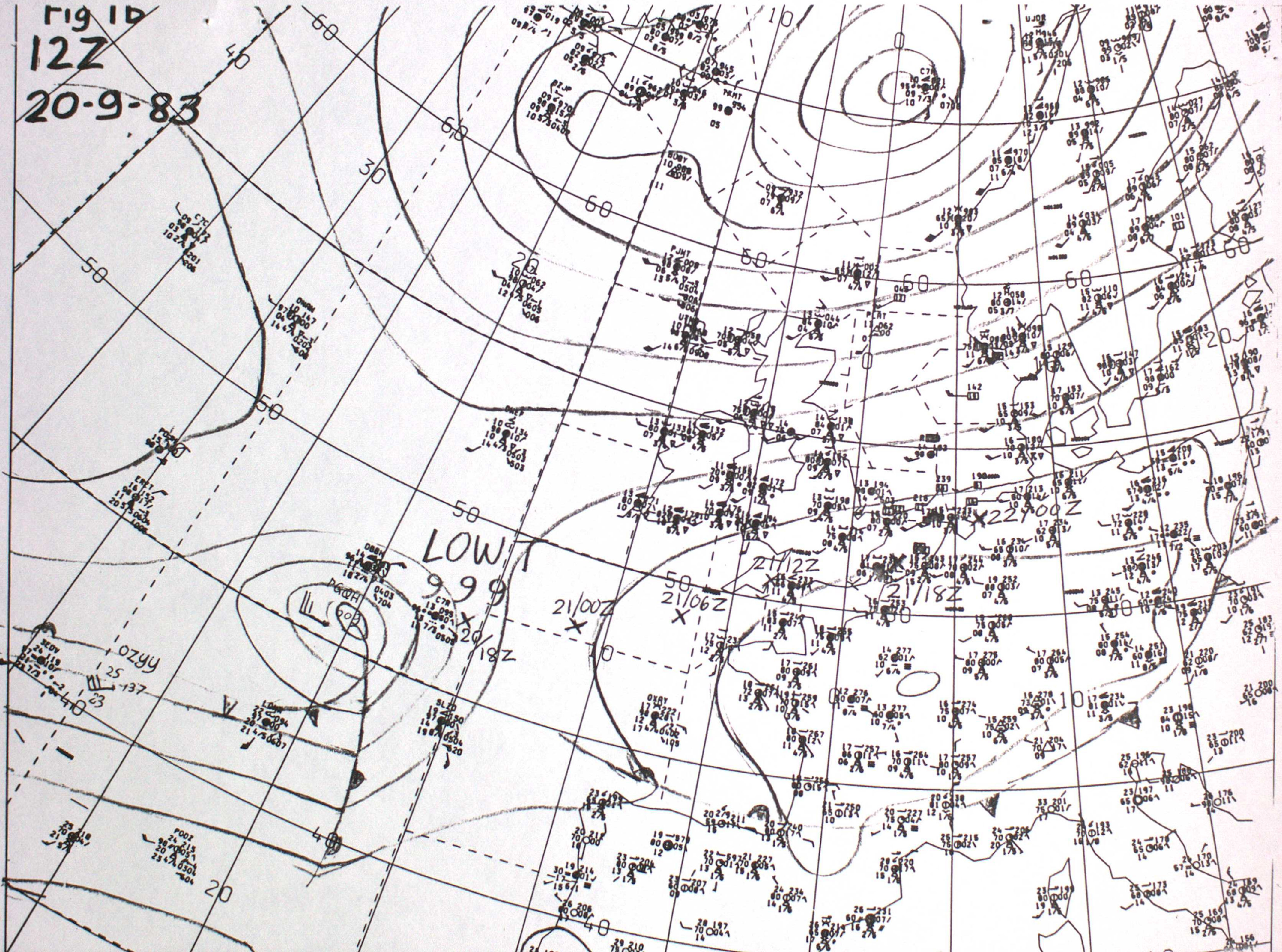


Fig 1b
12Z
20-9-83
LOW
999
21/00Z
21/06Z
21/12Z
21/18Z
22/00Z
20/18Z
OZYY

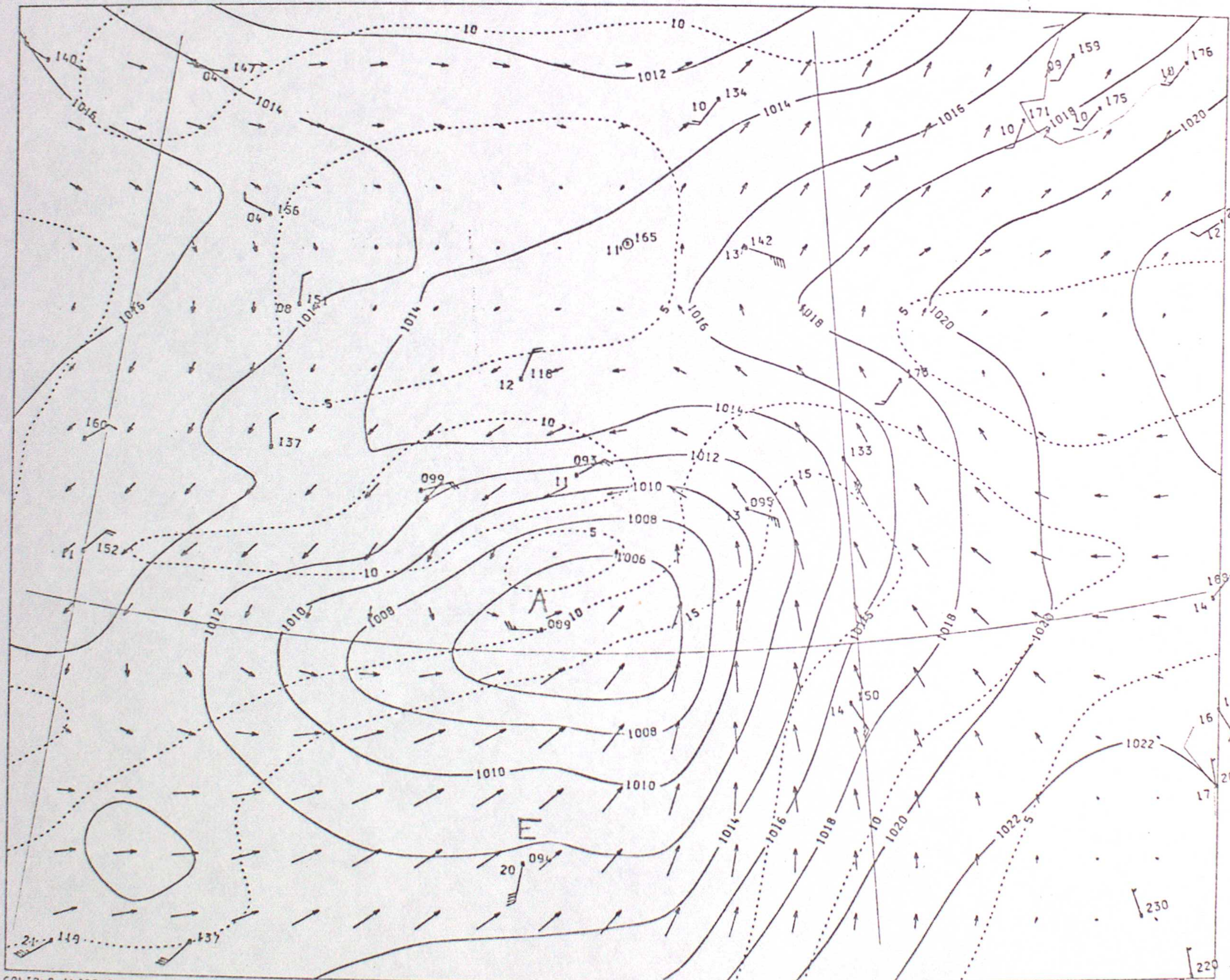
FIG 2A

OPERATIONAL UPDATE ANALYSIS (OPASSM)

PMSL (MB), 1000MB WIND, & VERIFYING SDB OBSERVATIONS

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB ——→ REPRESENTS 20 M/S CONTOUR INTERVAL: 5 M/S 7X SYNOP PLOTTED(4NOT) 1X OWS PLOTTED 245 SHIP PLOTTED(5NOT)
39PMSL MN= -0.8 RMS= 1.5MB. 41WIND MN= 0.3 RMS= 5.9M/S.

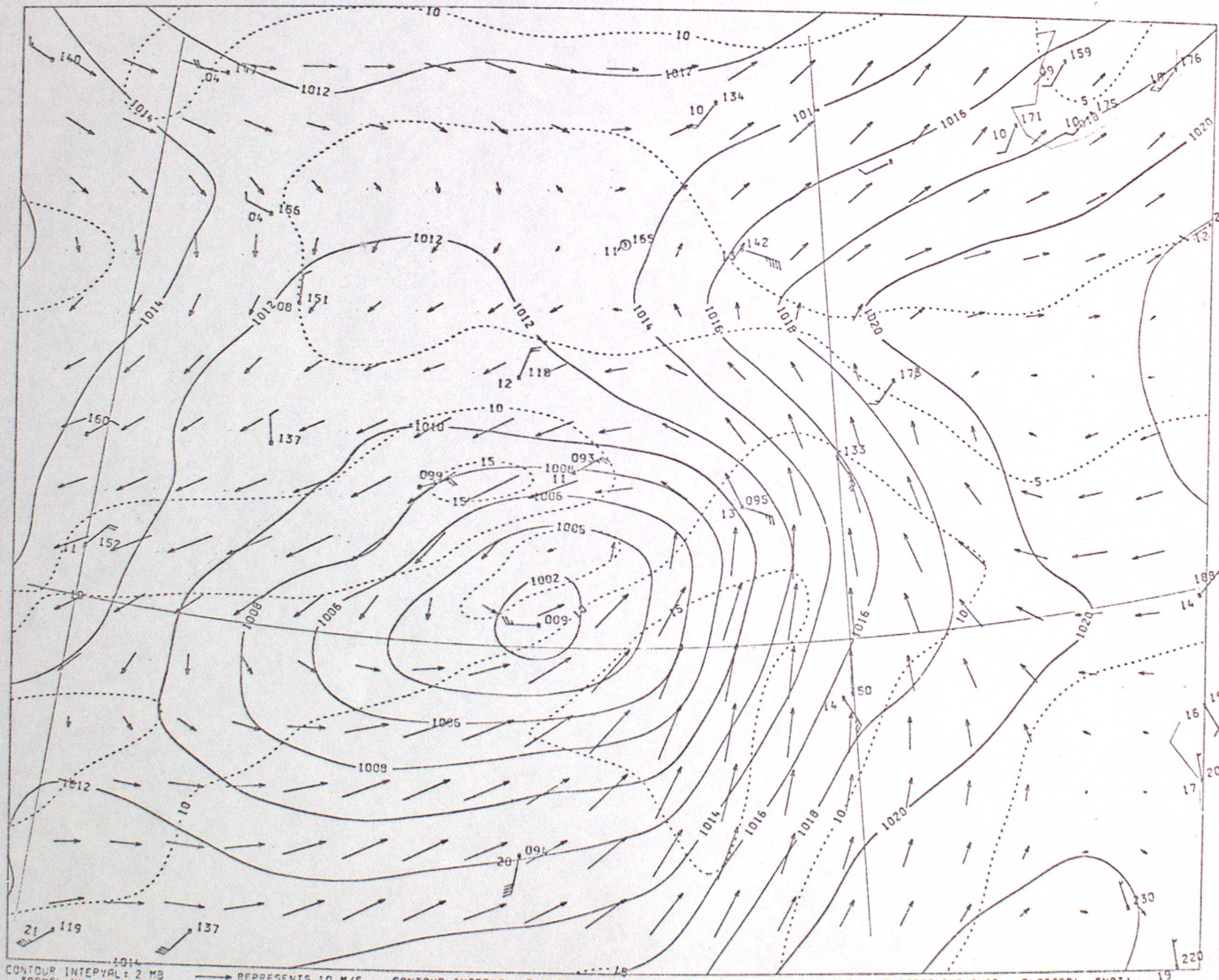
FIG 2B

OPERATIONAL UPDATE ANALYSIS AFTER INITIALIZATION (OPINIT)

PMSL (MB), 1000MB WIND, & VERIFYING SDB OBSERVATIONS

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB — REPRESENTS 10 M/S   CONTOUR INTERVAL: 5 M/S   7X SYNOP PLOTTED(4NOT) 1W OWS   PLOTTED 24S SHIP   PLOTTED(5NOT)

39PMSL MN= 0.2 RMS= 1.6MB. 41WIND MN= 1.1 RMS= 6.4M/S.

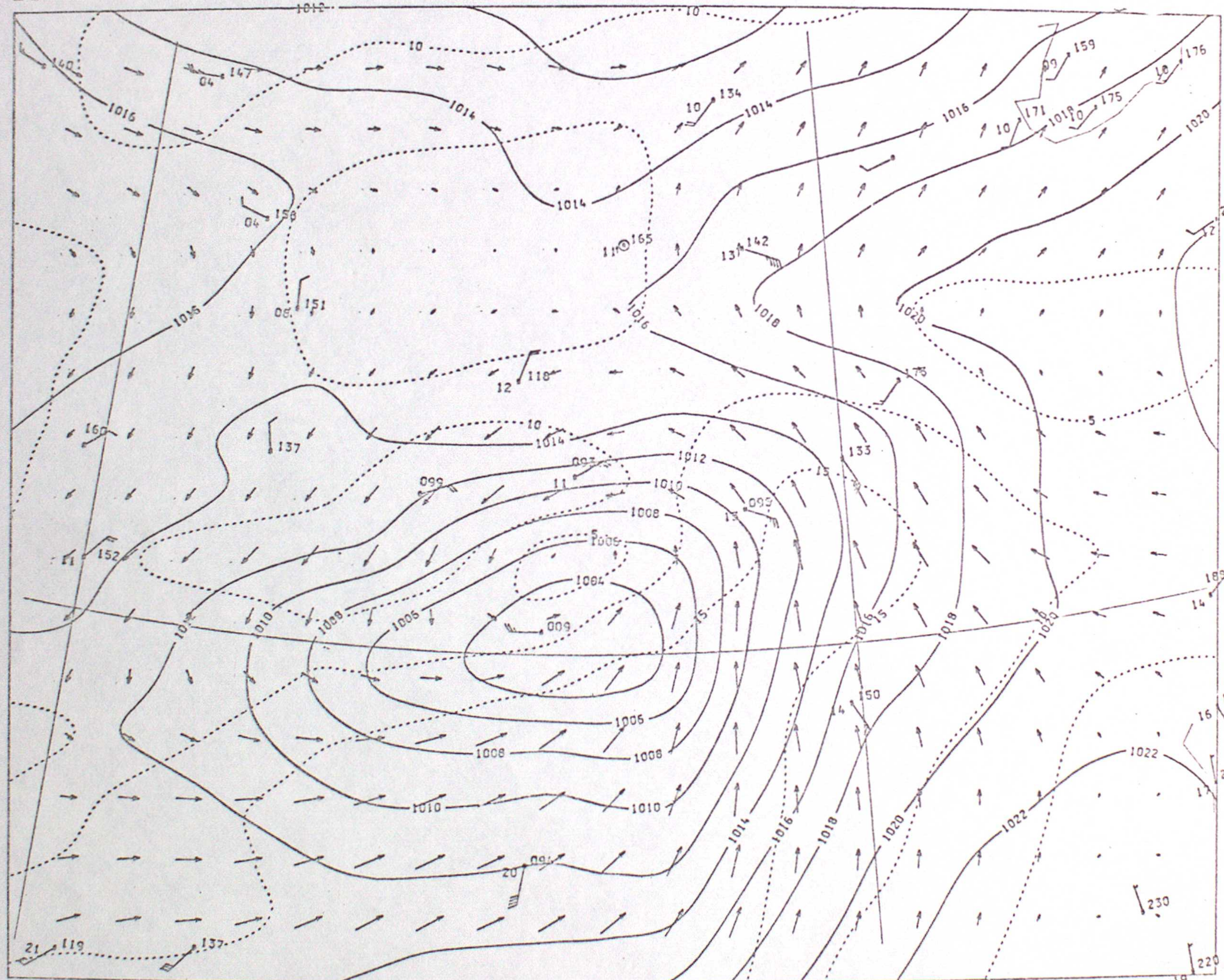
FIG 2C

D ASSIMILATION ANALYSIS (MODIFIED WIND RELAXATION COEFF ETC) *DASSM*

PMSL (MB), 1000MB WIND, & VERIFYING SDB OBSERVATIONS

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB ⟶ REPRESENTS 20 M/S CONTOUR INTERVAL: 5 M/S 7X SYNOP PLOTTED(4NOT) 1X OWS PLOTTED 24S SHIP PLOTTED(5NOT)
39PMSL MN= -0.7 RMS= 1.4MB. 41WIND MN= 0.0 RMS= 6.1M/S.

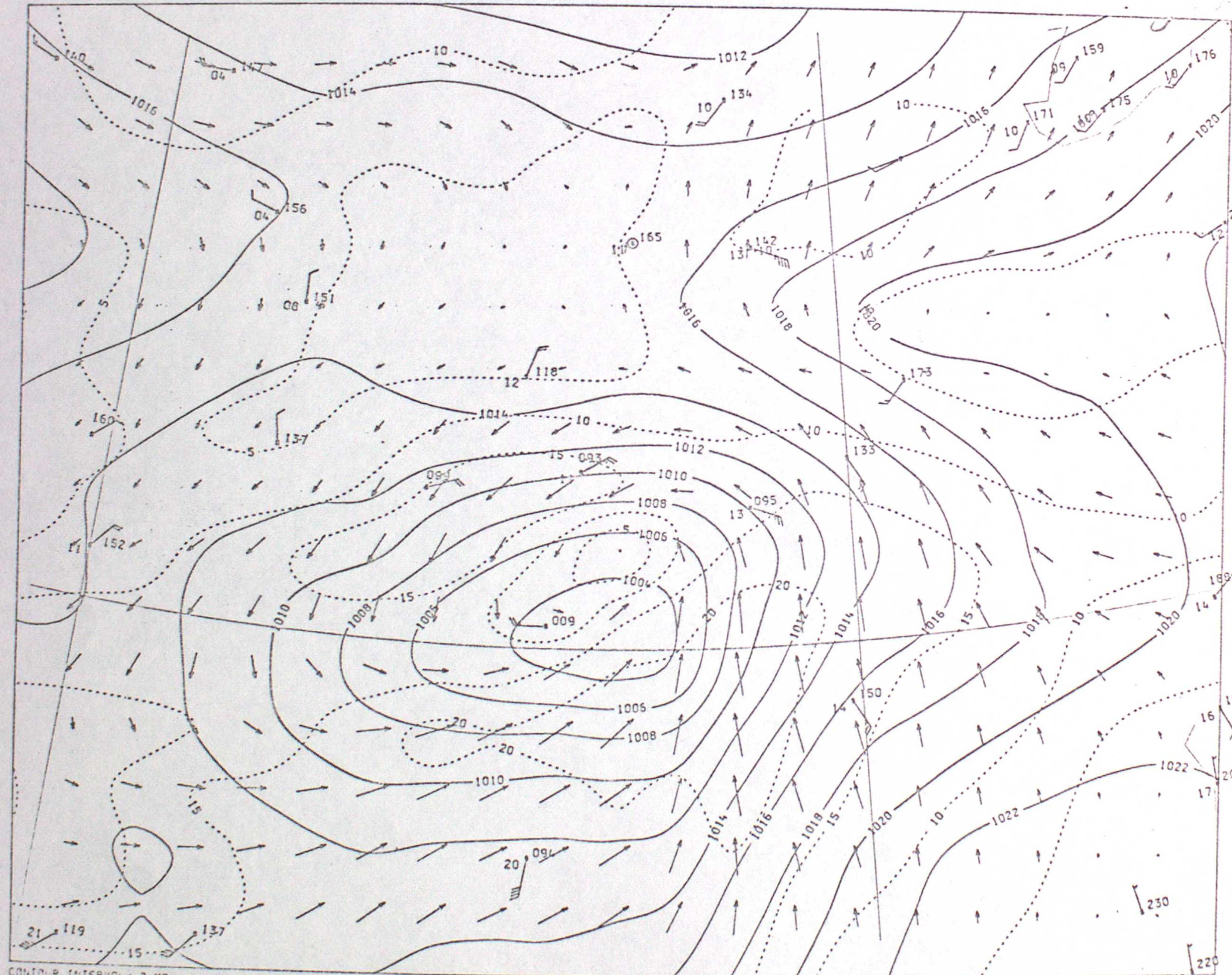
FIG 2D

D ASSIMILATION ANALYSIS WITH ZERO DIVERGENCE DAMPING (DNODD)

PMSL (MB), 1000MB WIND, & VERIFYING SDB OBSERVATIONS

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB ——→ REPRESENTS 20 M/S CONTOUR INTERVAL: 5 M/S 7X SYNOP PLOTTED(4NOT) 1X OWS PLOTTED 24S SHIP PLOTTED(5NOT)
39PMSL MN= -0.6 RMS= 1.3MB. 41WIND MN= -0.1 RMS= 6.5M/S.

FIG2E
UNIVARIATE OI (UNOI)
PMSL (MB), 1000MB WIND, & VERIFYING SOB OBSERVATIONS
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL

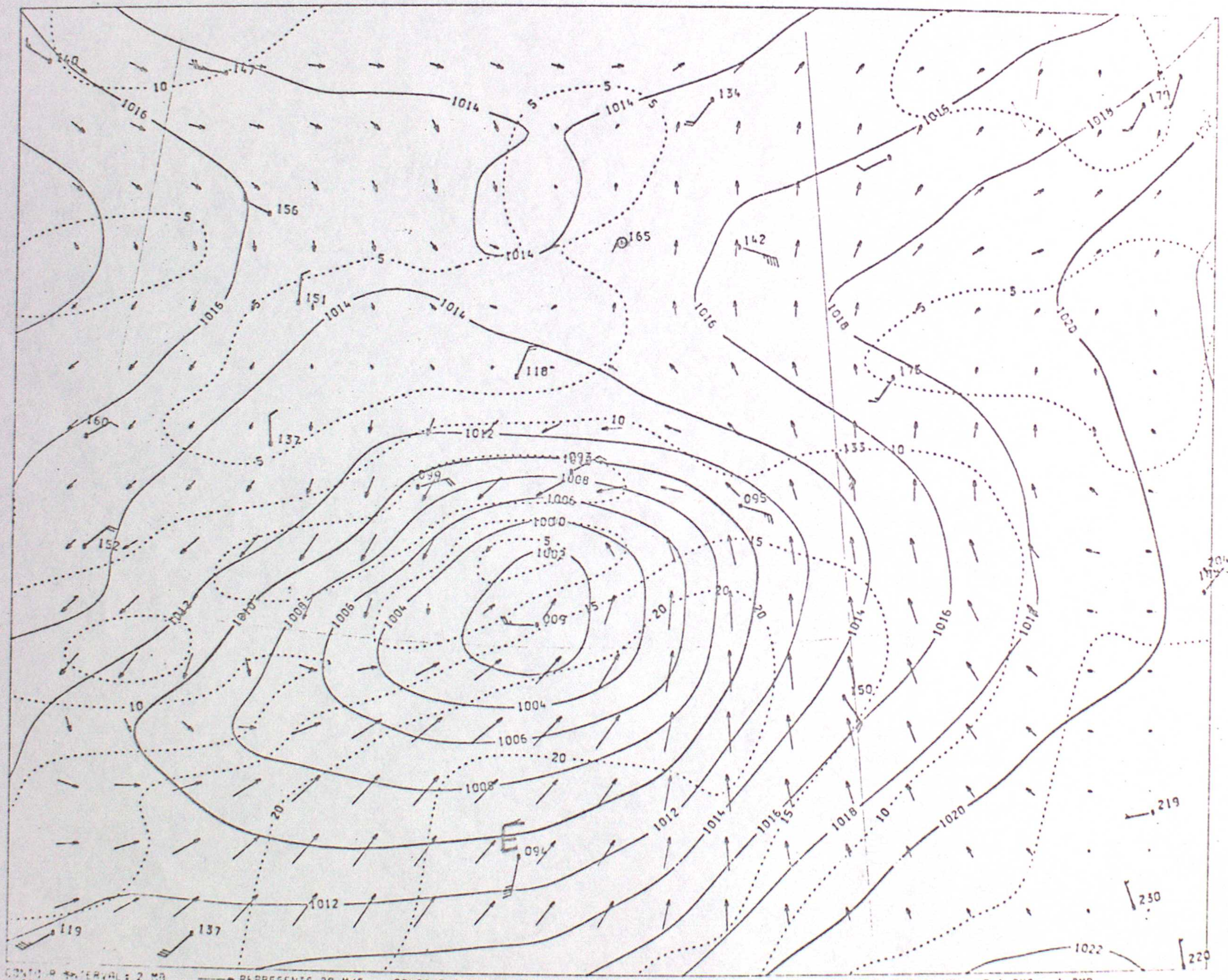
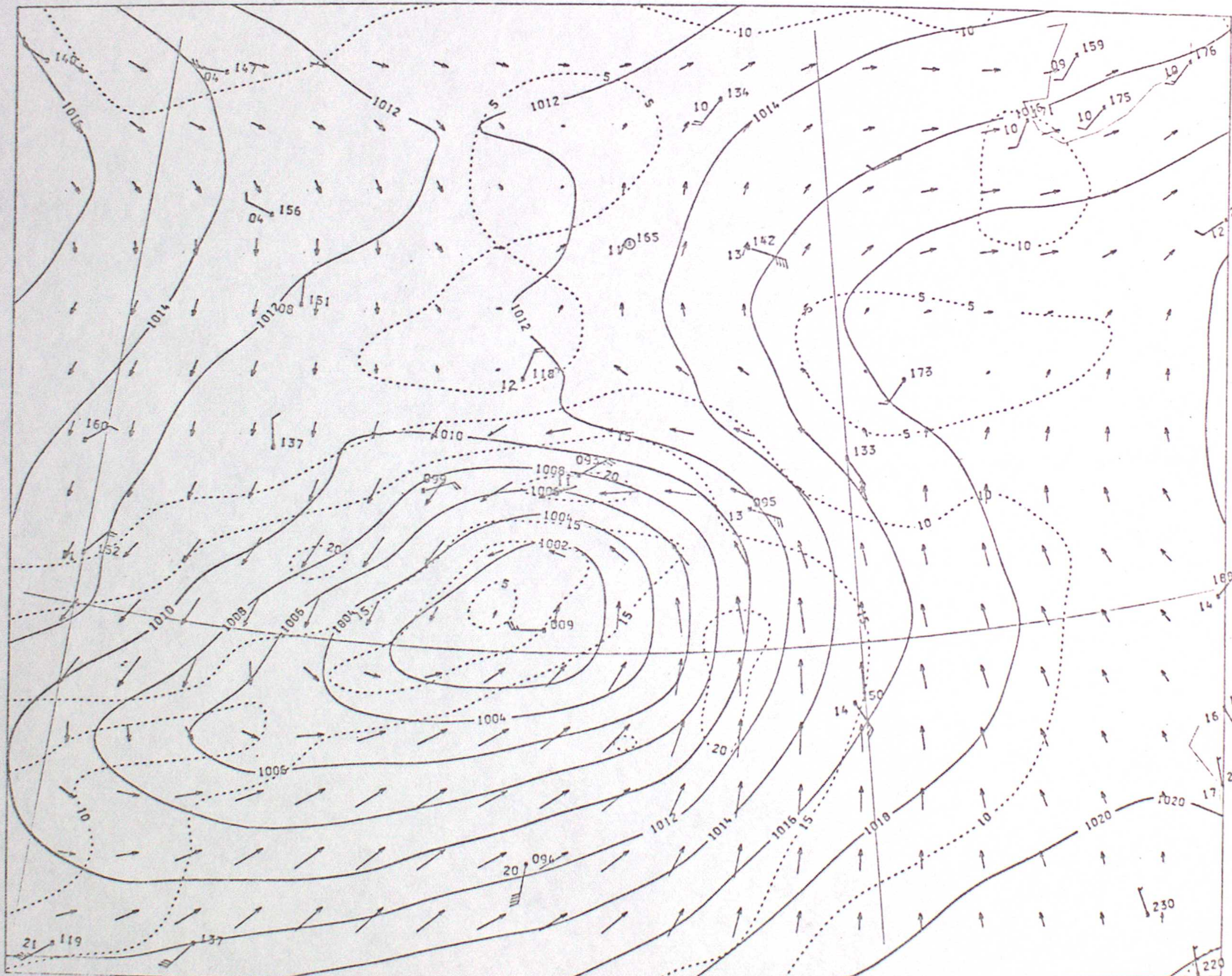


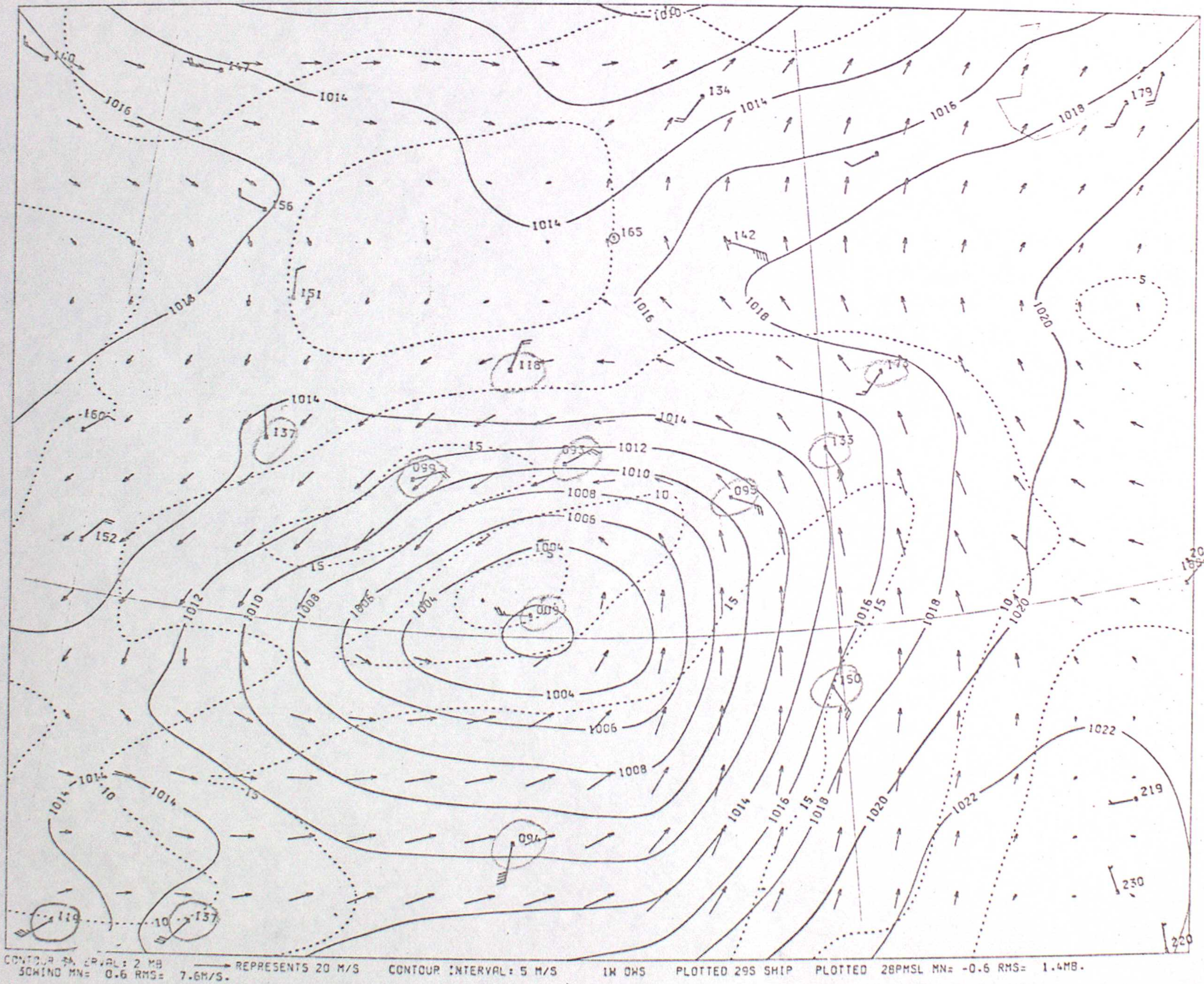
FIG 2F
OPERATIONAL BACKGROUND FIELD (BACK)
PMSL (MB), 1000MB WIND, & VERIFYING SDB OBSERVATIONS
VALID AT 12Z ON 20/9/1983 DAY 263 DATA TIME 6Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB ——→ REPRESENTS 20 M/S CONTOUR INTERVAL: 5 M/S 7X SYNOP PLOTTED(4NOT) 1W OWS PLOTTED 24S SHIP PLOTTED(5NOT)
39PMSL MN= 0.9 RMS= 1.8MB. 41WIND MN= -1.0 RMS= 7.7M/S.

FIG 2G

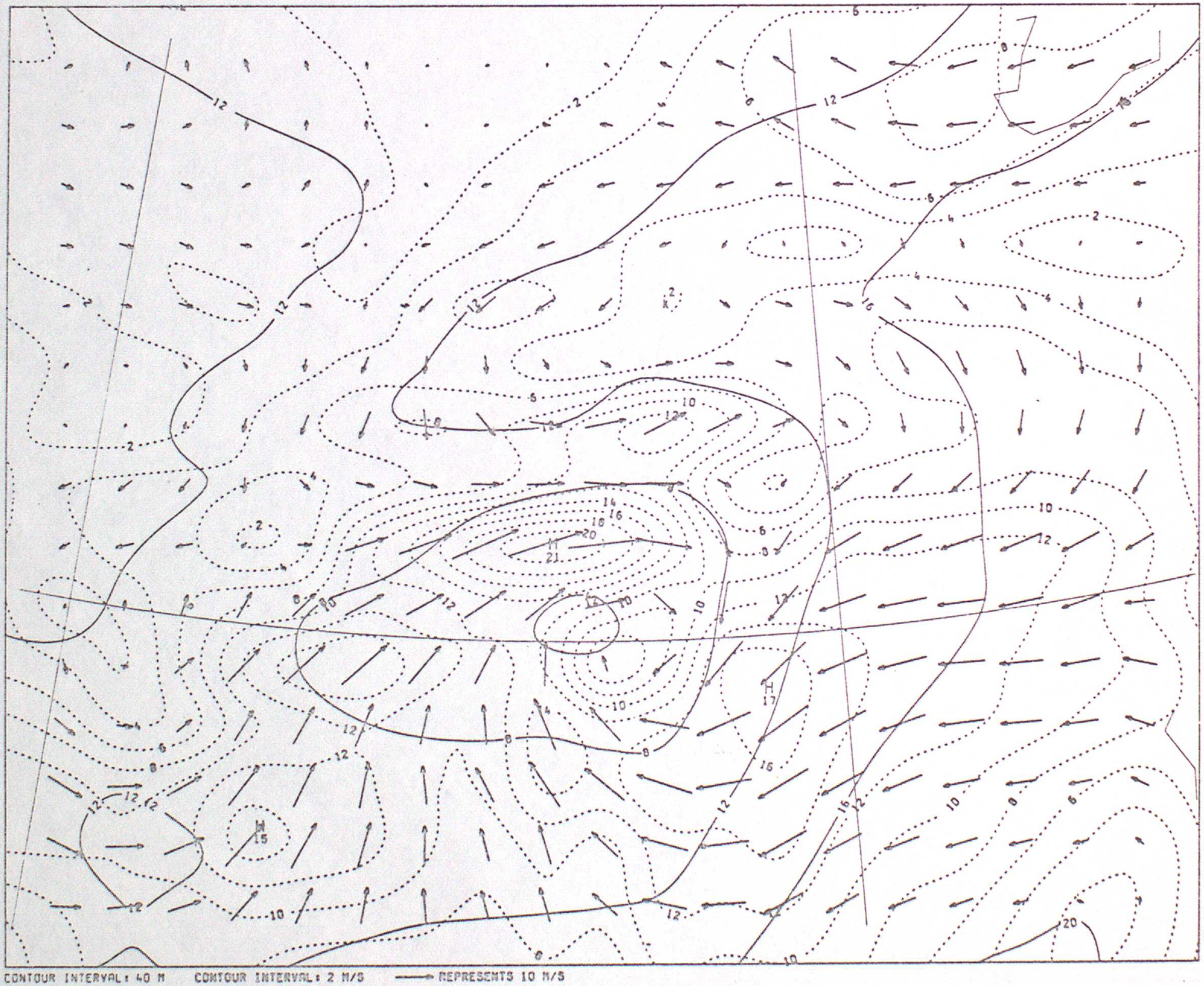
D ASSIMILATION RERUN WITH NO SHIP WINDS NEAR DEPRESSION (DASNS)
PMSL (MB), 1000MB WIND, & VERIFYING SDB OBSERVATIONS
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB —— REPRESENTS 20 M/S CONTOUR INTERVAL: 5 M/S 1W OWS PLOTTED 29S SHIP PLOTTED 28PMSL MN= -0.6 RMS= 1.4MB.
30WIND MN= 0.6 RMS= 7.6M/S.

The circled ship observations had their winds omitted in this assimilation

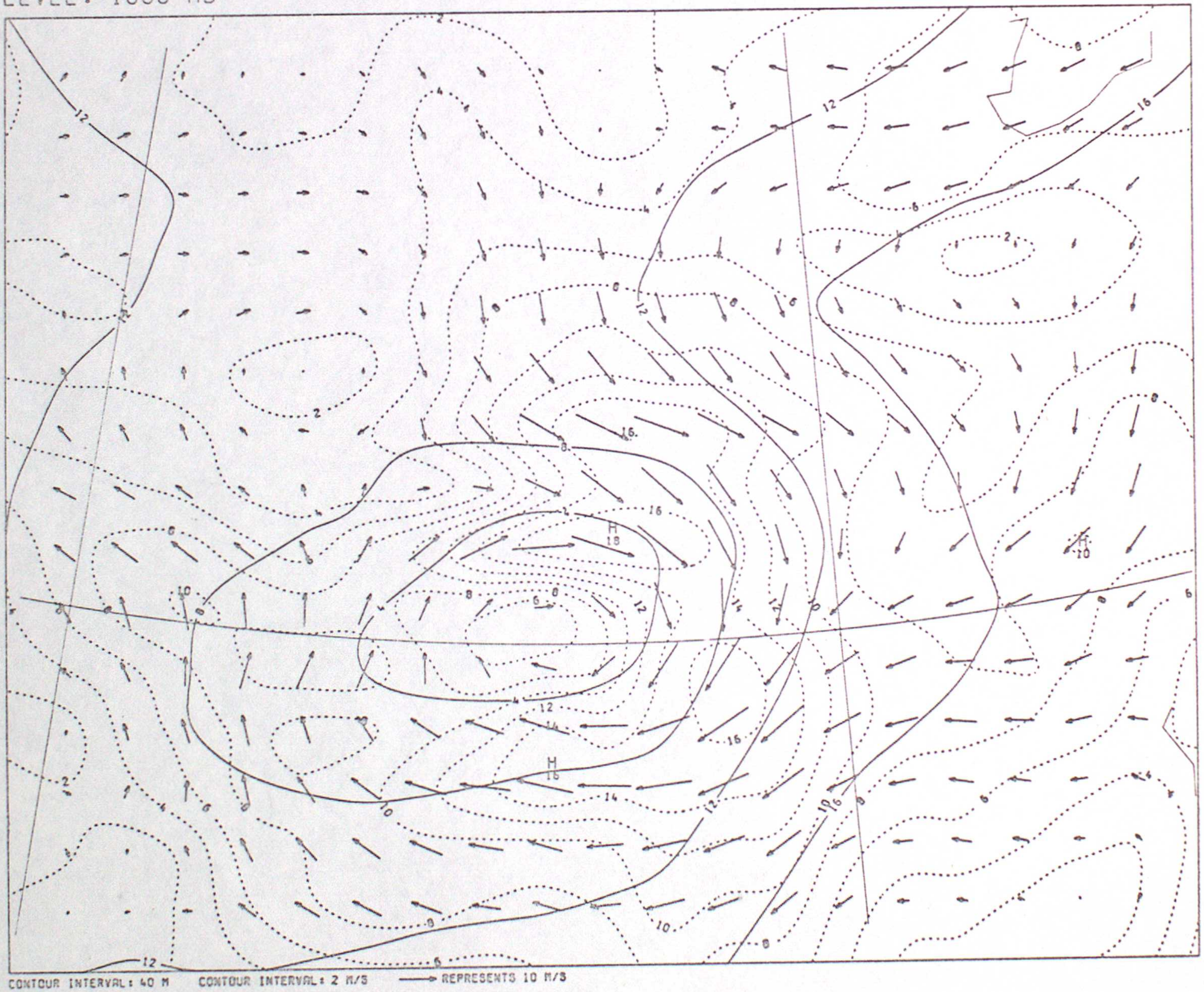
FIGURE 3A
OPERATIONAL ASSIMILATION (OPASSM)
HEIGHT & AGEOSTROPHIC WIND
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: 1000 MB



CONTOUR INTERVAL: 40 M   CONTOUR INTERVAL: 2 M/S   ——→ REPRESENTS 10 M/S

FIGURE 3B

OPERATIONAL ASSIMILATION(INITIALIZED) OPINIT
HEIGHT & AGEOSTROPHIC WIND
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: 1000 MB



CONTOUR INTERVAL: 40 M   CONTOUR INTERVAL: 2 M/S   ——→ REPRESENTS 10 M/S

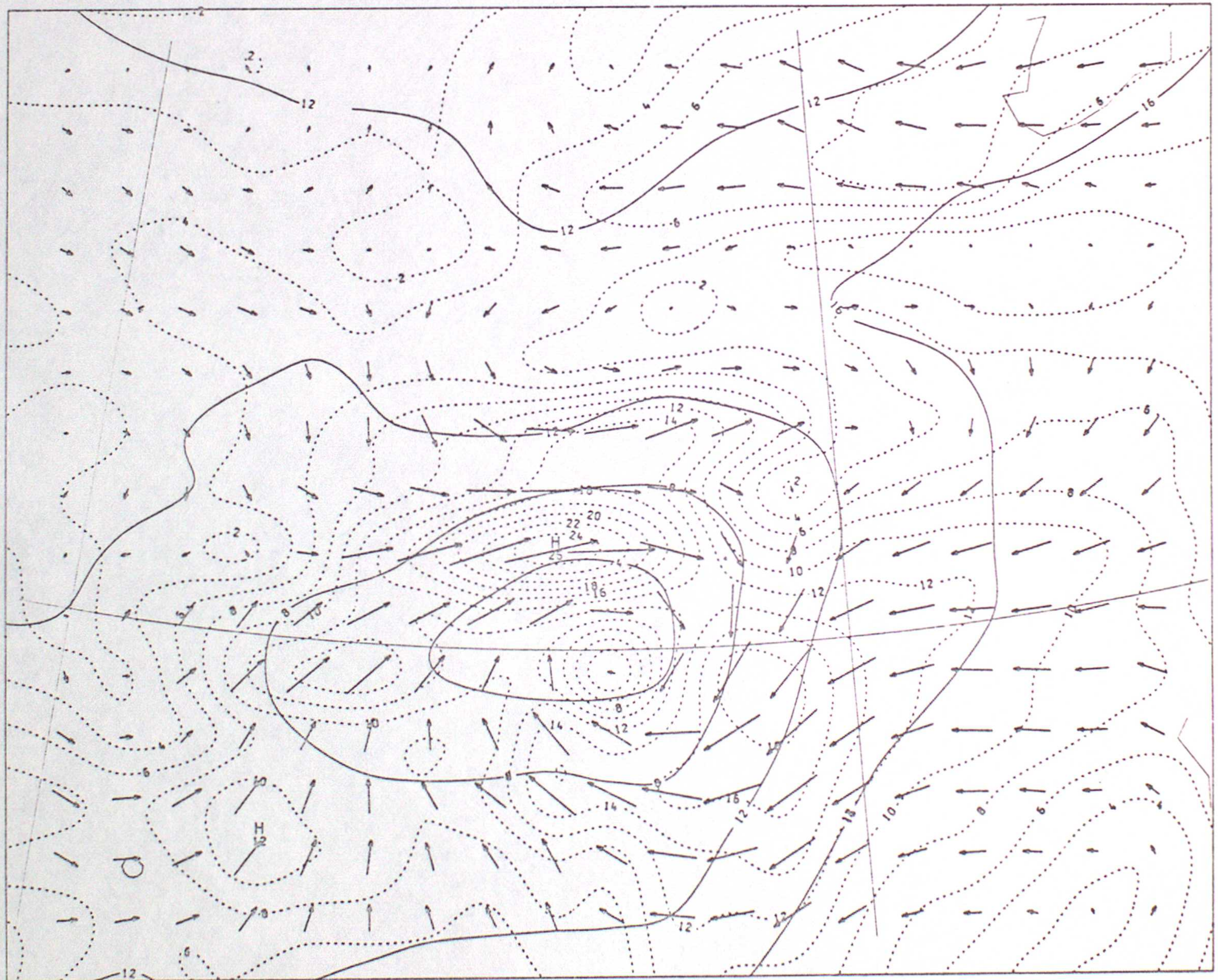
FIGURE 3C

D-ASSIMILATION(MODIFIED WIND RELAXATION COEFFICIENT) DASSM

HEIGHT & AGEOSTROPHIC WIND

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: 1000 MB



CONTOUR INTERVAL: 40 M   CONTOUR INTERVAL: 2 M/S   ——→ REPRESENTS 10 M/S

FIGURE 3D

D-ASSIMILATION(ZERO DIVERGENCE DAMPING) DNODD
HEIGHT & AGEOSTROPHIC WIND
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: 1000 MB

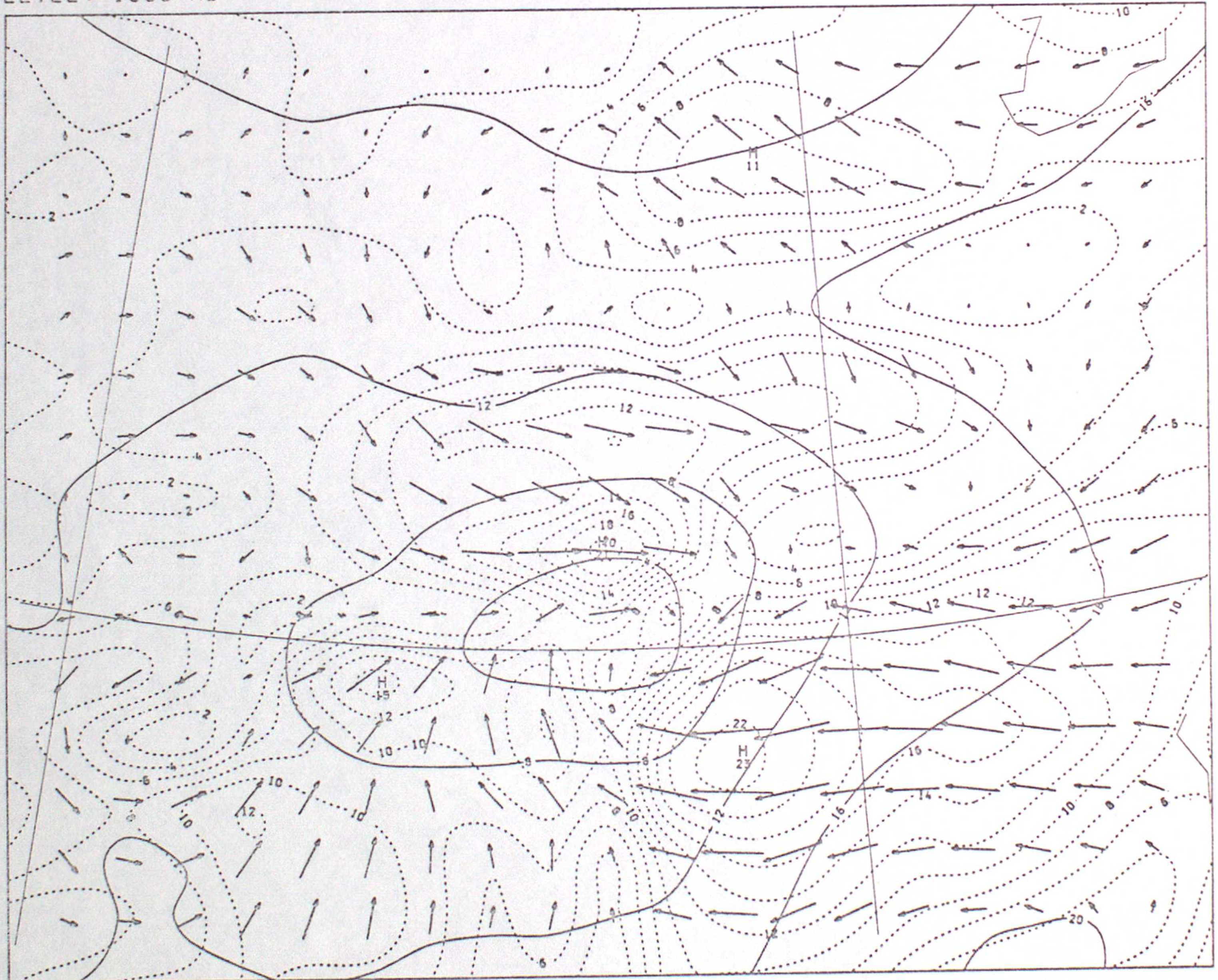


FIGURE 3E

UNIVARIATE OPTIMAL INTERPOLATION (UNOI)
HEIGHT & AGEOSTROPHIC WIND
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: 1000 MB

CONTOUR INTERVAL: 40 M   CONTOUR INTERVAL: 2 M/S   ——> REPRESENTS 10 M/S

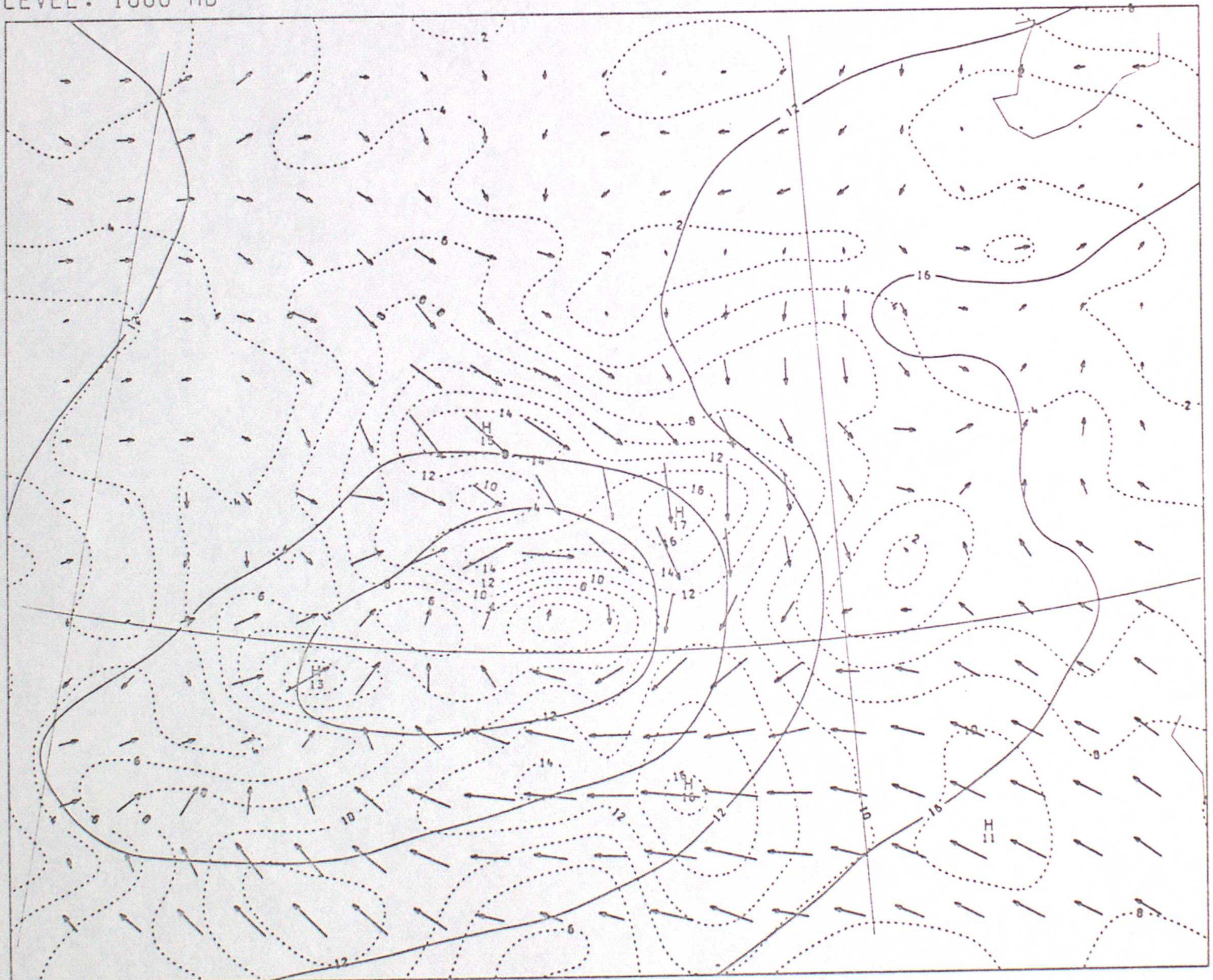
FIGURE 3F

OPERATIONAL BACKGROUND FIELD (BACK)

HEIGHT & AGEOSTROPHIC WIND

VALID AT 12Z ON 20/9/1983 DAY 263 DATA TIME 6Z ON 20/9/1983 DAY 263

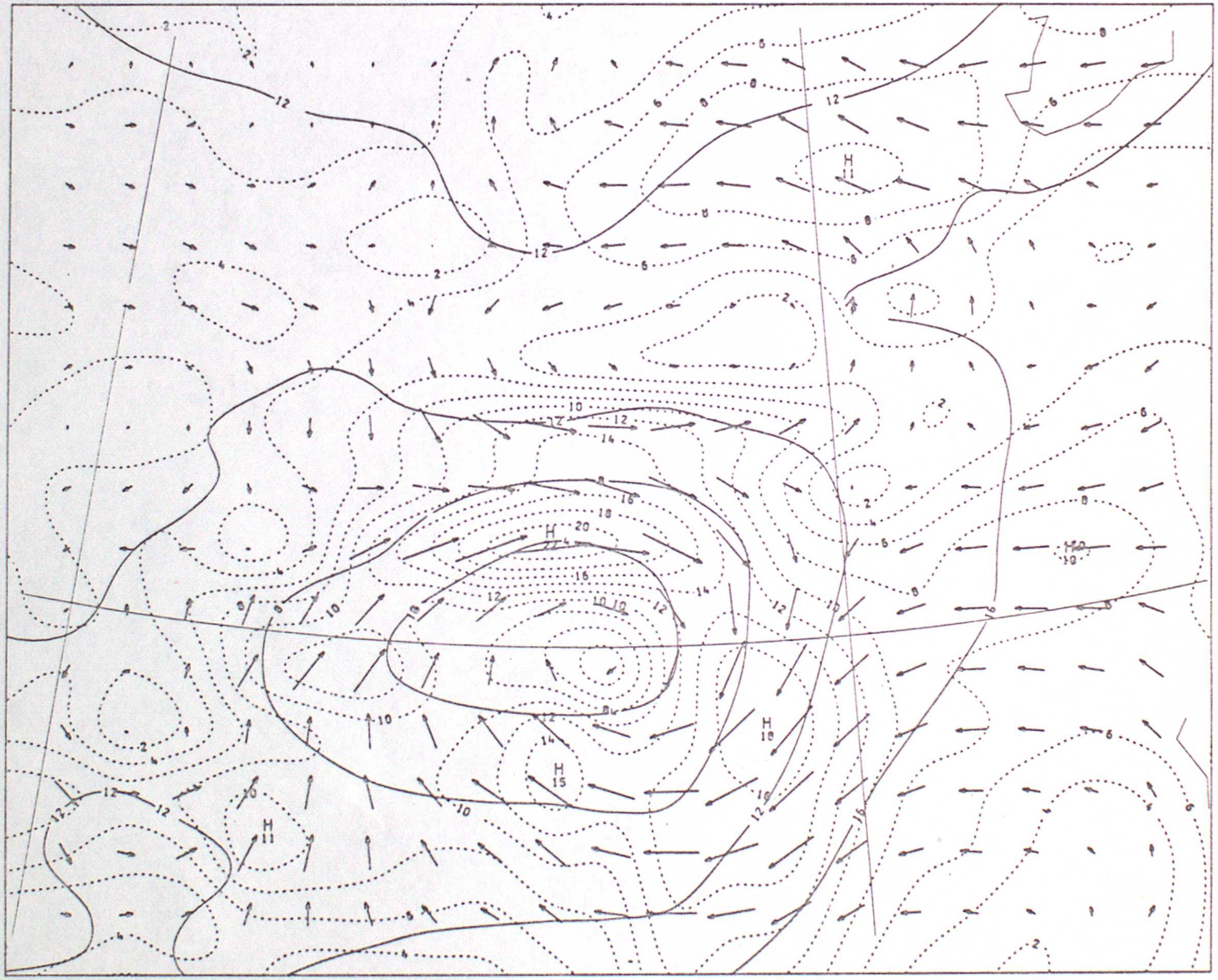
LEVEL: 1000 MB



CONTOUR INTERVAL: 40 M CONTOUR INTERVAL: 2 M/S ——→ REPRESENTS 10 M/S

FIGURE 3G

RERUN D-ASSM: NO SHIP WINDS NEAR DEPRESSION (DASNS)
HEIGHT & AGEOSTROPHIC WIND
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: 1000 MB



CONTOUR INTERVAL: 40 M CONTOUR INTERVAL: 2 M/S ——→ REPRESENTS 10 M/S

FIGURE 4A

MEAN SEA LEVEL PRESSURE DIFFERENCE FIELD(OPASSM-DASSM)
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL

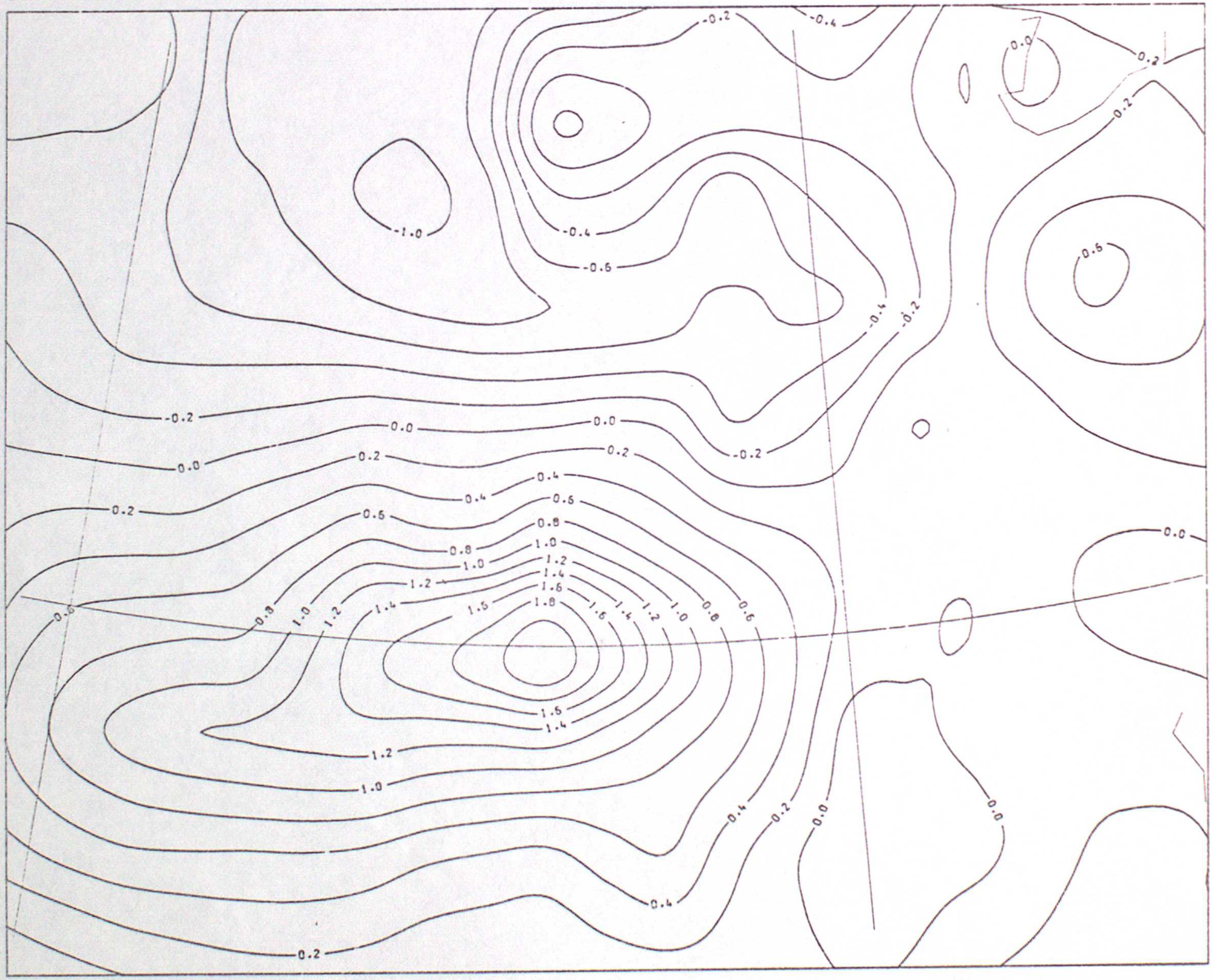


FIGURE 4B

DIFFERENCE FIELD (OPASSM-OPINIT)
MEAN SEA LEVEL PRESSURE (MB)
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL

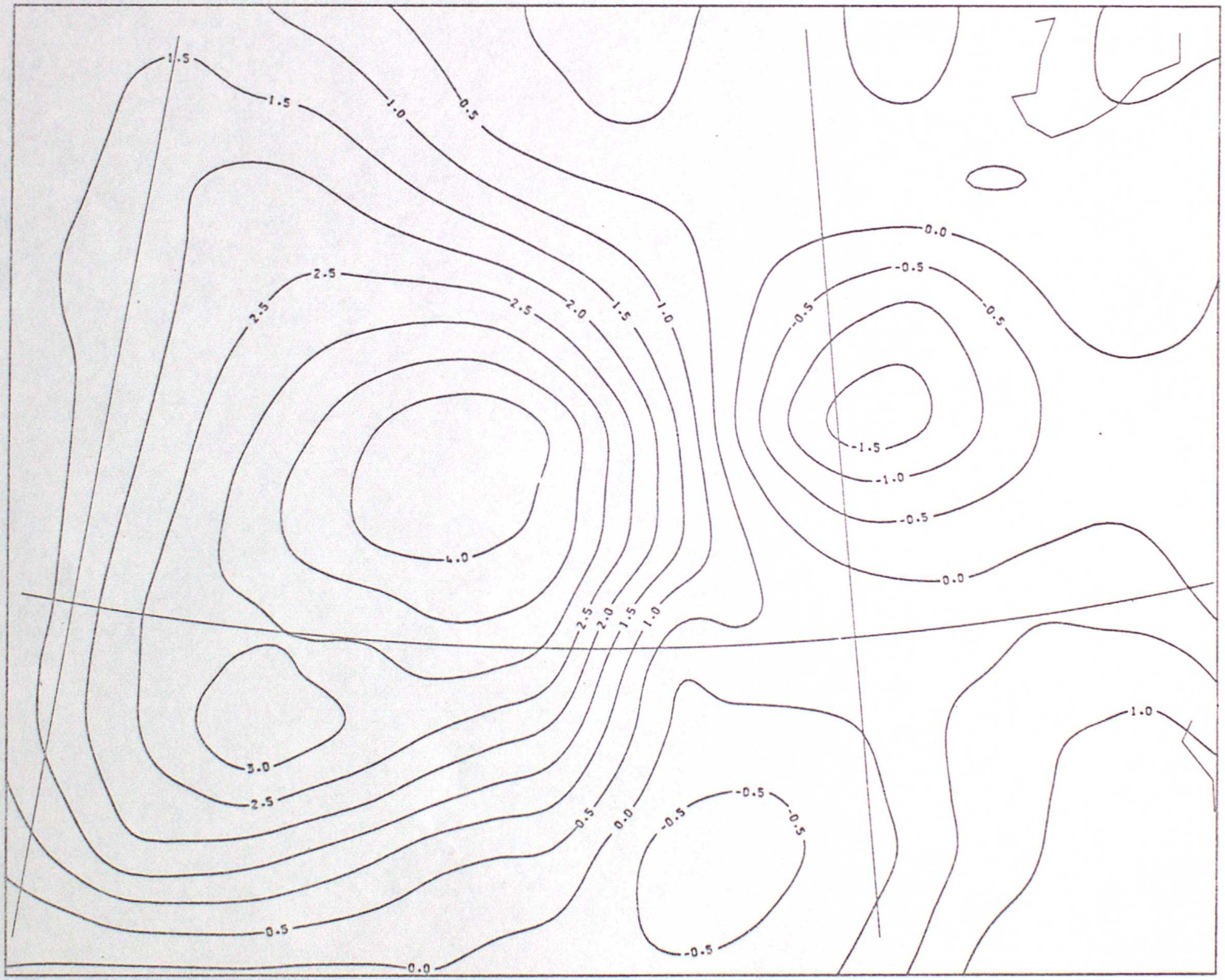


FIGURE 4C

DIFFERENCE FIELD (DASSN-DNODD)
MEAN SEA LEVEL PRESSURE (MB)
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL

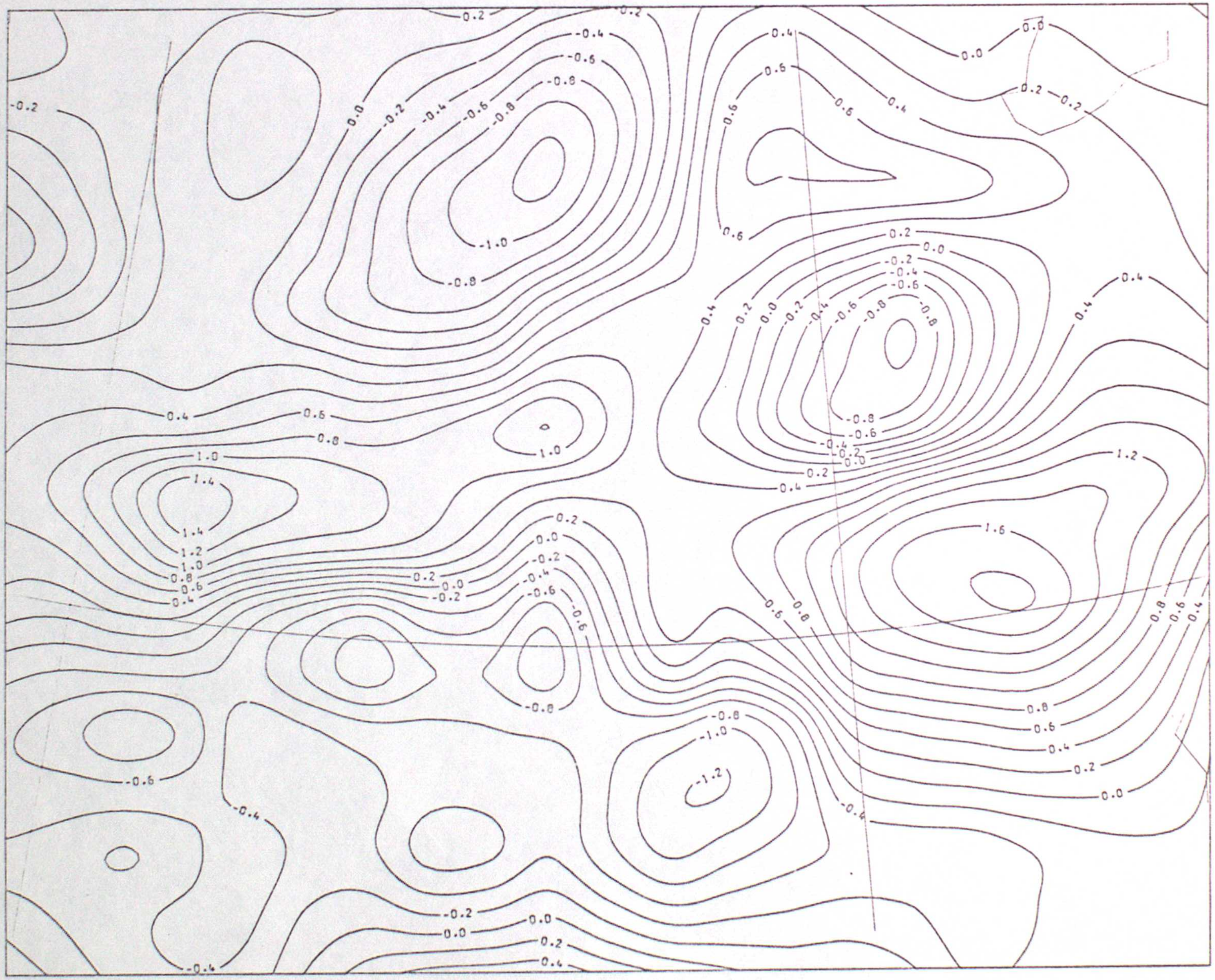


FIGURE 4D

MEAN SEA LEVEL PRESSURE DIFFERENCE FIELD (DASSM-DASNS)

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL

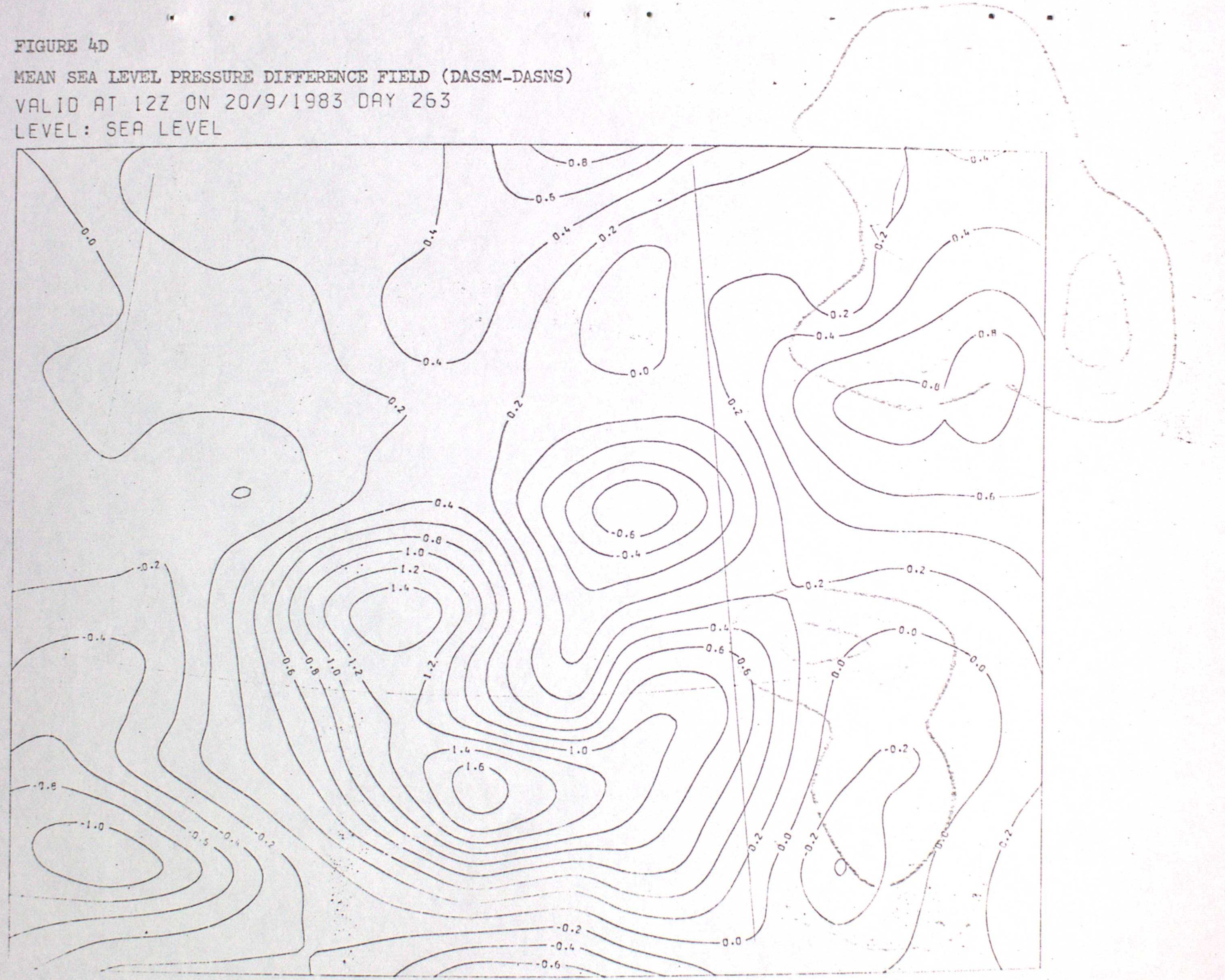


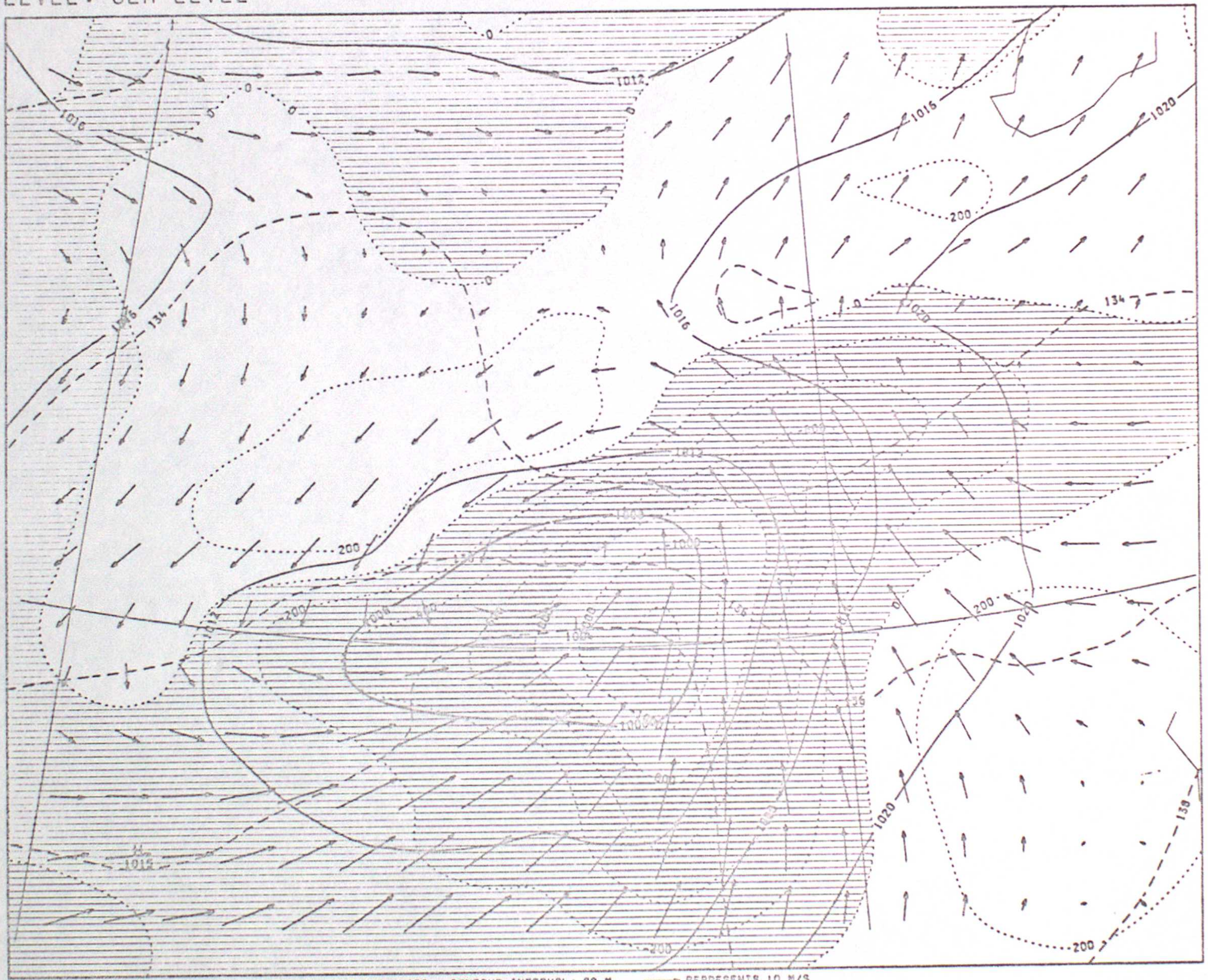
FIGURE 5A

OPERATIONAL UPDATE ANALYSIS

PMSL, 700MB OMEGA(UP SHADED), 1000-850MB THICKNESS, 1000MB WIND.

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL



CONTOUR INTERVAL: 4 MB CONTOUR INTERVAL: 0.2 MKS UNITS CONTOUR INTERVAL: 20 M ⟶ REPRESENTS 10 M/S

FIGURE 5B
OPERATIONAL UPDATE ANALYSIS AFTER NON-LINEAR NORMAL MODE INITIALIZATION
PMSL, 700MB OMEGA(UP SHADED), 1000-850MB THICKNESS, 1000MB WIND.
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL

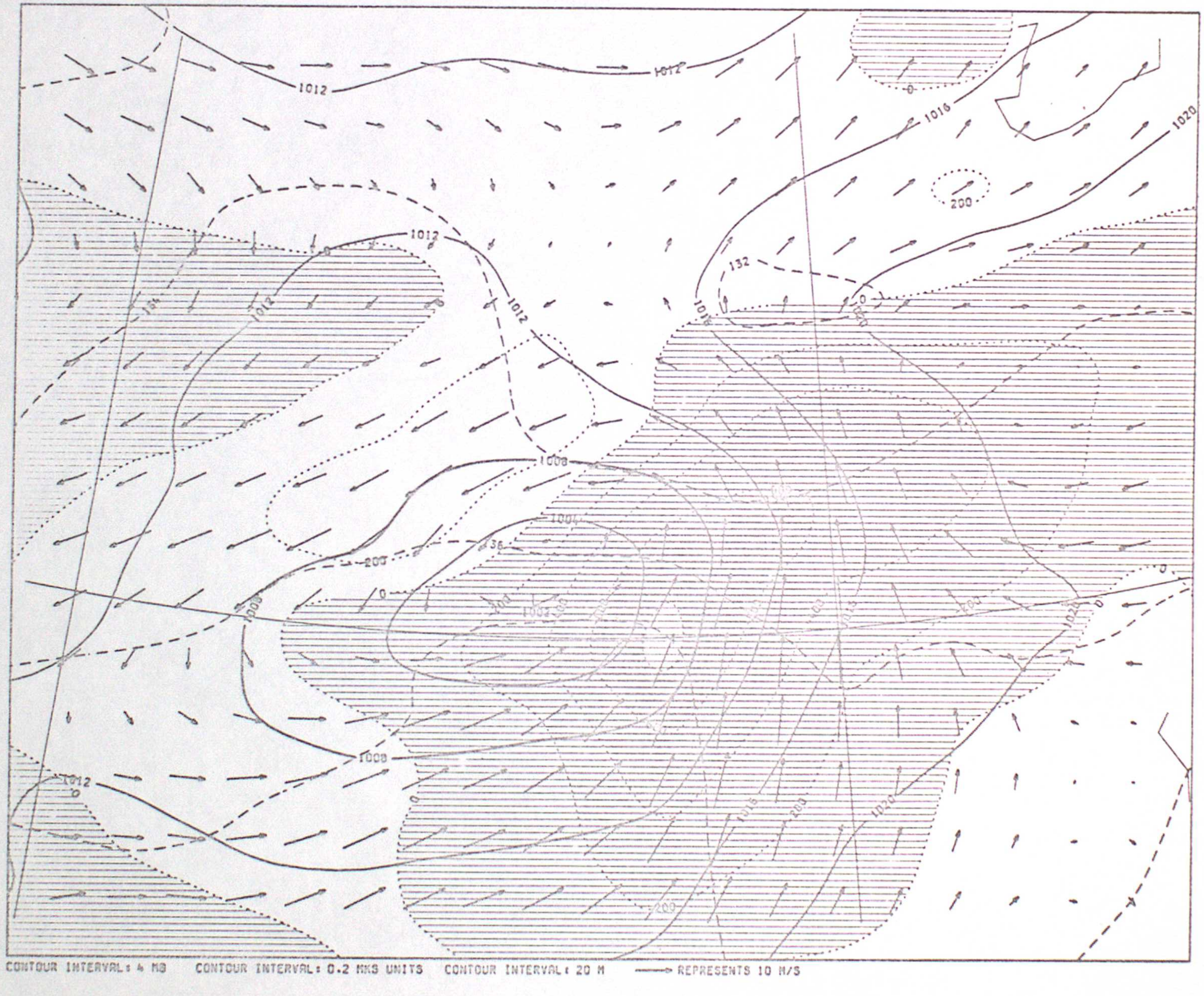


FIGURE 5C

'D' ASSIMILATION ANALYSIS (MODIFIED WIND RELAXATION COEFF. ETC.)
PMSL, 700MB OMEGA(UP SHADED), 1000-850MB THICKNESS, 1000MB WIND.
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL

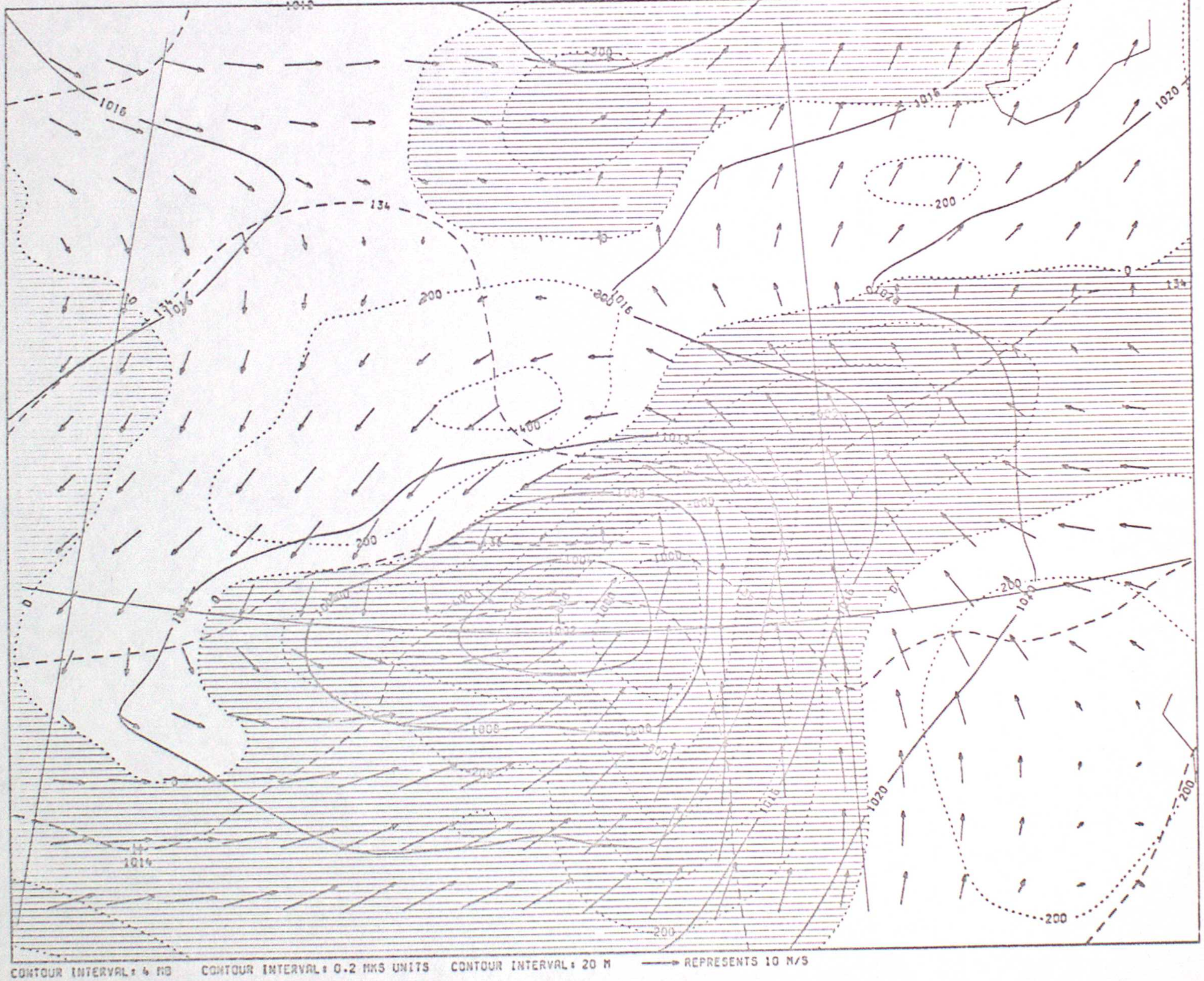
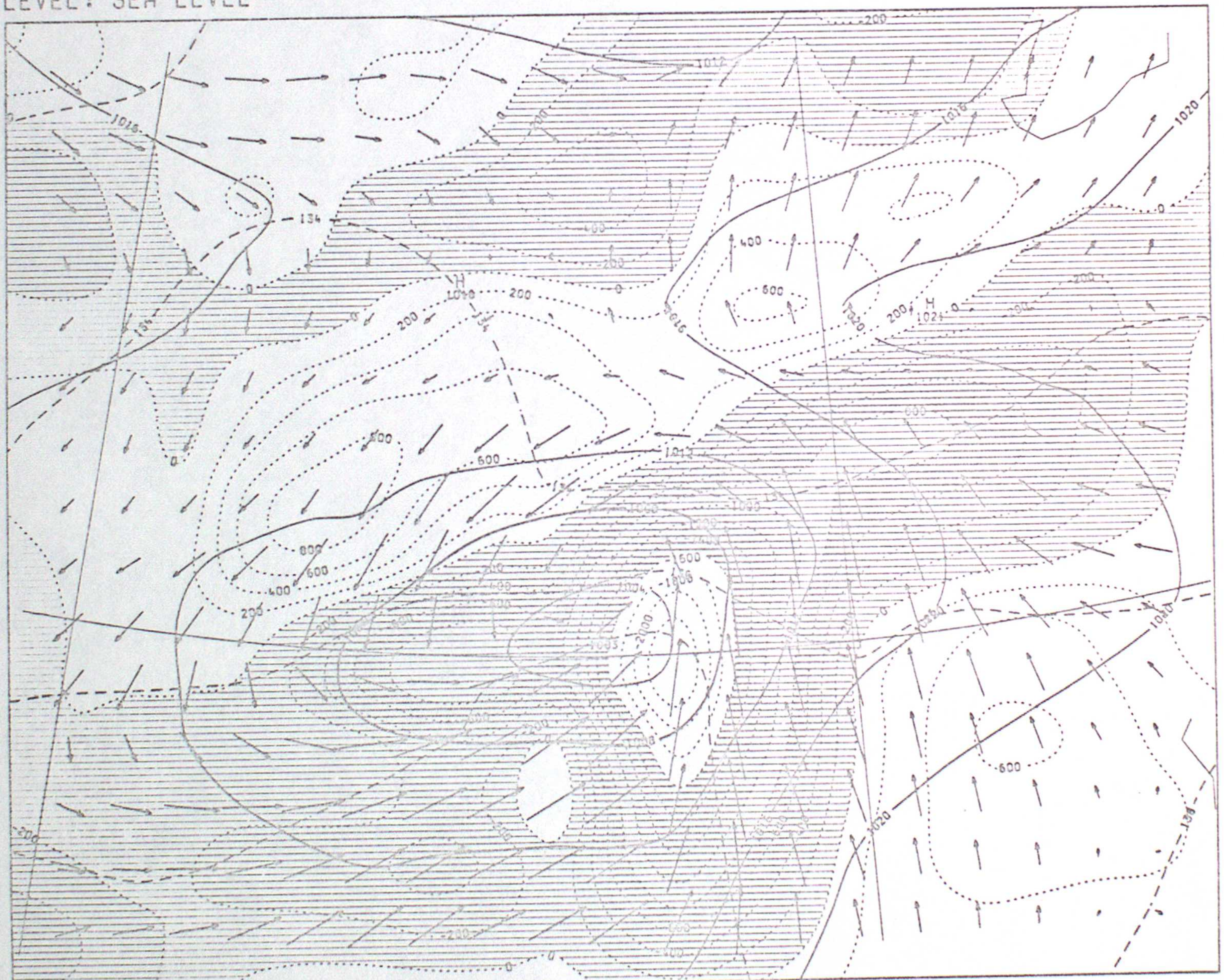


FIGURE 5D

'D' ASSIMILATION ANALYSIS WITH ZERO DIVERGENCE DAMPING.
PMSL, 700MB OMEGA(UP SHADED), 1000-850MB THICKNESS, 1000MB WIND.
VALID AT 12Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL



CONTOUR INTERVAL: 4 MB   CONTOUR INTERVAL: 0.2 MKS UNITS   CONTOUR INTERVAL: 20 M   ⟶ REPRESENTS 10 M/S

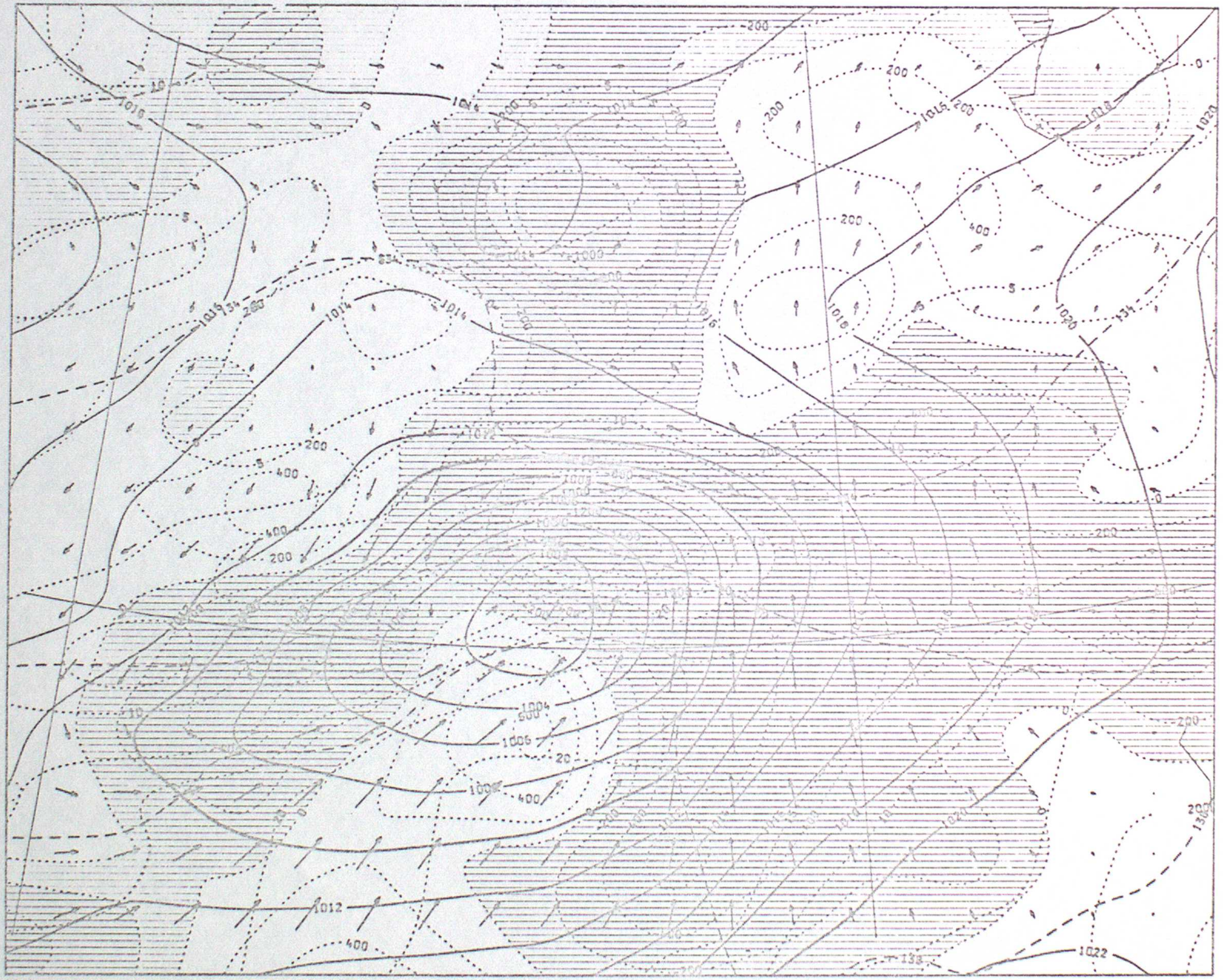
FIGURE 5E

UNIVARIATE OI

PMSL,1000MB WIND & ISOTACHS, 1000-850 THICKNESS, UPWARD MOTION SHADED

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB —— REPRESENTS 20 M/S CONTOUR INTERVAL: 5 M/S CONTOUR INTERVAL: 20 M CONTOUR INTERVAL: 0.2 MKS UNITS

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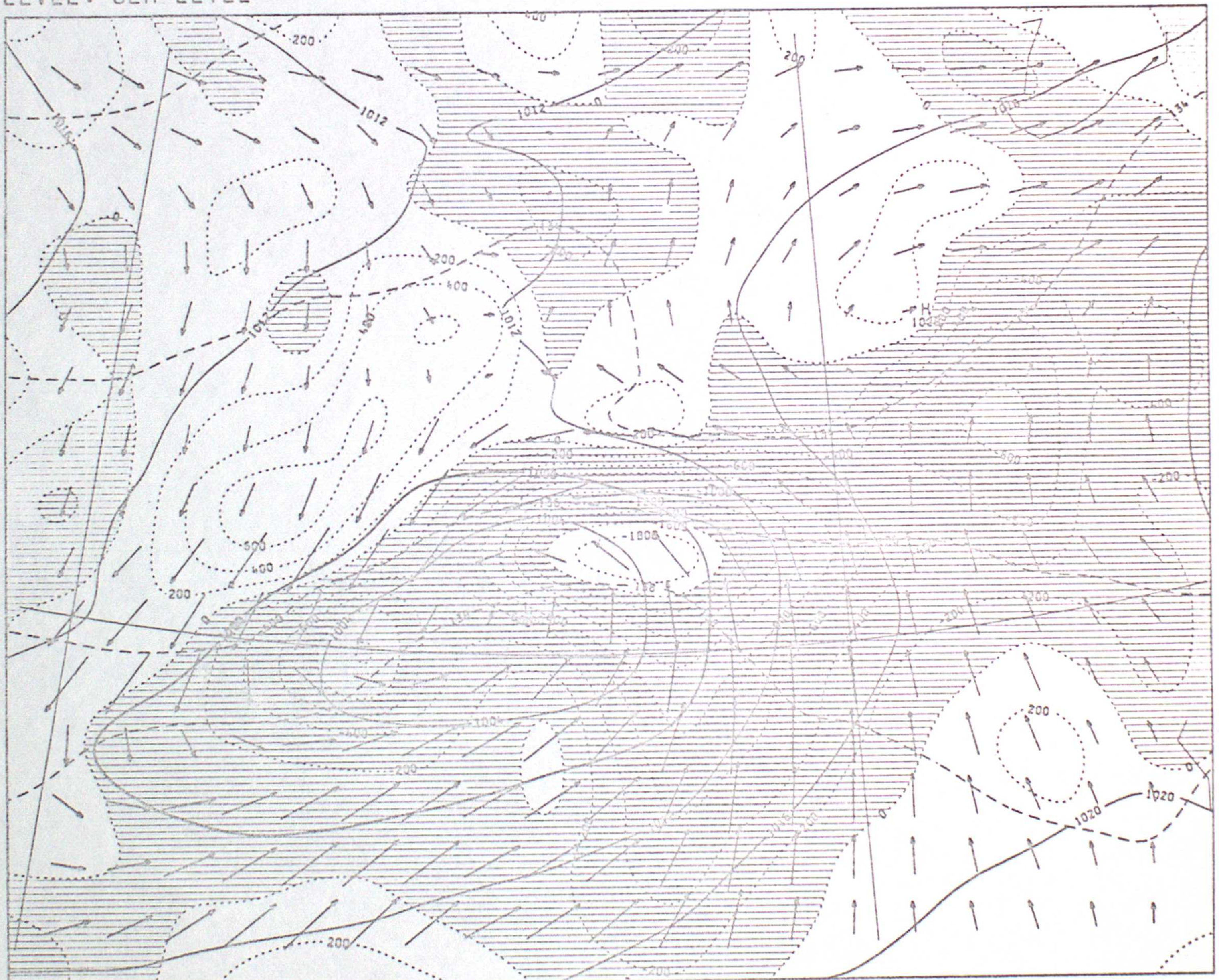
FIGURE 5F

OPERATIONAL BACKGROUND FIELD
PMSL, 700MB OMEGA(UP SHADED), 1000-850MB THICKNESS, 1000MB WIND.
VALID AT 12Z ON 20/9/1983 DAY 263 DATA TIME 6Z ON 20/9/1983 DAY 263
LEVEL: SEA LEVEL



CONTOUR INTERVAL: 4 MB   CONTOUR INTERVAL: 0.2 MKS UNITS   CONTOUR INTERVAL: 20 M   ——→ REPRESENTS 10 M/S

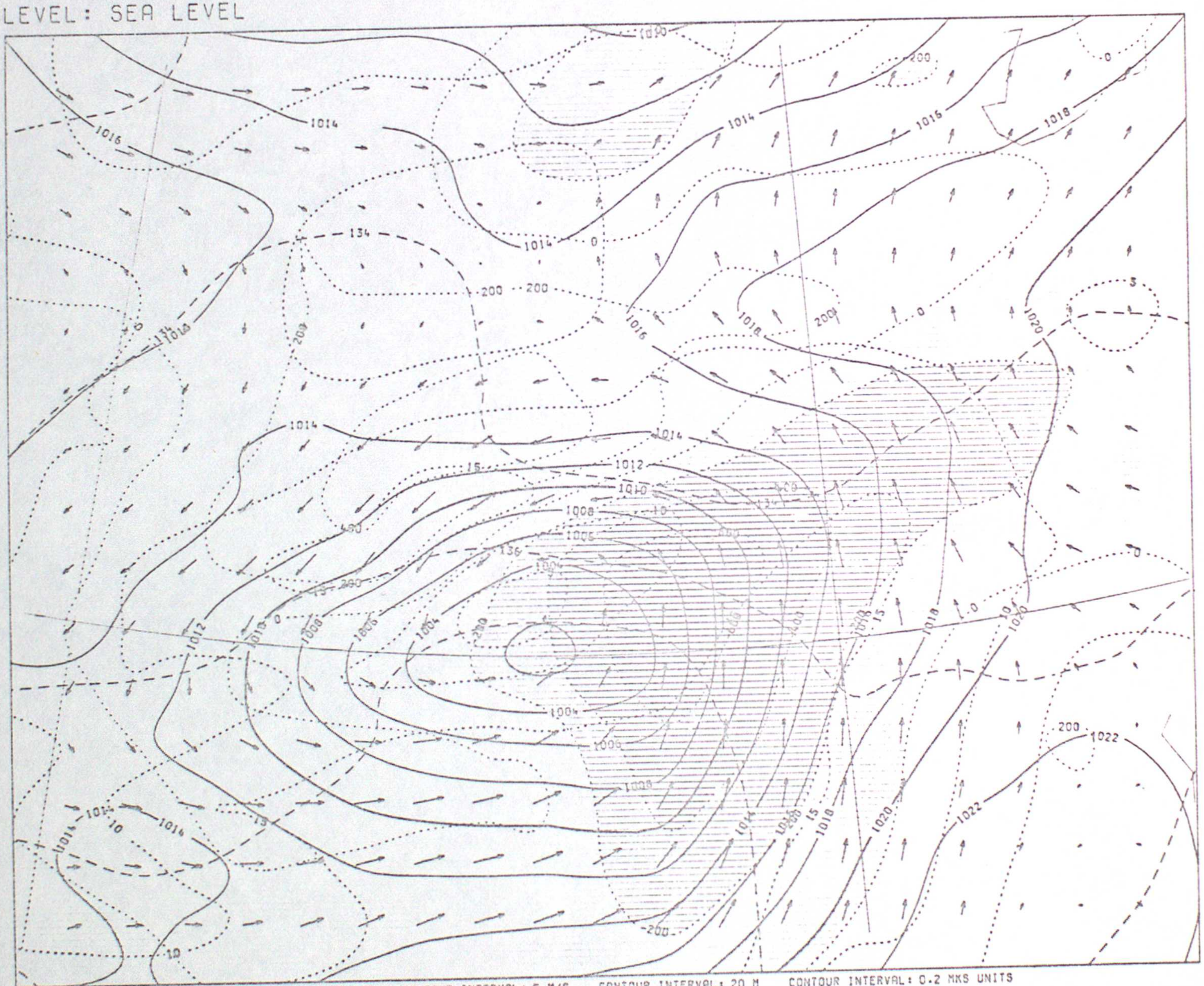
FIGURE 5G

D-ASSM RERUN:NO SHIP WINDS NEAR DEPRESSION

PMSL,1000MB ISOTACHS, 1000-850 THICKNESS, UPWARD MOTION SHADED

VALID AT 12Z ON 20/9/1983 DAY 263

LEVEL: SEA LEVEL



CONTOUR INTERVAL: 2 MB —— REPRESENTS 20 M/S CONTOUR INTERVAL: 5 M/S CONTOUR INTERVAL: 20 M CONTOUR INTERVAL: 0.2 MKS UNITS

FIGURE 6A

OPERATIONAL BACKGROUND FIELD (BACK)

DIVERGENCE
VALID AT 12Z ON 20/9/1983 DAY 263 DATA TIME 6Z ON 20/9/1983 DAY 263
LONGITUDE: -20

FIGURE 6B

OPERATIONAL ASSIMILATION ANALYSIS (OPASSM)

DIVERGENCE
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

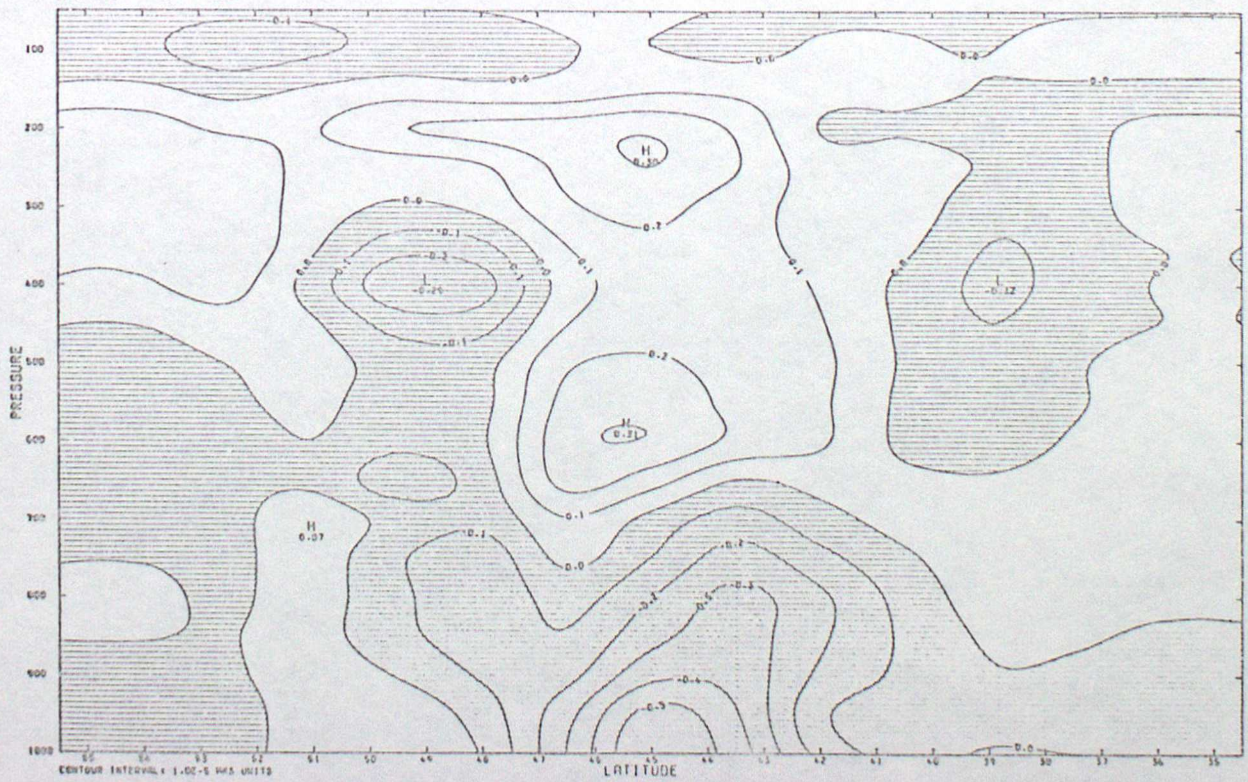


FIGURE 6C

OPERATIONAL UPDATE ANALYSIS AFTER NON-LINEAR NORMAL MODE INITIALISATION(OPINIT)

DIVERGENCE
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

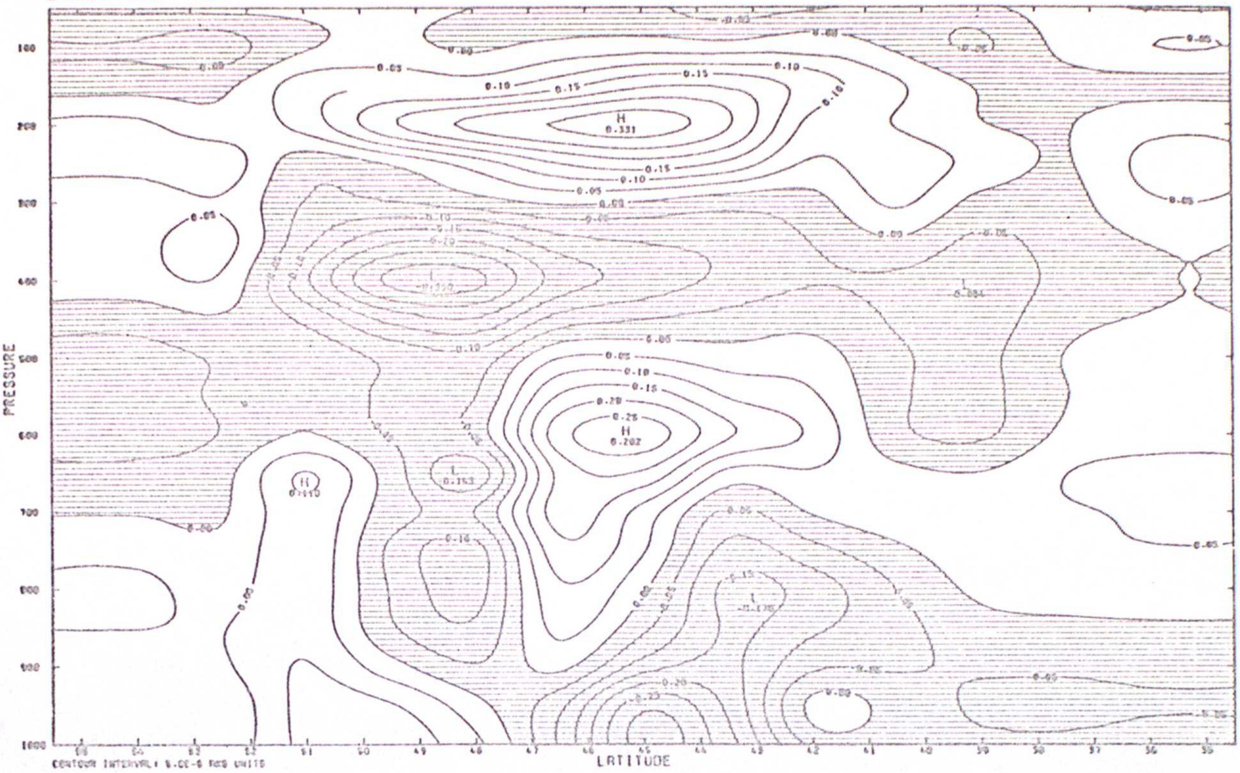


FIGURE 6D

'D' ASSIMILATION ANALYSIS (MODIFIED WIND RELAXATION COEFF. ETC.) DASSM

DIVERGENCE
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

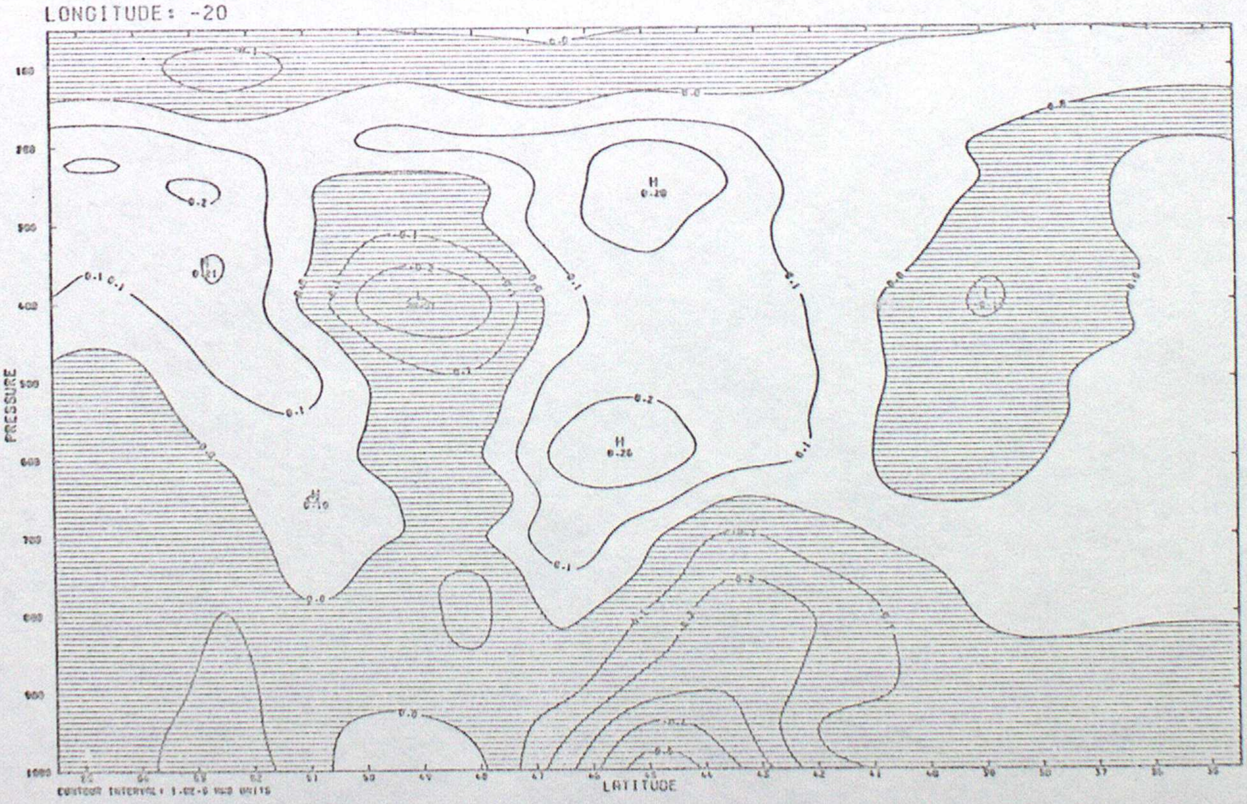


FIGURE 6E

'D' ASSIMILATION ANALYSIS WITH ZERO DIVERGENCE DAMPING (DNODD)

DIVERGENCE
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

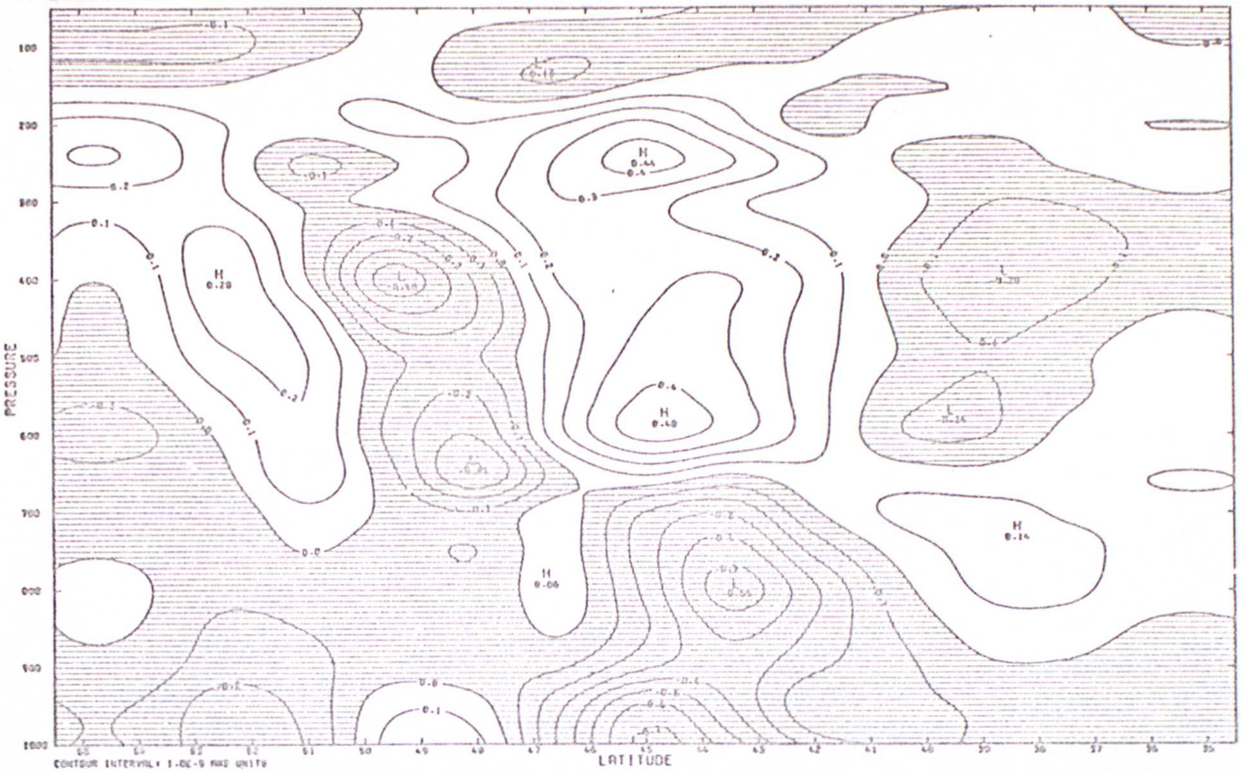


FIGURE 6F

'D' ASSIMILATION RERUN WITH NO SHIPS' WINDS NEAR LOW T (DASNS)

DIVERGENCE
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

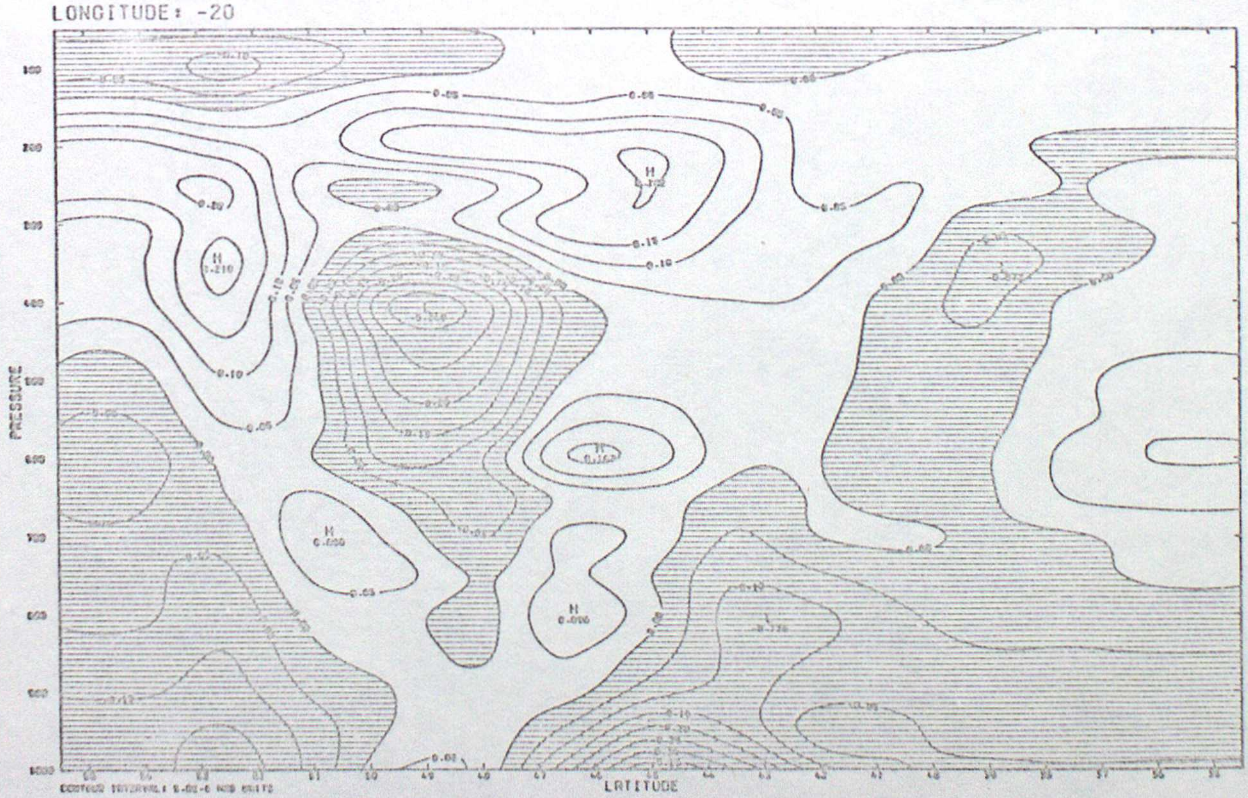


FIGURE 6G

UNIVARIATE OPTIMAL INTERPOLATION
DIVERGENCE
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

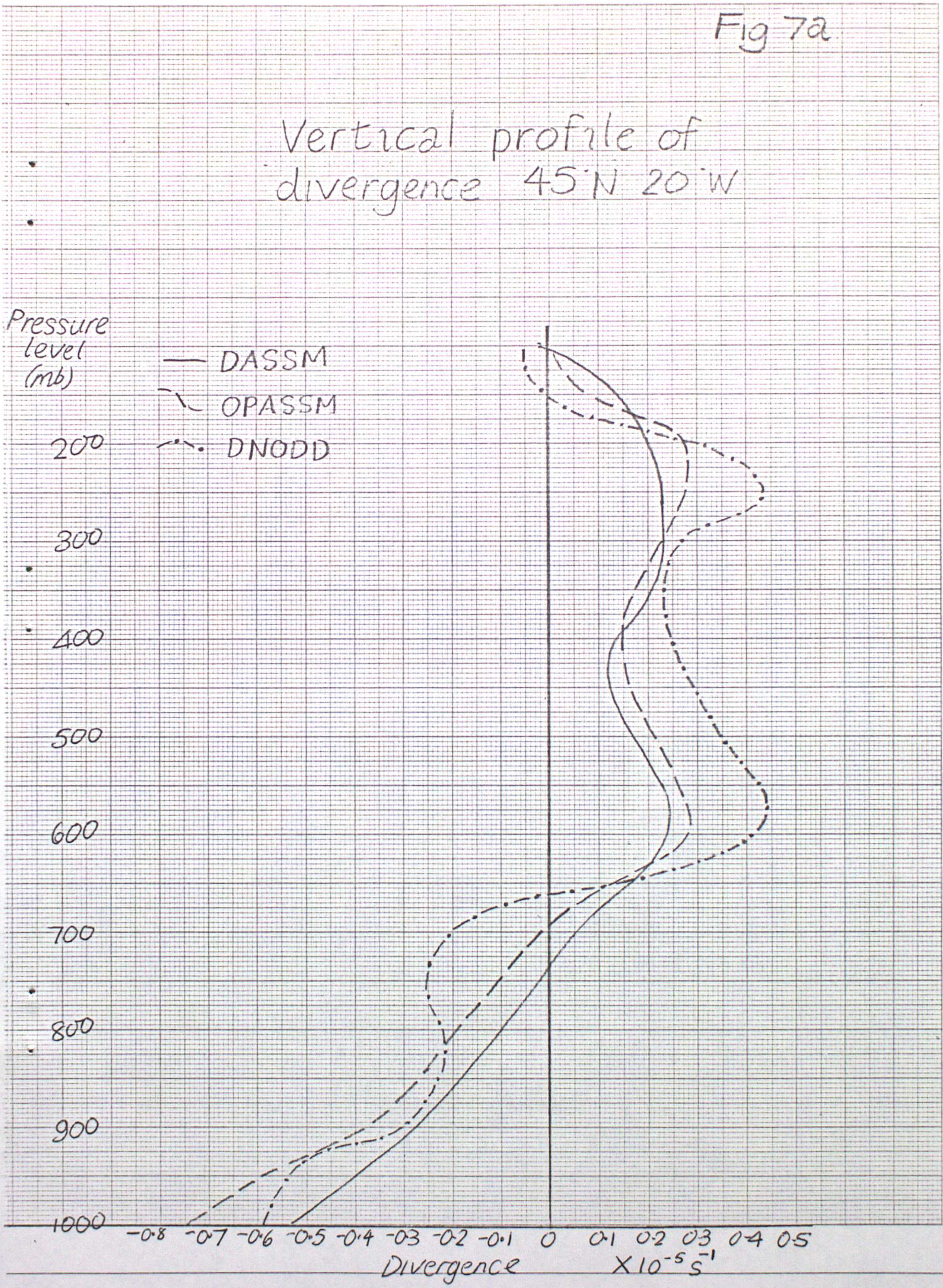


Fig 7a
Vertical profile of divergence 45°N 20°W
Pressure level (mb)
DASSM
OPASSM
DNODD
200
300
400
500
600
700
800
900
1000
-0·8
-0·7
-0·6
-0·5
-0·4
-0·3
-0·2
-0·1
0
0·1
0·2
0·3
0·4
0·5
Divergence
X10⁻⁵ s⁻¹

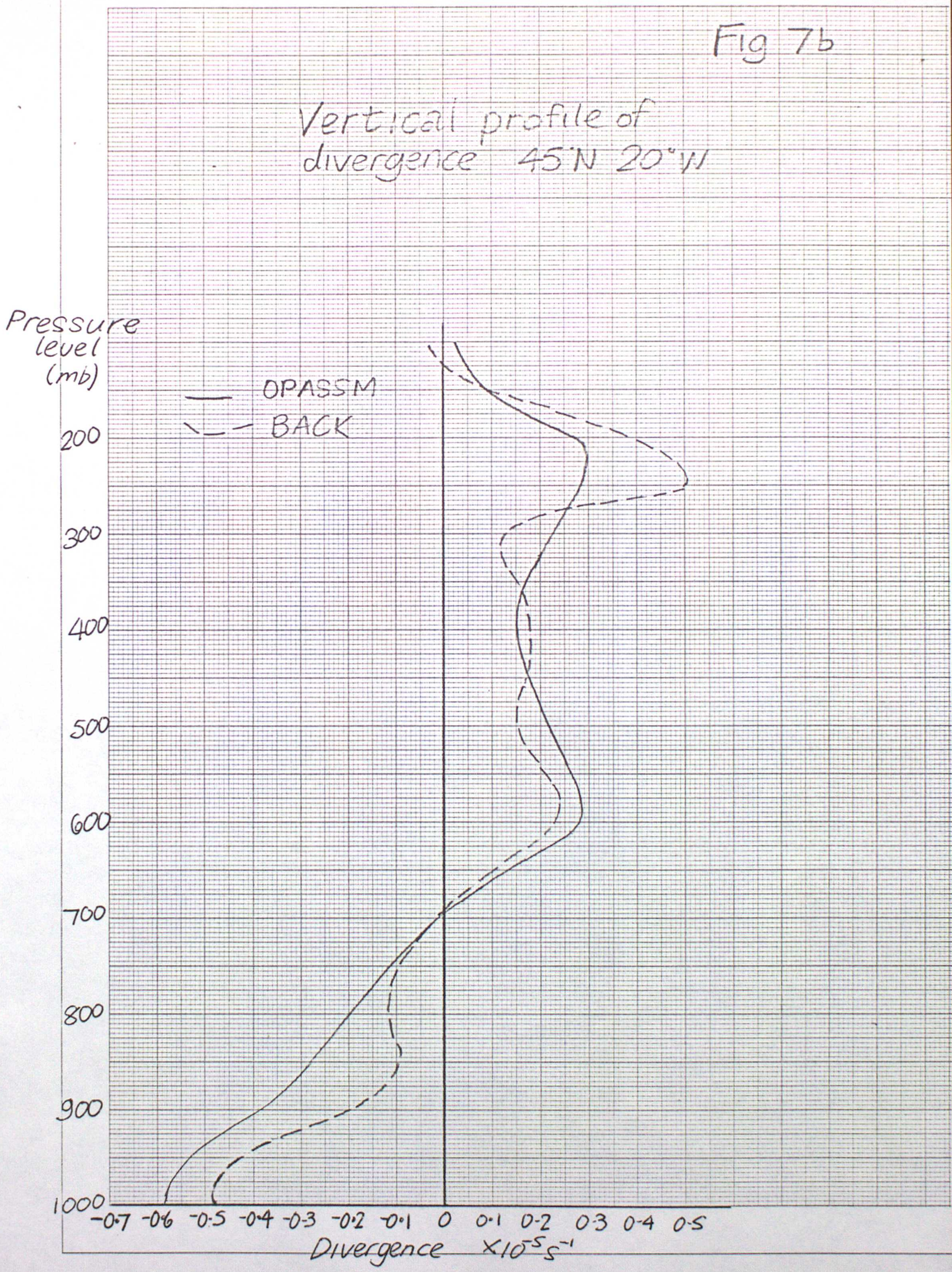


Fig 7b
Vertical profile of divergence 45°N 20°W
Pressure level (mb)
OPASSM
BACK
200
300
400
500
600
700
800
900
1000
-0·7 -0·6 -0·5 -0·4 -0·3 -0·2 -0·1 0 0·1 0·2 0·3 0·4 0·5
Divergence $\times 10^{-5} s^{-1}$

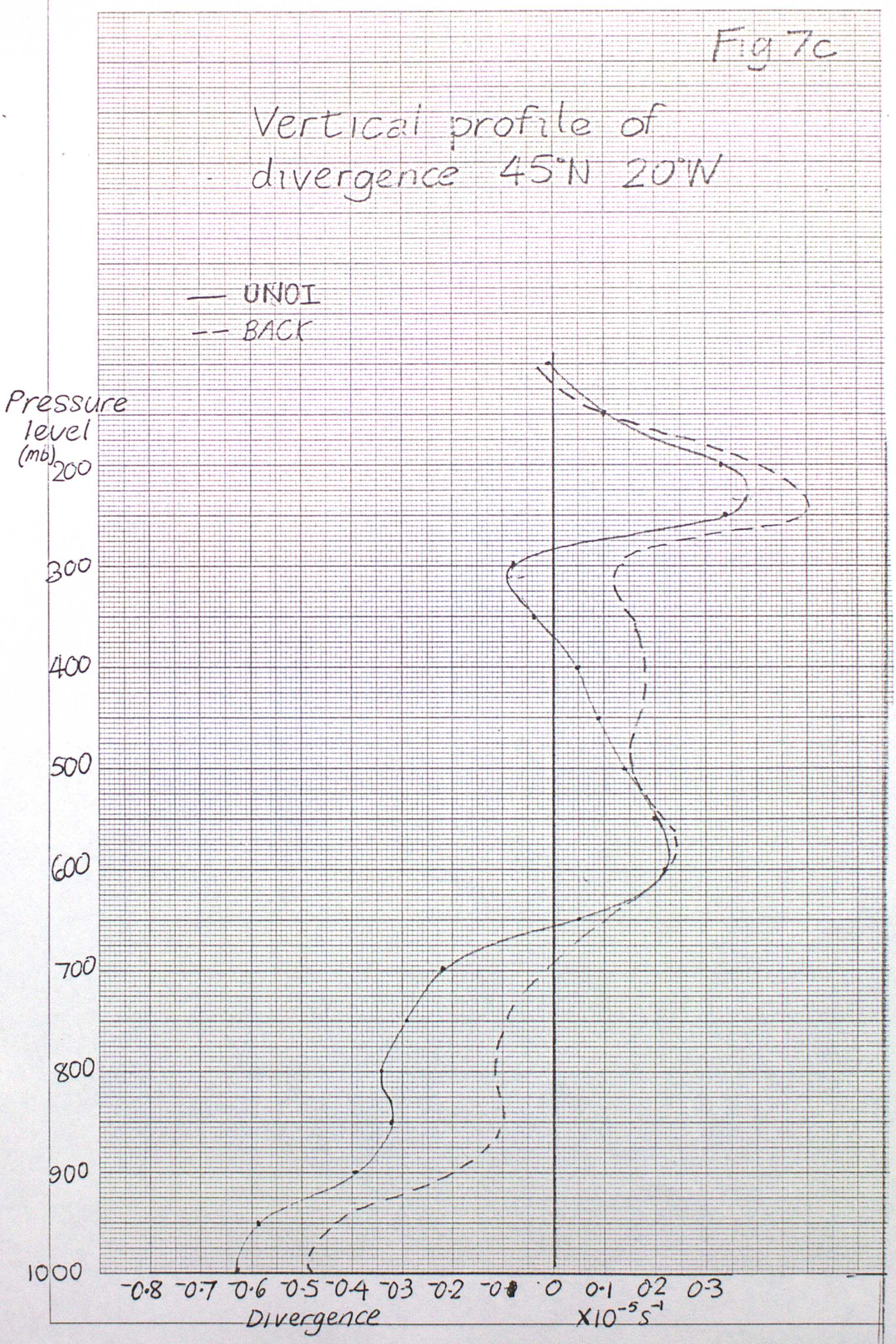
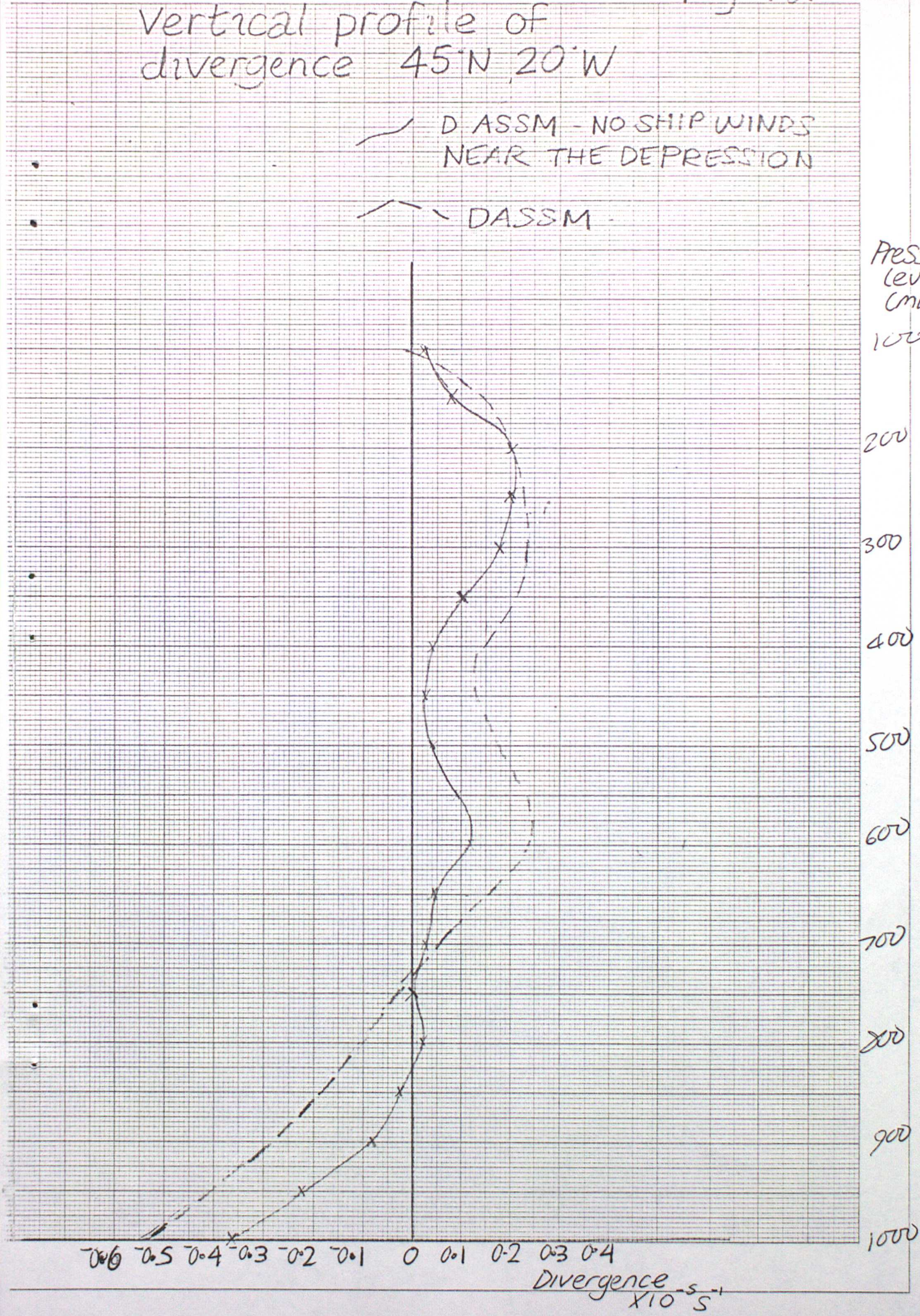


Fig 7c
Vertical profile of
divergence 45°N 20°W
UNOI
BACK
Pressure level (mb)
200
300
400
500
600
700
800
900
1000
-0·8 -0·7 -0·6 -0·5 -0·4 -0·3 -0·2 -0·1 0 0·1 0·2 0·3
Divergence
X10⁻⁵s⁻¹

Fig 7d

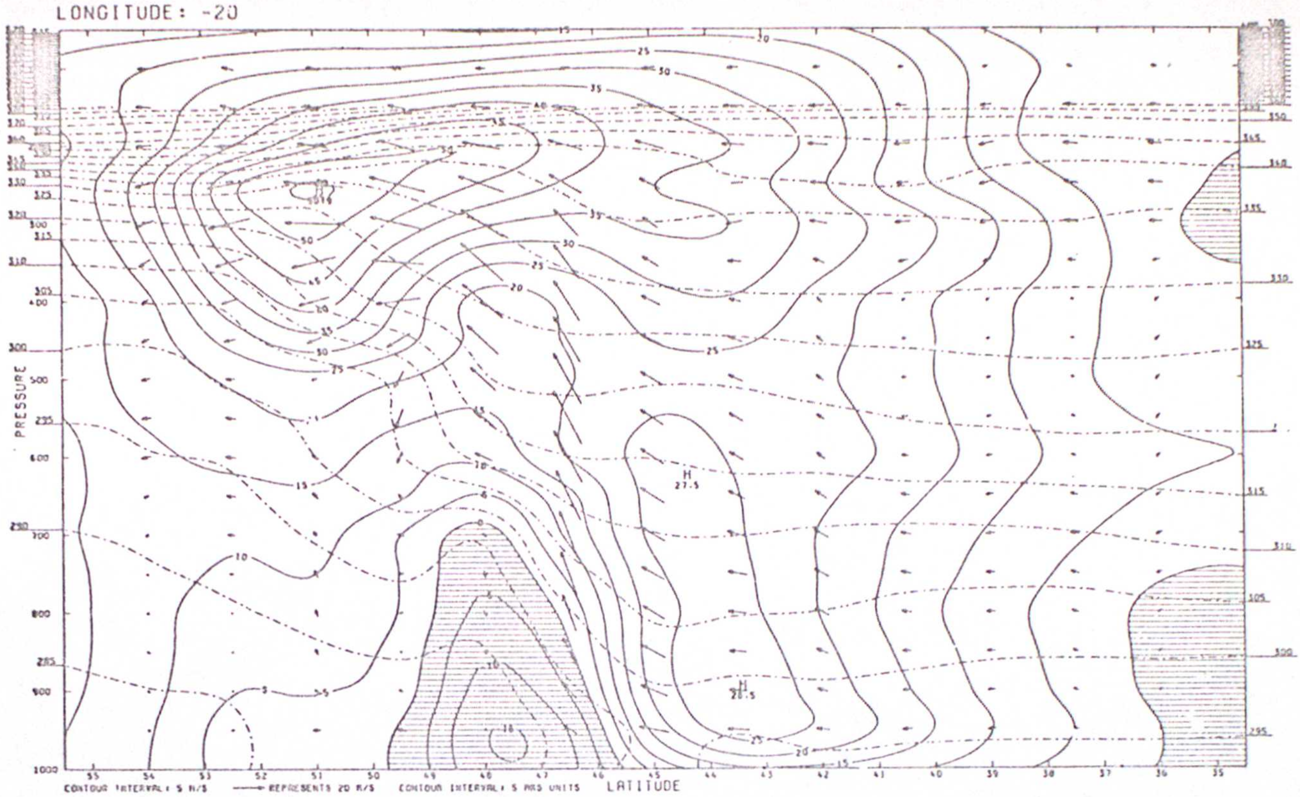


Vertical profile of divergence 45°N, 20°W
D ASSM - NO SHIP WINDS NEAR THE DEPRESSION
DASSM
Pressure level (mb)
100
200
300
400
500
600
700
800
900
1000
-0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4
Divergence $\times 10^{-5} s^{-1}$

FIGURE 8A

OPERATIONAL BACKGROUND FIELD (BACK)

N-S X-SECTION. U=SOLID CONTOURS -VE SHADED. V&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 12Z ON 20/9/1983 DAY 263 DATA TIME 6Z ON 20/9/1983 DAY 263
LONGITUDE: -20



N-S X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 12Z ON 20/9/1983 DAY 263 DATA TIME 6Z ON 20/9/1983 DAY 263
LONGITUDE: -20

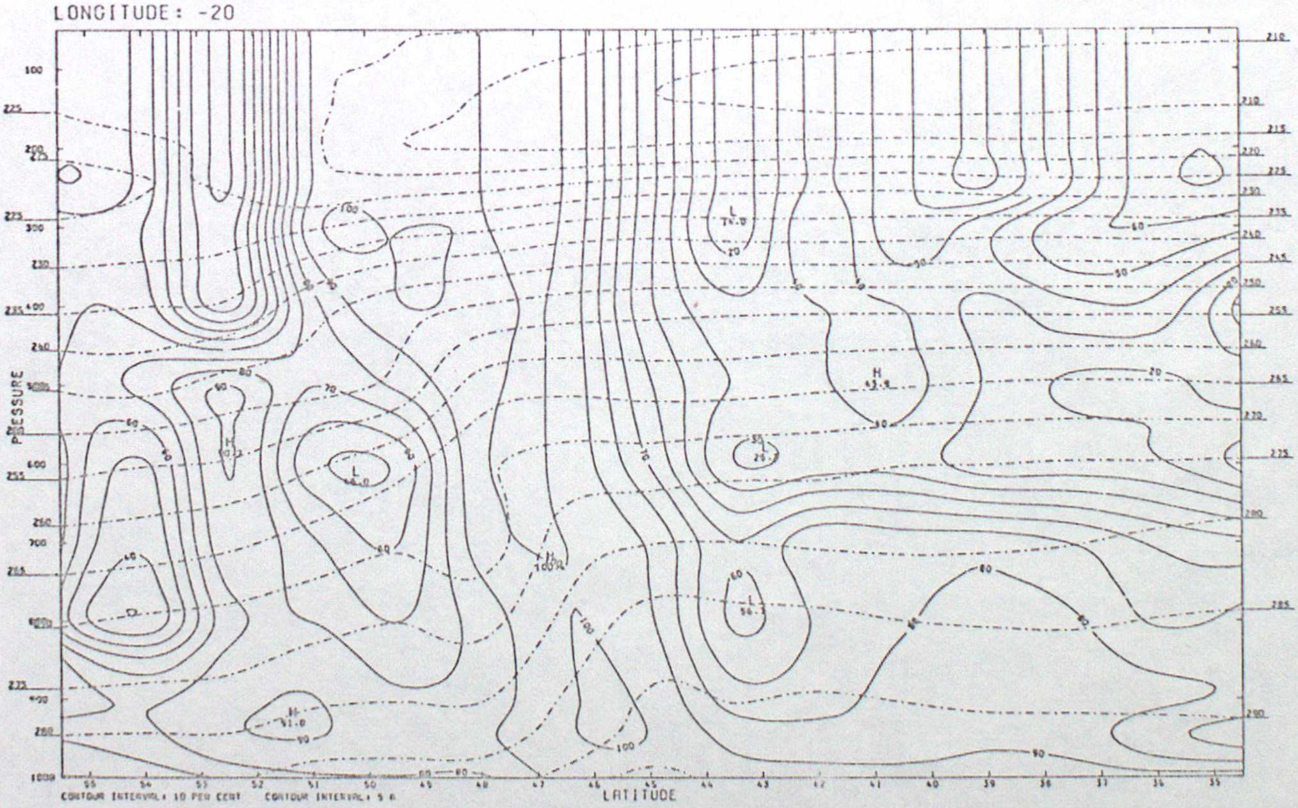
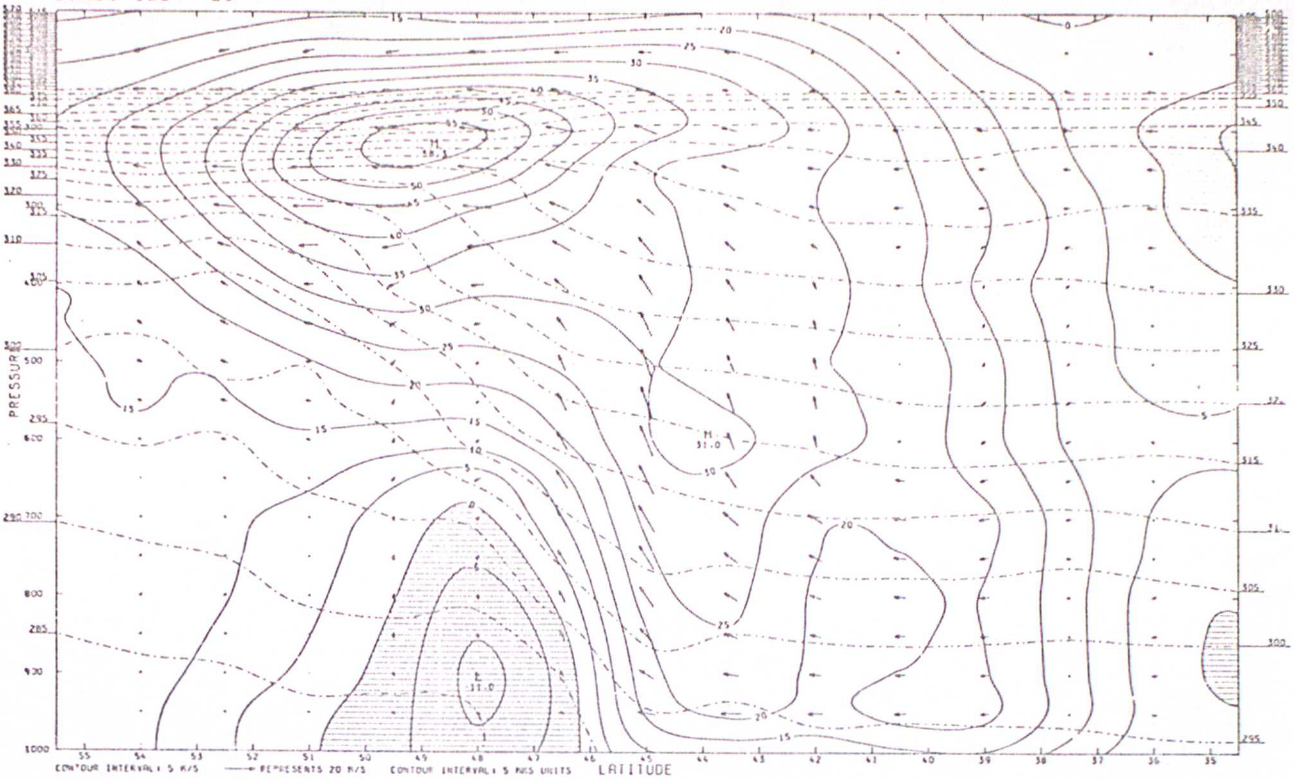


FIGURE 8B

OPERATIONAL ASSIMILATION (OPASSM)

N-S X-SECTION. U=SOLID CONTOURS -VE SHADED. V&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20



N-S X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

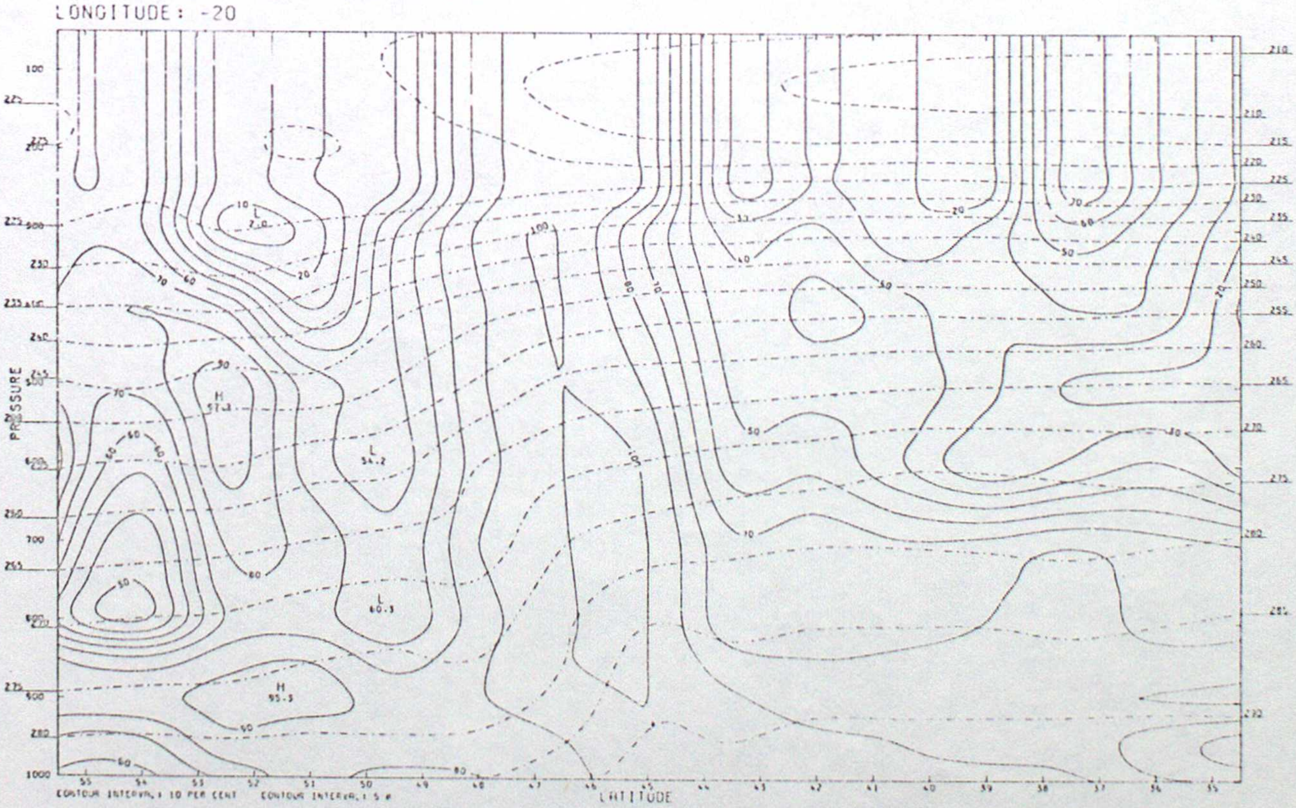
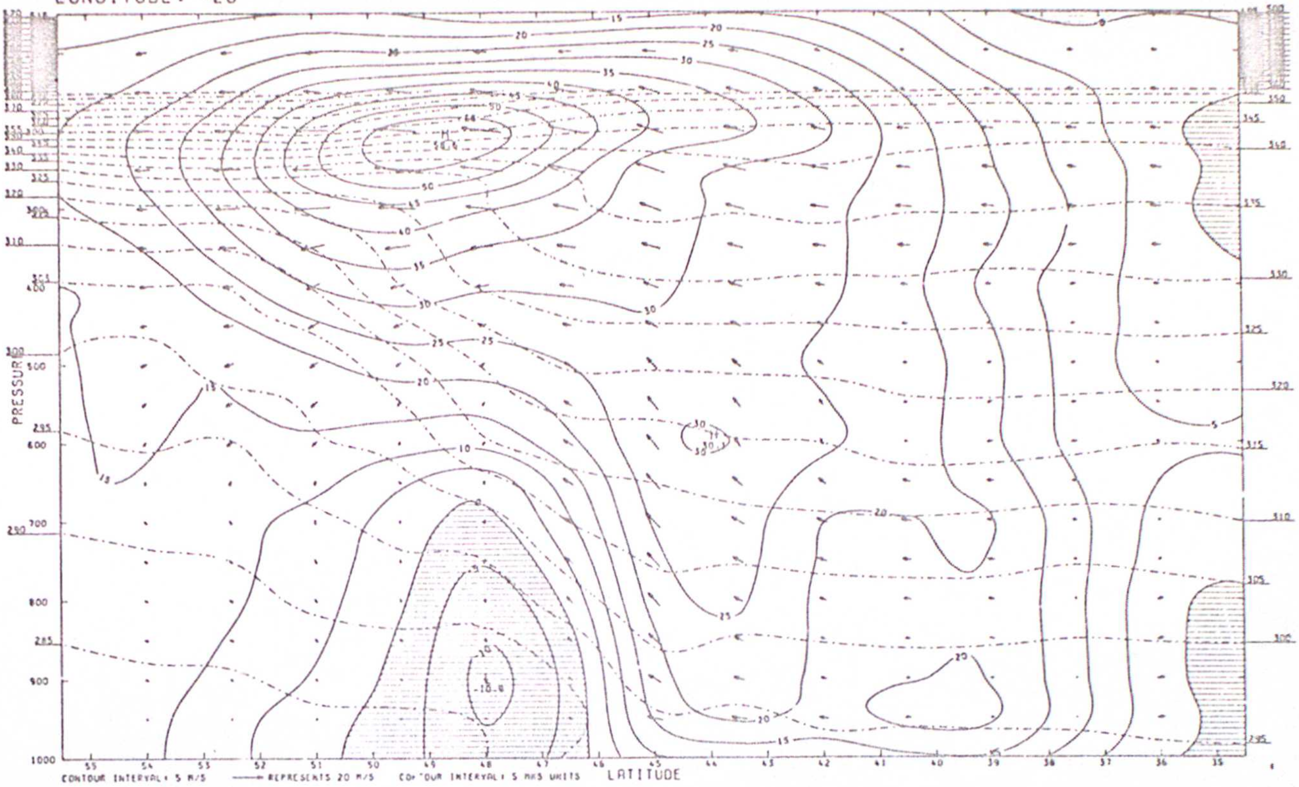


FIGURE 8C

QPERATIONAL UPDATE ANALYSIS AFTER NON-LINEAR NORMAL MODE INITIALIZATION(OPINIT)

N-S X-SECTION. U=SOLID CONTOURS -VE SHADED. V&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20



N-S X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

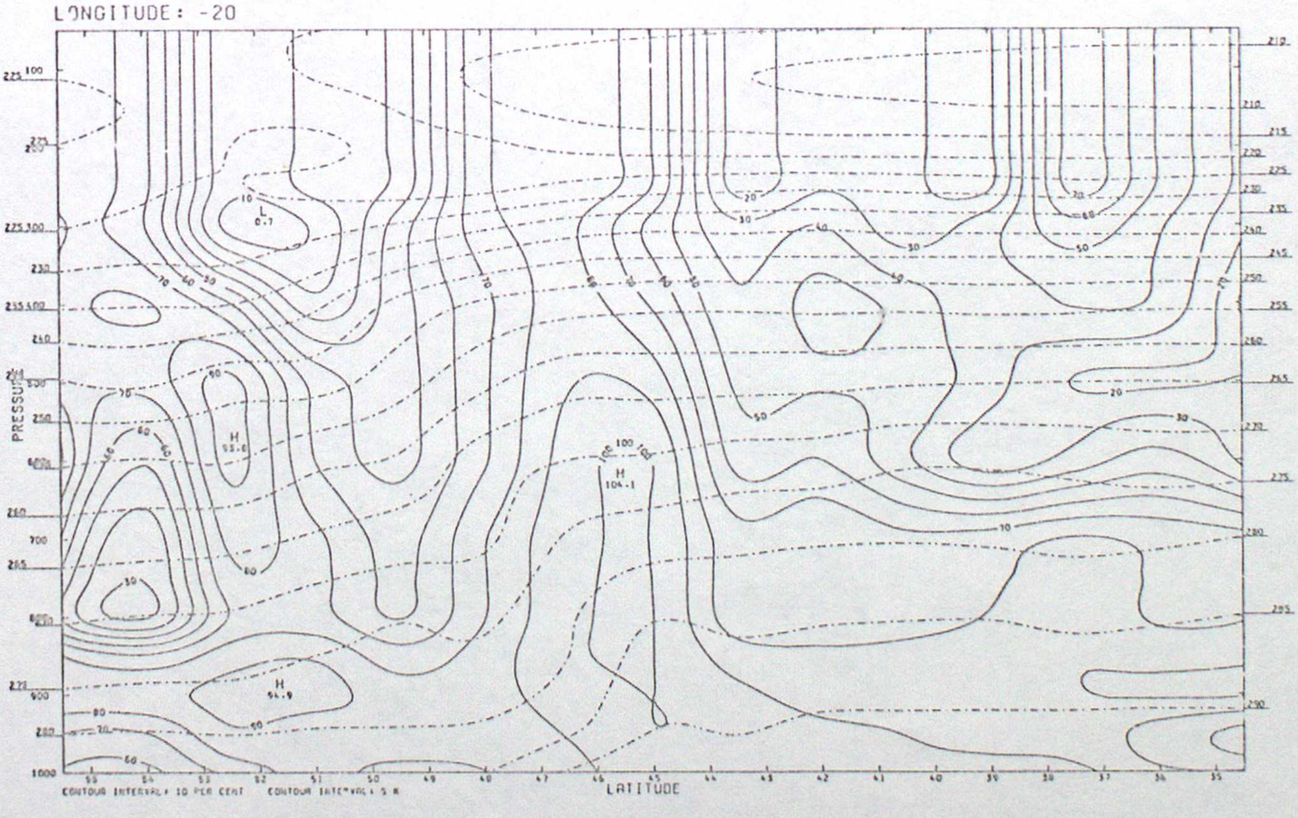
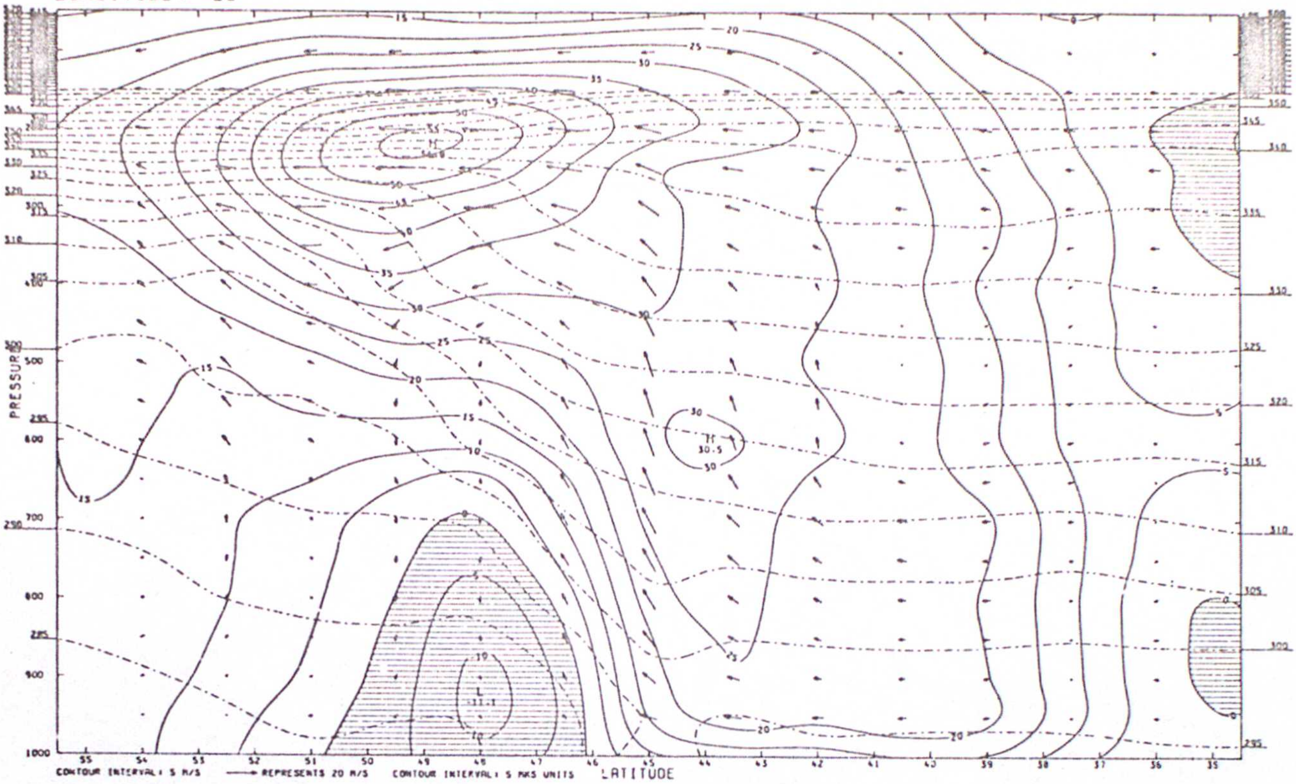


FIGURE 8D

'D' ASSIMILATION ANALYSIS (MODIFIED WIND RELAXATION COEFF. ETC.)
N-S X-SECTION. U=SOLID CONTOURS -VE SHADED. V&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20



'D' ASSIMILATION ANALYSIS (MODIFIED WIND RELAXATION COEFF. ETC.)
N-S X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

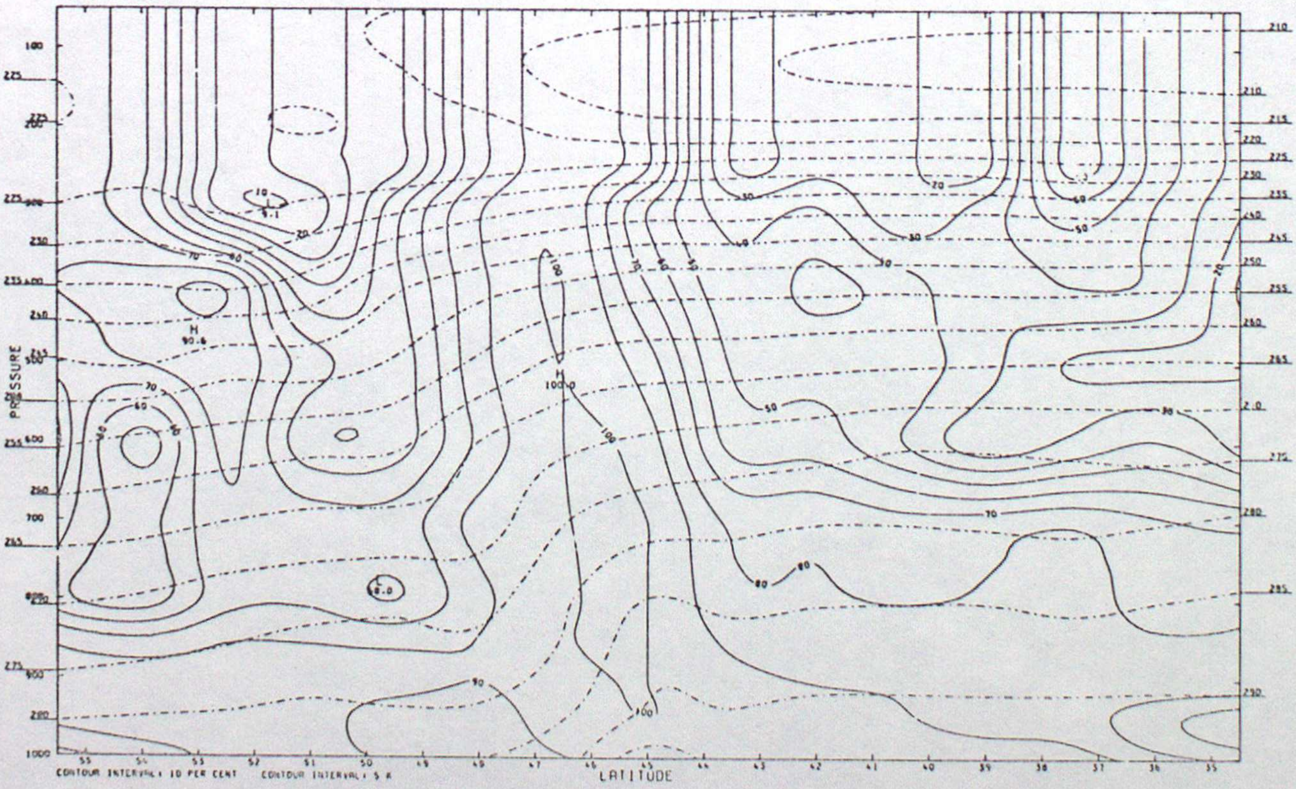
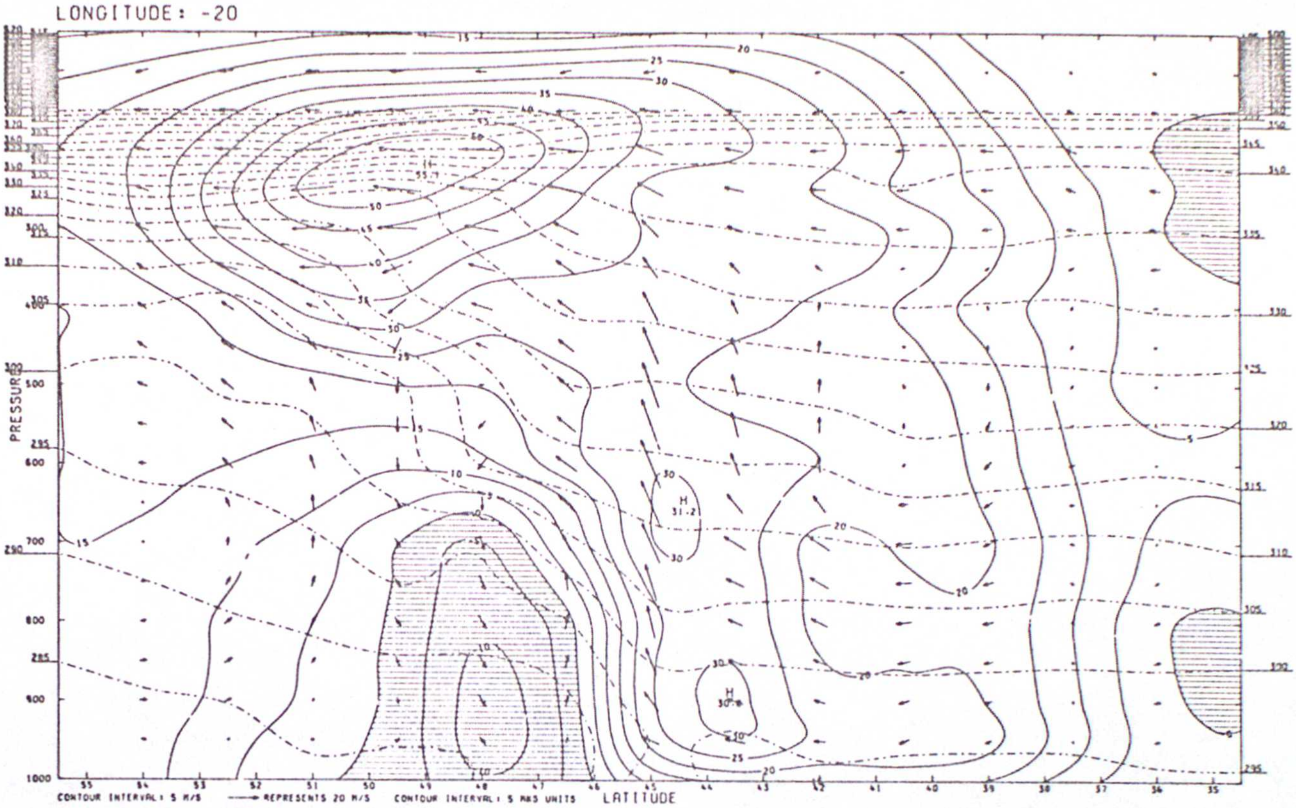


FIGURE 8E

'D' ASSIMILATION ANALYSIS WITH ZERO DIVERGENCE DAMPING (DNODD)

N-S X-SECTION. U=SOLID CONTOURS -VE SHADED. V&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20



N-S X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

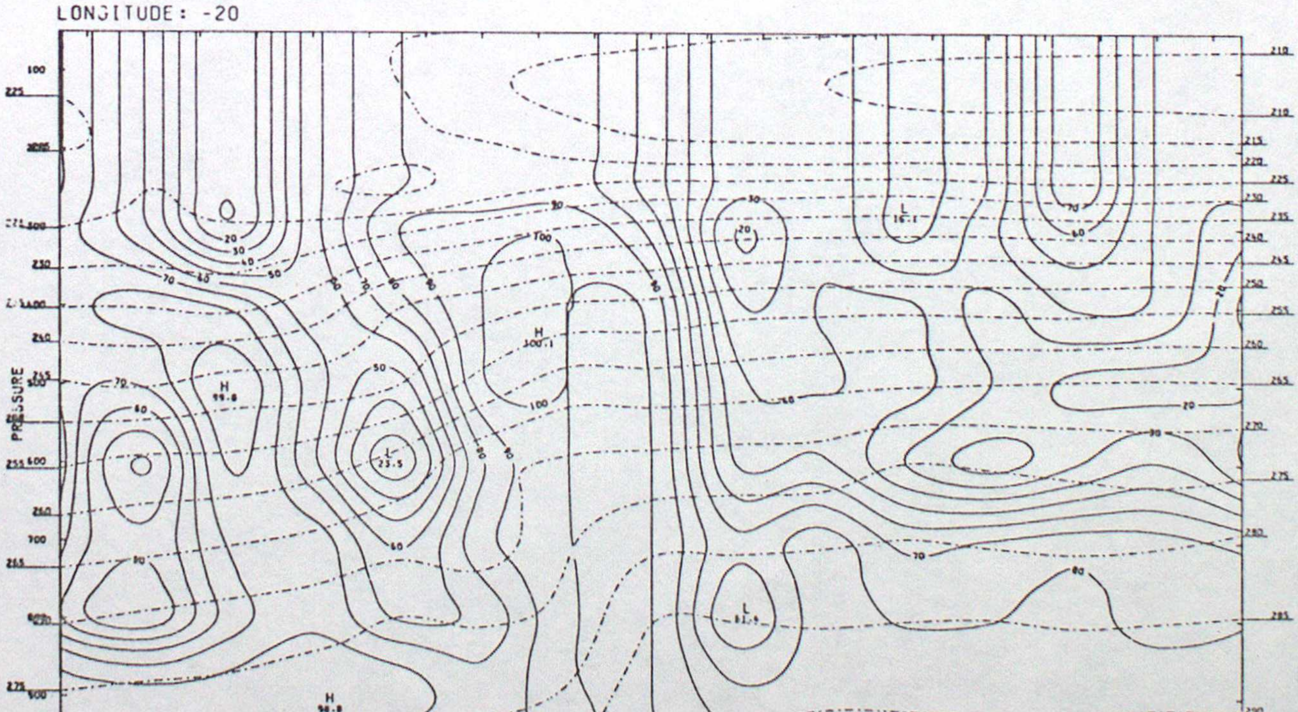
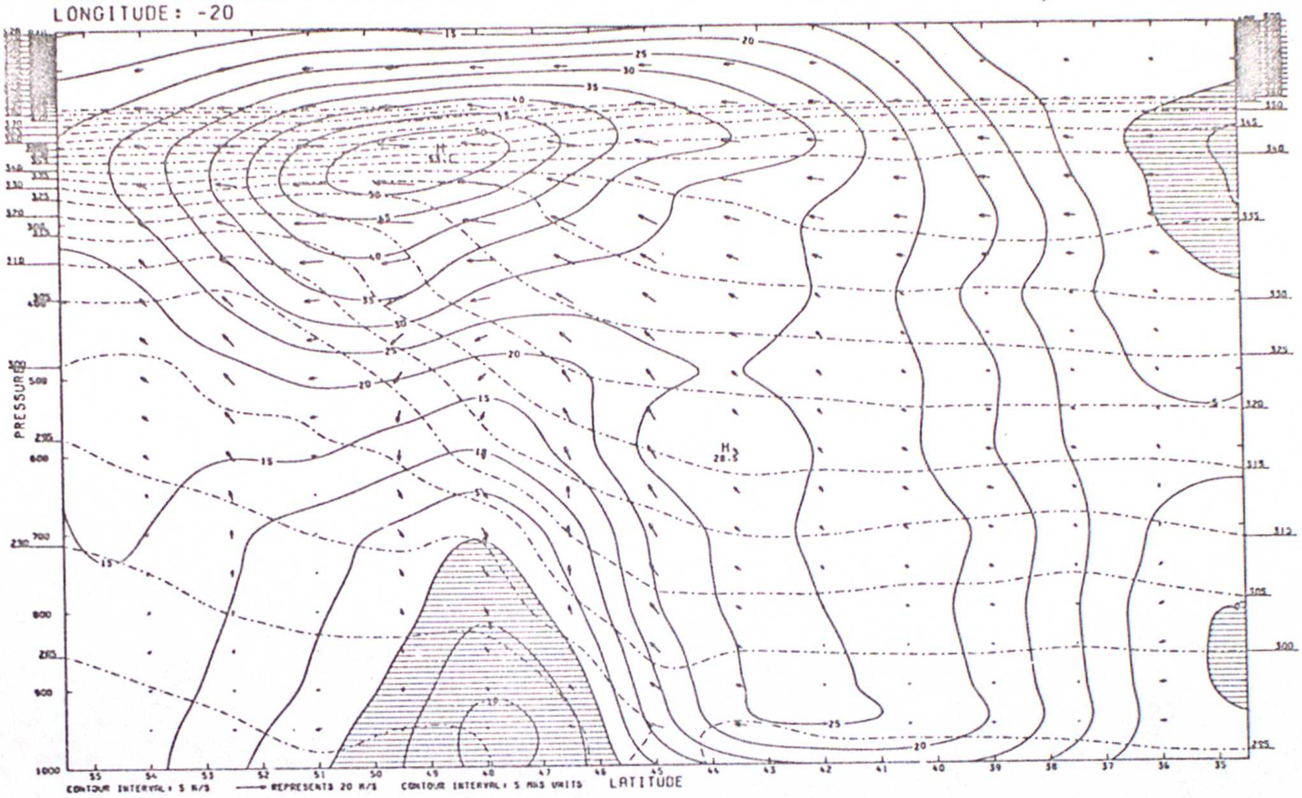


FIGURE 8F

'D' ASSIMILATION RERUN WITH NO SHIPS' WINDS NEAR LOW T (DASNS)

N-S X-SECTION. U=SOLID CONTOURS -VE SHADED. V&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20



N-S X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

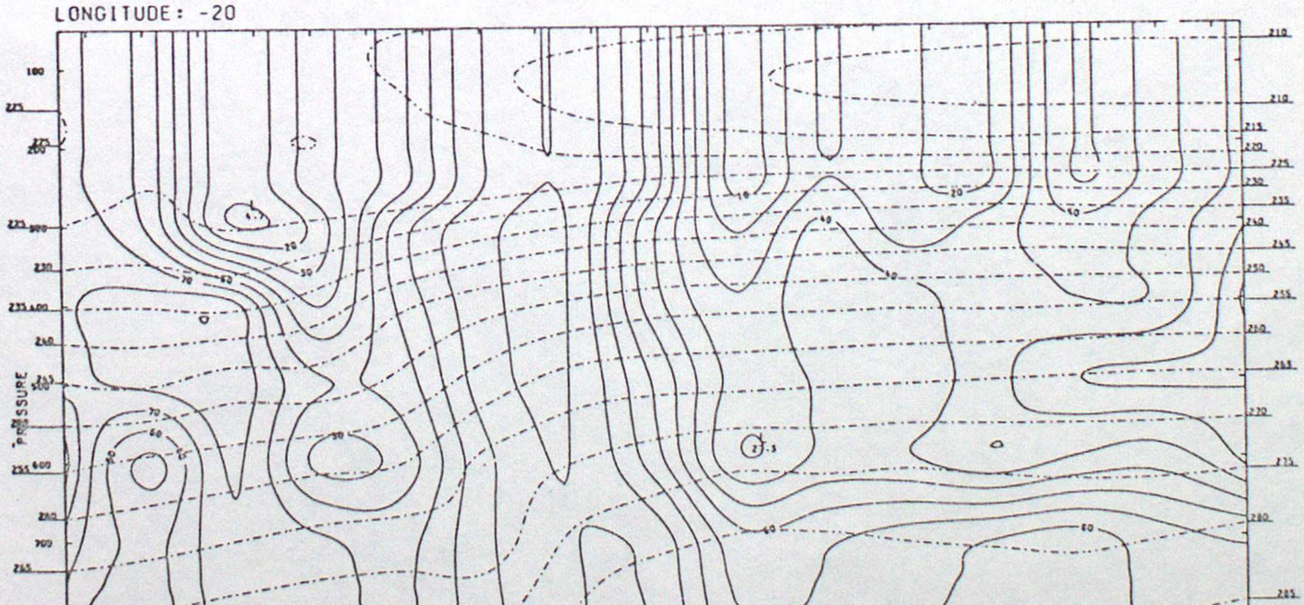
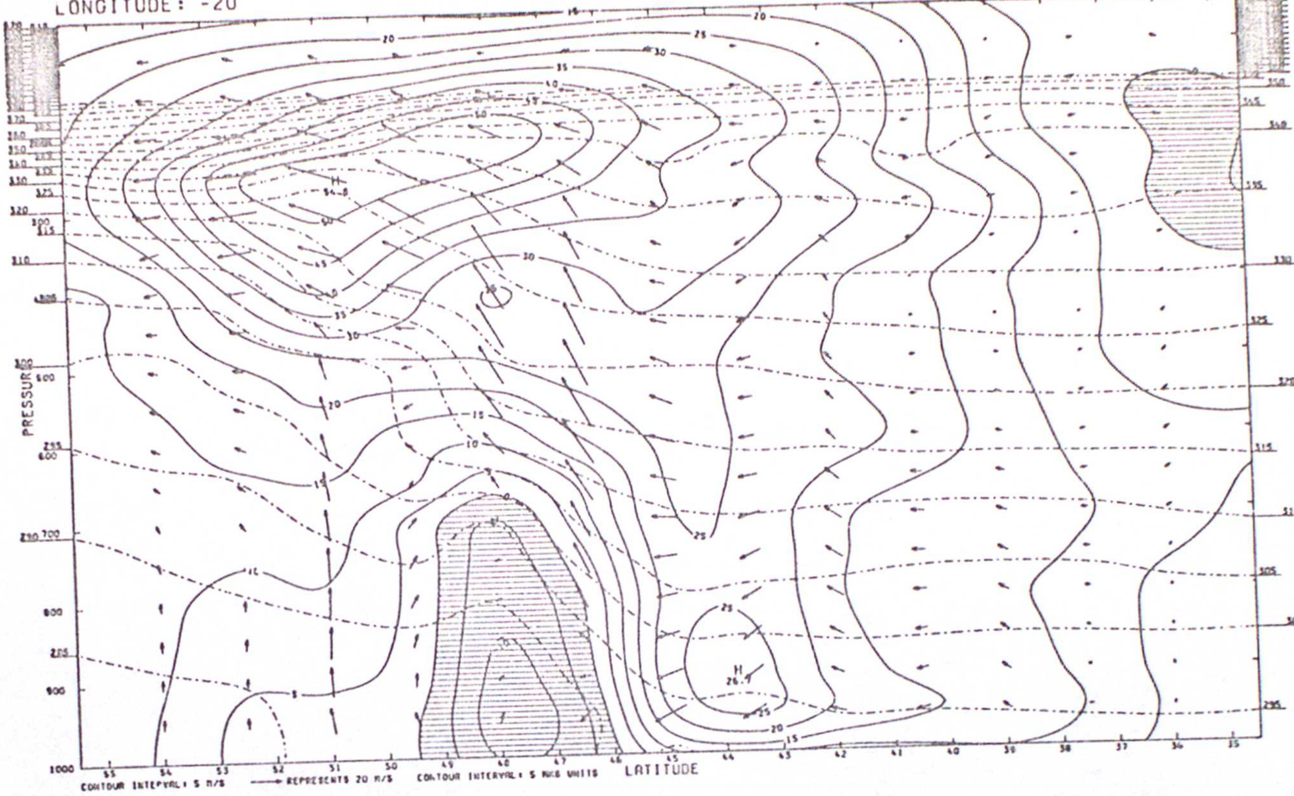


FIGURE 8G

UNIVARIATE OPTIMAL INTERPOLATION
N-S X-SECTION. U=SOLID CONTOURS -VE SHADED. V&W=ARROWS. POT.TEMP=PECKED CONTOURS
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20



UNIVARIATE OPTIMAL INTERPOLATION
N-S X-SECTION. RELATIVE HUMIDITY=SOLID CONTOURS. TEMPERATURE=PECKED CONTOURS.
VALID AT 12Z ON 20/9/1983 DAY 263
LONGITUDE: -20

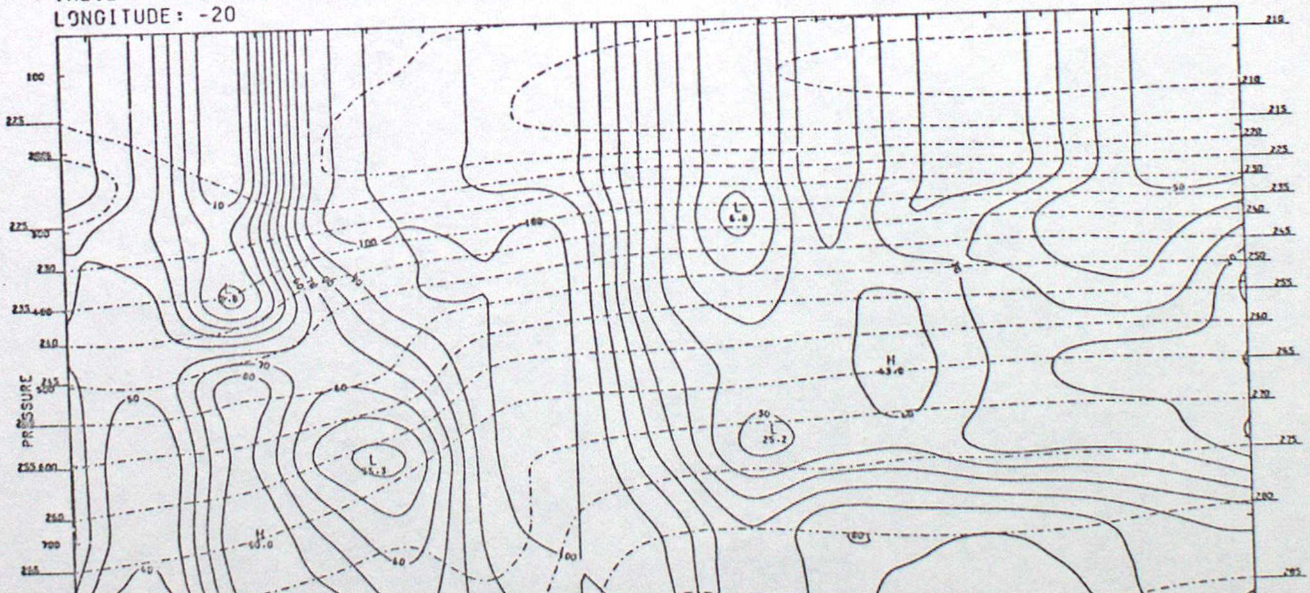


FIGURE 9A

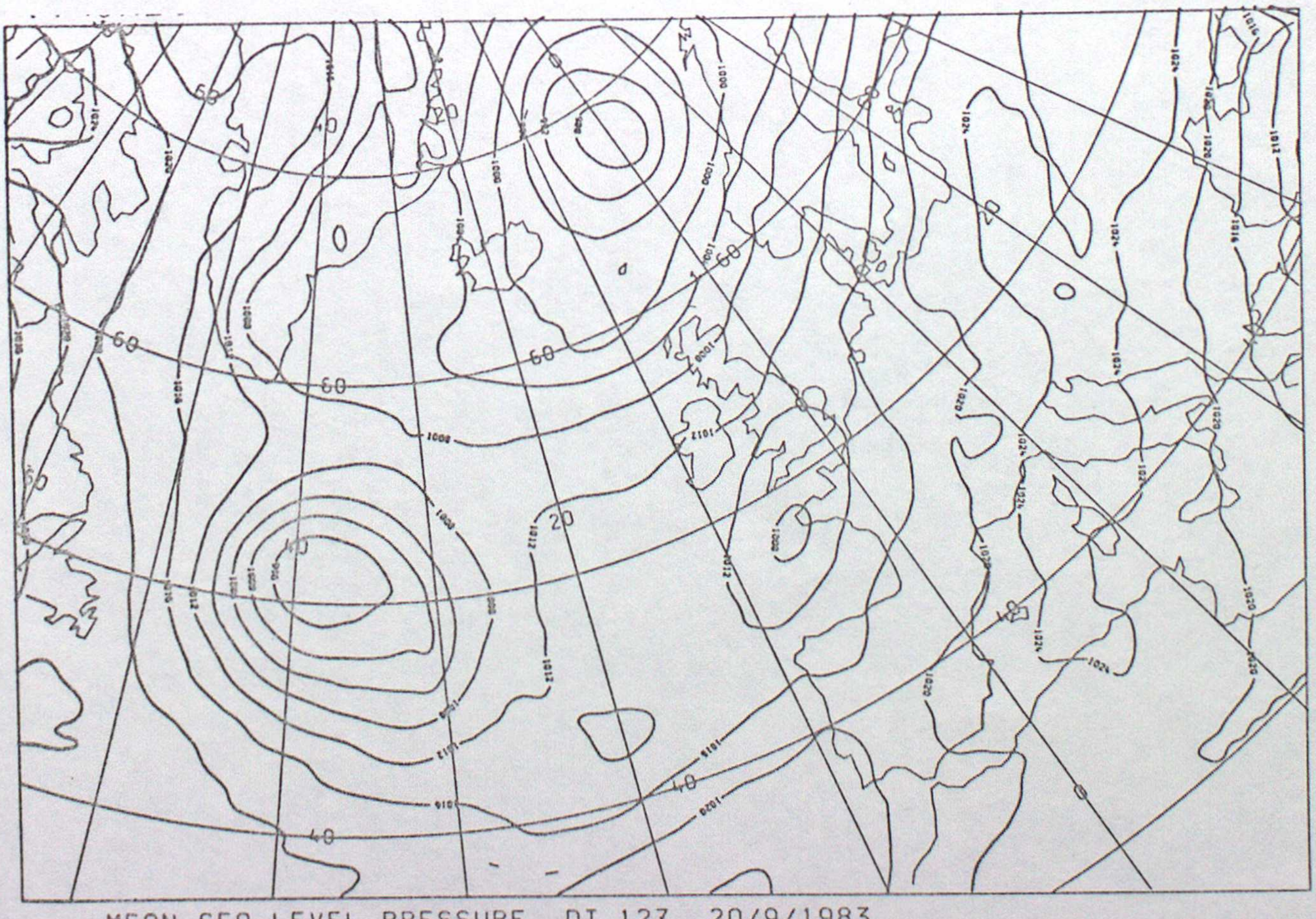
30-HOUR FINE-MESH FORECAST RUN FROM 06Z 20/9/83 DATA

MEAN SEA-LEVEL PRESSURE DT 6Z 20/9/1983
VT 12Z 21/9/1983 FINE-MESH F/C

FM FC FROM 6Z

FIGURE 9B

24-HOUR FINE-MESH FORECAST RUN FROM OPASSM

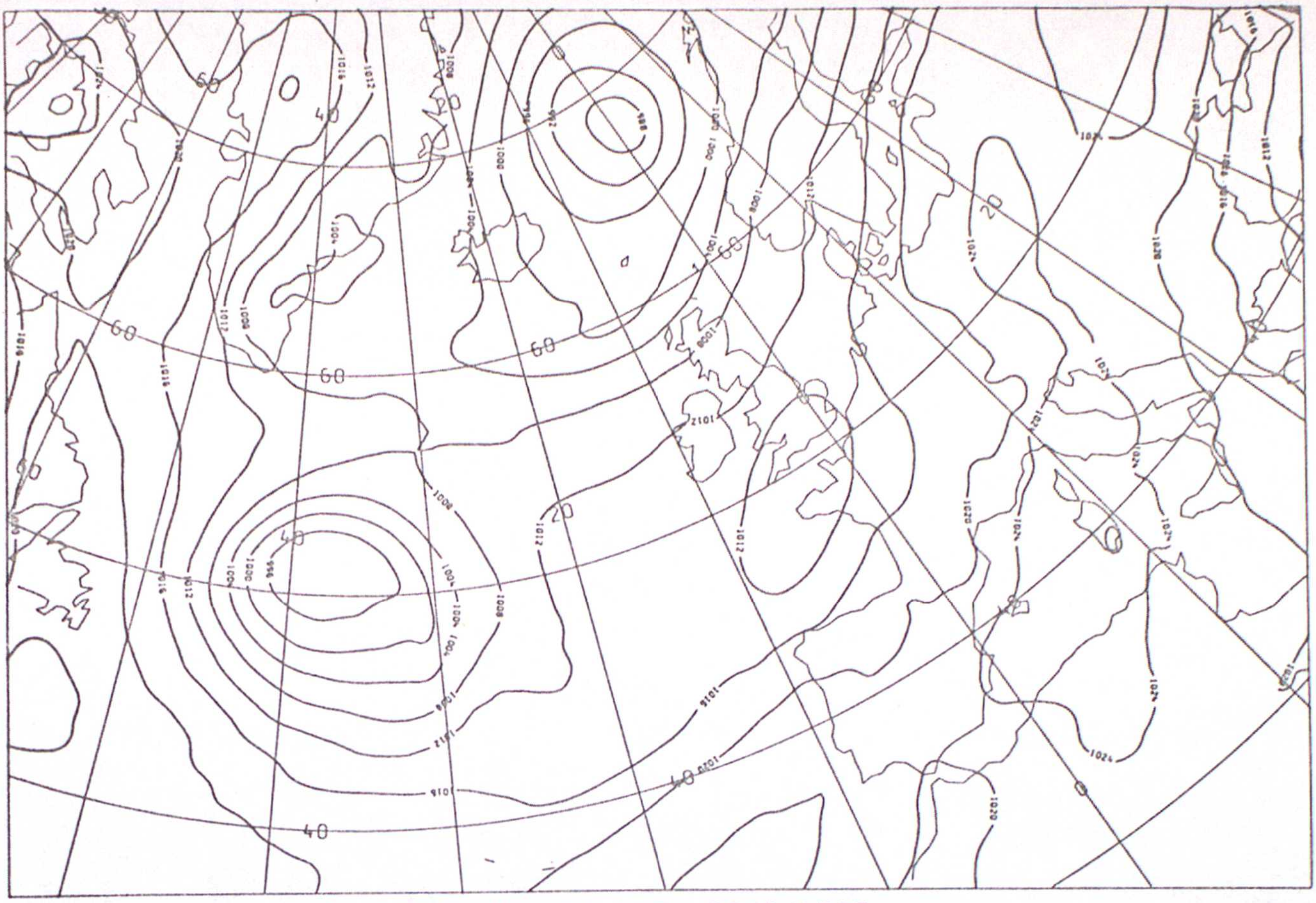


MEAN SEA-LEVEL PRESSURE DT 12Z 20/9/1983
VT 12Z 21/9/1983 FINE-MESH F/C

FINE MESH FC OP ASSIMILATION.

FIGURE 9C

24-HOUR FINE-MESH FORECAST RUN FROM OPINIT

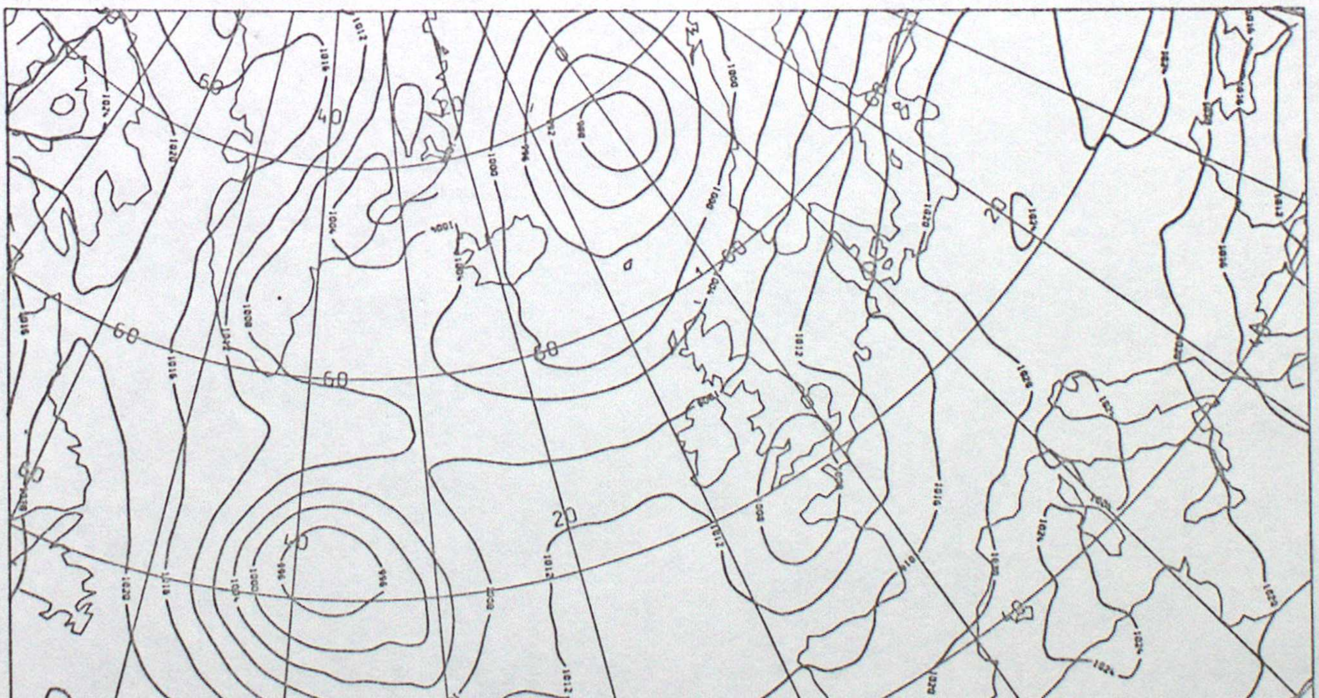


MEAN SEA-LEVEL PRESSURE DT 12Z 20/9/1983
VT 12Z 21/9/1983 FINE-MESH F/C

FINE MESH FC INITIALISED OP ASSIMILATION.

FIGURE 9D

24-HOUR FINE-MESH FORECAST RUN FROM DASSM

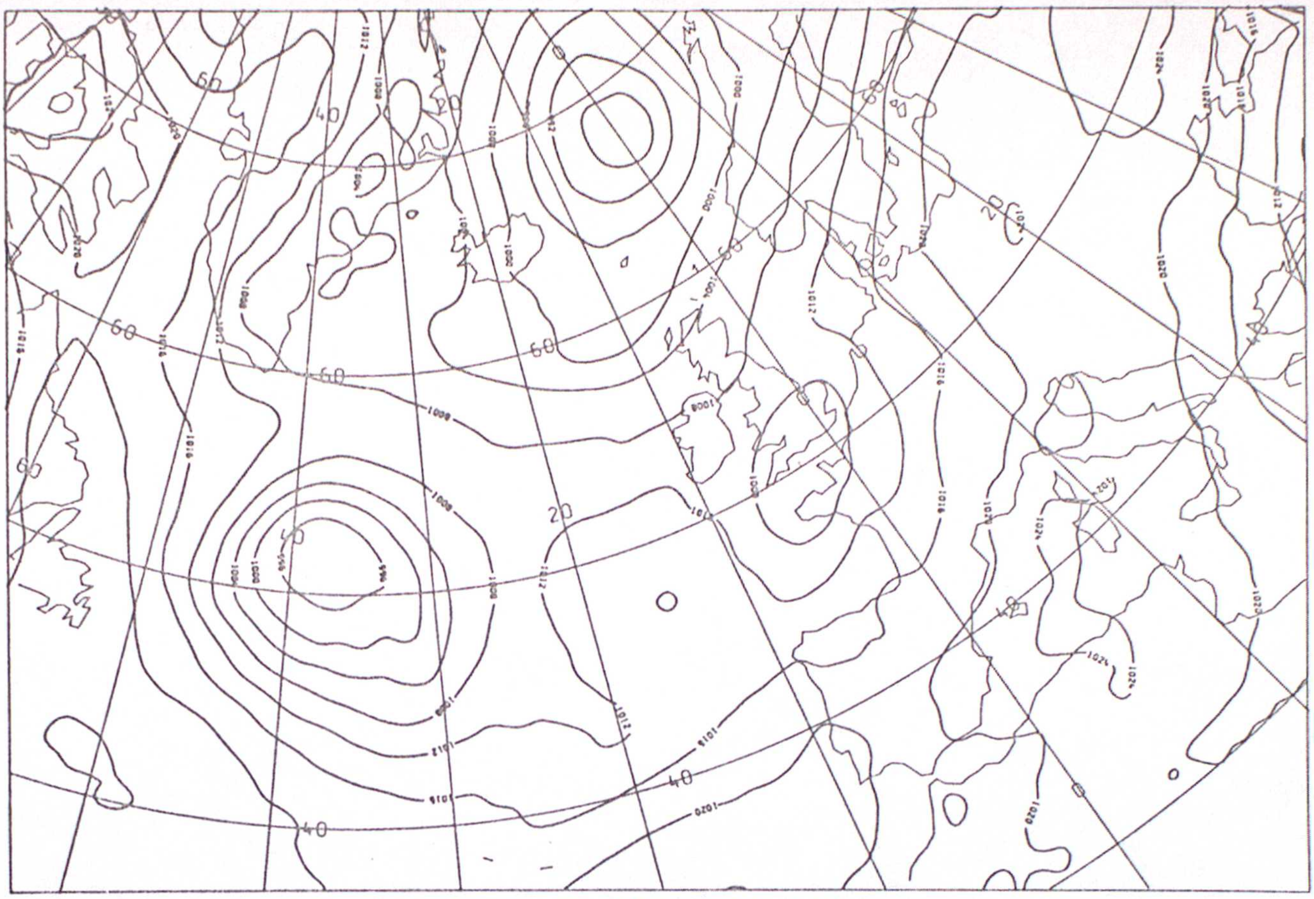


MEAN SEA-LEVEL PRESSURE DT 12Z 20/9/1983
VT 12Z 21/9/1983 FINE-MESH F/C

FINE MESH FC RERUN ASSIMILATION YASSMPLD.

FIGURE 9E

24-HOUR FINE-MESH FORECAST RUN FROM DNODD



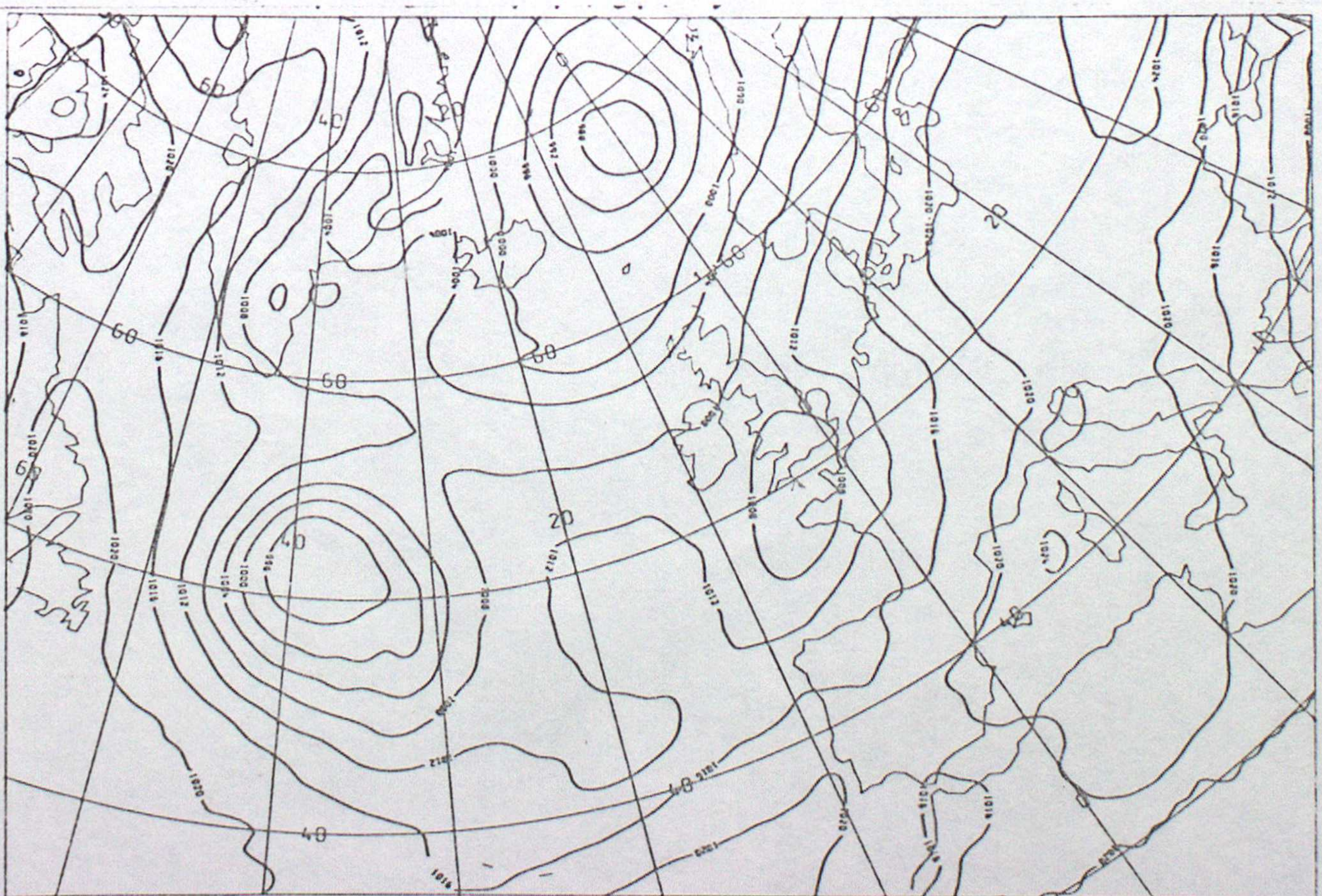
MEAN SEA-LEVEL PRESSURE DT 12Z 20/9/1983

VT 12Z 21/9/1983 FINE-MESH F/C

FINE MESH FC RERUN ASSIMILATION YASSMPLD

FIGURE 9F

24-HOUR FINE-MESH FORECAST RUN FROM DASNS



MEAN SEA-LEVEL PRESSURE DT 12Z 20/9/1983

VT 12Z 21/9/1983 FINE-MESH F/C

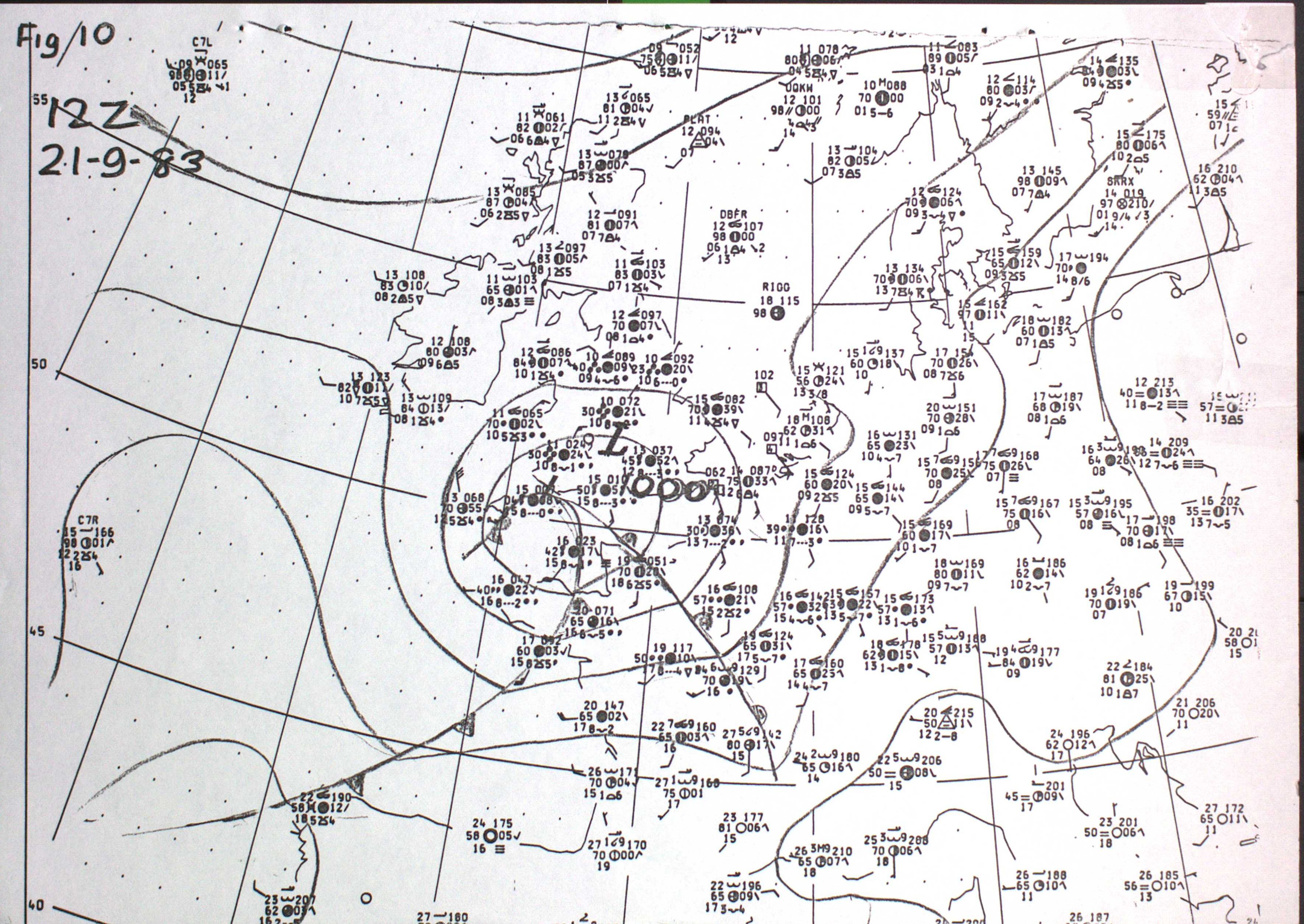
FIGURE 9G

24-HOUR FINE-MESH FORECAST RUN FROM UNOI

MEAN SEA-LEVEL PRESSURE DT 12Z 20/9/1983
VT 12Z 21/9/1983

FINE-MESH F/C

FINE MESH FC UNIVARIATE OI


Fig/10
12Z
21-9-83
L
1000
55
50
45
40