MET O 11 TECHNICAL NOTE NO 133

Forecasts of cloud cover using the 10 - level model

by

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Abstract

Forecast fields of cloud cover are derived using several methods which fall into two basic categories. The first category uses empirical relationships between cloud cover and relative humidity, whereas the second makes use of the subgridscale condensation scheme devised by Riddaway (1978). The quality of the cloud forecasts using schemes from the second category are only slightly better than the best of the empirical schemes (that used in the operational version of the 10 - level model). The improvement over the empirical schemes is useful but not sufficient to justify the extra computation time involved. On the other hand, subgridscale condensation schemes have a beneficial effect on the rainfall forecasts and so if a scheme of this type is used to improve the rainfall forecasts a useful by - product will be the slight improvement in the forecasts of cloud cover described in this paper.

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December 1979.

1. Introduction

In the operational use of numerical weather prediction models the forecaster is limited in the number of charts that can be examined before issuing the forecast. For short period forecasts the main forecast charts used are

(i) Surface pressure and rainfall charts.

(ii) Charts used to help in the location of fronts (eg 1000-500 mb thickness and θ_w).

Using these charts means that the procedure is biased towards forecasting the behaviour of fronts whereas we should be more concerned about the problem of forecasting the position of rain and cloud belts, some of which may not be related to fronts. In this paper we examine the possibility of using forecast cloud cover as an aid to producing a surface prognosis. This approach may

(i) provide information about non-precipitating cloud bands

(ii) help in the interpretation of cloud bands which have only isolated areas of rain associated with them; this rain may appear spurious at first

(iii) give information about the structure of rain bands which is not readily apparent in the rainfall fields.

Good cloud forecasts would also be desirable for use in the radiation calculations of the surface exchanges parameterisation scheme.

One way of deriving cloud cover is to use a subgridscale condensation scheme of the kind described by Riddaway (1978). Such schemes are based on the idea that, after condensation occurs, we can specify the statistical distribution of temperature and water vapour in a grid box. Earlier experiments showed that this type of scheme had a beneficial effect on the rainfall forecasts and that it was possible to produce reasonable forecasts of cloud cover. In this paper we will concentrate upon the cloud forecasts and compare them with predictions based on more empirical methods. In all the schemes the cloud amounts will depend in some way upon the relative humidities.

In the experiments described later we will be mainly concerned with cloud due to large-scale ascent and to a limited extent Sc; cloud due to deep convection will not be considered although it may be possible to estimate the amount of this type of cloud by using the deep convection parameterisation scheme.

Before proceeding it should be emphasised that the following experiments are not entirely satisfactory because the initial fields for both versions of the model (ie with and without subgridscale condensation) are derived from background fields based on forecasts using the standard dynamic rain parameterisation. To overcome this the two sets of forecasts should be run with their own forecast-analysis cycle. However this was thought unnecessary for a preliminary study such as this. Therefore to minimise the effect of any inconsistencies we will concentrate upon the cloud fields at T+36.

2. Calculation of the total cloud cover

Before considering the way in which the cloud cover in any given layer is derived we discuss the method by which cloud from all the model layers is combined to give the total cloud cover.

Suppose we have n layers in our model and that the fractional cloud cover in layer i is denoted by f_i. If there is a random overlap of cloud layers then the total fractional cloud cover (f_T) is

$$f_T = 1 - \prod_{i=1}^{n} (1 - f_i) \qquad (2.1)$$

However this expression is not entirely satisfactory because f_T tends to increase as the number of model layers increases. For example if we have two layers (n=2) each with f=0.5, then f_T=0.75. If we now split each layer into two parts (n=4) keeping f=0.5 in all the layers we have f_T=0.94. This behaviour is undesirable and so we consider ways of amending (2.1).

Assume that our numerical model can only describe a given number of cloud layers (N say) which in general is less than the total number of model layers (n). The cloud layers will be labelled j=1,2,...,N and the j'th cloud layer will consist of m_j model layers labelled $k=1,2,\ldots,m_j$. If f_{jk} is the fractional cloud cover of the k'th model layer in the j'th cloud layer then we could define the fractional cloud cover in the j'th cloud layer as either

$$f_j = \max(f_{j1}, f_{j2}, \ldots, f_{jm_j}) \quad \text{or} \quad f_j = \frac{\sum_{k=1}^{m_j} f_{jk}}{m_j} \qquad (2.2)$$

It is then assumed that there is a random overlap between the N cloud layers so that

$$f_T = 1 - \prod_{j=1}^{N} (1 - f_j) \qquad (2.3)$$

Using either of the expressions given in (2.2) in conjunction with (2.3) overcomes the inadequacies of using (2.1). The first expression for f_j in (2.2) comes about by assuming maximum overlap of the cloud in adjacent model layers. However, despite its simple physical interpretation, this expression was not used because an error in the calculated cloud cover of just one model layer could dominate f_j. Instead we use the second formulation given in (2.2) which has no simple physical interpretation but does minimise the effect of any single layer. The value of f_j computed using the second expression will usually be less than that using the first.

In some of the schemes described in the next section empirical expressions are used to determine the fractional cloud cover of high, medium and low cloud (f_H, f_M and f_L). In this case we set N=3 and rewrite (2.3) as

$$f_T = 1 - (1 - f_H)(1 - f_M)(1 - f_L) \qquad (2.4)$$

Although we are mainly concerned with cloud formed by large-scale ascent most of the schemes described in the next section will take into account the presence of Sc; in an area where Sc occurs the boundary layer tends to be moist and this is reflected in high relative humidities in the lowest model layer. This in turn produces cloud in the lowest layer since, in all the schemes, large cloud amounts are associated with high relative humidities.

3. Calculation of the cloud in each layer

We first consider empirical expressions that have been used to derive estimates of low, medium and high cloud from relative humidity fields.

Burridge and Gadd (1977), hereafter referred to B-G, used data collected by Ricketts (1973) to produce a linear relationship between the maximum relative humidity in a given set of model layers and the cloud cover; different expressions were derived for low, medium and high cloud. In order to describe these expressions it is convenient to introduce the relative humidities (H_0 and H_1) for which there is no cloud (f=0) or complete cloud cover (f=1). The empirical relationships then have the form

$$f = \frac{H - H_0}{H_1 - H_0} \qquad H_1 \geqslant H \geqslant H_0 \qquad (3.1)$$

where f refers to either low, medium or high cloud. Outside the prescribed range of relative humidity f has a value of either 1 or 0. For the B-G scheme the combination of layers, and values of H_0 and H_1, are given by

Cloud type	H	H_0	H_1	
low	max (H_{950}, H_{850})	0.55	0.95	
medium	max $(H_{750}, H_{650}, H_{550})$	0.45	0.95	(3.2)
high	max (H_{450}, H_{350})	0.35	0.95	

Having calculated the cloud cover for each type of cloud (f_L, f_M and f_H) we use (2.4) to compute f_T. Table 1a shows the calculated cloud cover for an atmosphere with constant relative humidity; 5 different relative humidities are used.

Recently a new cloud scheme was introduced into the operational model. In this the cloud covers are still given by (3.1) but now the model layers are grouped in a different way; also new values of H_0 and H_1 are used and the representative humidity for each group of layers (H) is the mean of the group of layers rather than the maximum value. The scheme is summarised below

Cloud type	H	H_0	H_1	
low	$\frac{1}{2}(H_{850}+H_{750})$	0.50	1.00	
medium	$\frac{1}{3}(H_{650}+H_{550}+H_{450})$	0.50	1.00	(3.3)
high	H_{350}	0.50	1.00	

Note that H_{950} no longer appears in the calculations of f_L and so this scheme is likely to underestimate the low cloud when Sc or St is present. The characteristics of this scheme are illustrated by the results in Table 1b. Comparison with the B-G scheme shows that both schemes are similar for high relative humidities but the differences become more pronounced for the lower humidities.

Walker (1978), hereafter referred to as W, examined GATE data and found that in the Tropics there was an approximate quadratic relationship between cloud cover and the relative humidity in each of the layers of the 11-level model so that

$$f = \left(\frac{H - H_0}{H_1 - H_0}\right)^2 \qquad H_1 \geq H \geq H_0 \qquad (3.4)$$

If we divide up our layers in a way consistent with that done by W, then the scheme she proposed is characterised by the use of (3.4) along with

Cloud types	H	H_0	H_1	
low	H=max (H_{950},H850)	0.80	1.00	
medium	H=max (H_{750},H_{650},H_{550},H_{450})	0.65	1.00	(3.5)
high	$H=H_{350}$	0.80	1.00	

Walker also included an explicit determination of cloud cover due to Sc (f_{Sc} say) given by

$$f_{Sc} = -16.67 \frac{\partial \theta}{\partial p} - 0.1167 \qquad -0.007 \leq \frac{\partial \theta}{\partial p} \leq -0.067 \qquad (3.6)$$

In the experiments described here the relevant gradient of θ is taken to be that between the 950 mb and 850 mb levels. The total cover of low cloud is then given by the addition of the cloud covers from (3.5) and (3.6). The characteristics of this scheme are illustrated in Table 1c; note that this scheme gives less cloud than the previous two schemes and that, for a given relative humidity, the cloud cover is dominated by the medium cloud.

We now consider the use of a subgridscale condensation scheme of the kind described by Riddaway (1978) - hereafter referred to as R. An integral part of this scheme is the derivation of the fractional cloud volume in each grid box. If this is taken to be identical to the fractional cloud cover then (2.1) can be used to combine the cloud cover from each layer to give f_T Table 1d shows the sample cloud covers derived in this way and they are similar to those from the B-G scheme. This is to be expected since the basic parameter required for the subgridscale condensation scheme was derived from the relationship between cloud cover and relative humidity used by B-G. However it should be noted that when this subgridscale condensation scheme is used the relative humidity never reaches high values because rain forms before the complete grid box is saturated (see R for further details); this in turn affects the maximum cloud cover that is possible.

Earlier the problems of using (2.1) to compute f_T were discussed and it was suggested that these could be overcome by first grouping the model layers into cloud layers and using (2.2) to derive the cloud cover for each type of cloud; f_T is then derived from (2.3). The results of doing this with the cloud covers derived from the subgridscale condensation scheme are given in Table 1e (the levels have been grouped in the way suggested by B-G). This procedure causes a marked reduction in cloud cover when compared with that using the cloud cover from each level independently.

4. The Forecasts

A series of 36 hour forecasts were run using the version of the 10-level model described by B-G. Here we will consider forecasts based on data from 00Z on the 26/9/78 to 28/9/78. This period was chosen for convenience rather that because of the quality of the forecasts. Two forecasts were run for each data time - one used the standard dynamic rain parameterisation whereas the other included subgridscale condensation.

Overall there were no gross errors in the forecasts and the effect on the rainfall of incorporating subgridscale condensation was consistent with the conclusions of R - there was an increase in dynamic rain and a decrease in convective rain along with a net increase in rainfall.

From the forecasts using the standard dynamic rain parameterisation the total cloud cover was derived empirically using the following methods.

E(B-G) - the B-G formulation - (3.1) and (3.2).

E(O) - the present operational scheme - (3.2) and (3.4)

E(W) - the W formulation - (3.4), (3.5) and (3.6).

In all these schemes (2.4) is used to compute f_T from f_L, f_M and f_H.

The forecasts which included the parameterisation of subgridscale condensation produce predictions of fractional cloud volume (interpreted as fractional cloud cover) for each model layer. Two methods of combining these cloud covers were examined.

S(1) - using (2.1)

S(2) - dividing up the model layers in the same way as B-G (forming 3 cloud layers) and using (2.2) and (2.3).

In the next section we examine the cloud forecasts. The first in the sequence will be examined in some detail, but the other two will be considered in a more cursory fashion. Unfortunately in a rather limited experiment it is difficult to prove that charts of forecast cloud cover would be useful as an aid to interpreting the output from numerical models. All that we can do is show that in the cloud forecasts we have most of the features whose behaviour we would like to predict.

5. The first forecast

Figure 1 shows the initial surface pressure field for the first forecast of the sequence (d.t. 00Z 26/9/78); the forecast fields after 36 hours are given in Figure 2 (using the standard dynamic rain parameterisation) and Figure 3 (using subgridscale condensation). Comparison of those forecasts shows that the main differences in rainfall intensity and distribution are consistent with the findings of Riddaway which have already been summarised in the previous section. Also both versions of the model produced essentially the same synoptic forecast - there is little difference in the pressure patterns and the position of the main rain belts.

Figure 4 is an enlarged version of the surface pressure forecast given in

Figure 3, and Figure 5 is the verifying analysis. Overall the behaviour of the main features is predicted very well. Consider the following

(i) the main Atlantic low - this moved through the boundary near Newfoundland and travelled northeastwards; both the position and depth are accurately forecast.

(ii) the main Atlantic fronts - by mid-day on the 27th there were two distinct fronts stretching southwest from the main low; both fronts also had waves on them. The model predicted the position of the rain band well although there doesn't appear to be much evidence of the double structure. However the width of the rain band may be an indication of this structure. Figures 2 and 3 show two distinct maxima in the rainfall in this band and these represent the waves on the front.

(iii) features in the vicinity of the UK - during the early part of the period a wave moved southeastwards across England and by mid-day on the 27th the only remnant of this was a trough over Northern France. Meanwhile a cold front moved southeast over the continent towards Italy. The movement of both these features was predicted quite well although the speed was overestimated. On the T+36 forecast there is evidence of a rain area over Southern England; this did not actually occur but six hours earlier the observations did indicate a wave to the west of Ireland.

Figure 6 shows a nephanalysis at about mid-day on the 27th along with the analysed position of the main surface features (the complete surface analysis is given in the previous figure). The nephanalysis is a simplified version of the CFO nephanalysis; it shows the areas of frontal cloud (XXXX) and areas designated as cloudy (////). Areas of little cloud have also been delineated (marked by O). Elsewhere there is convective cloud and we have differentiated between open cells (MOP) and closed cells (MCO).

The nephanalysis clearly shows the cloud bands associated with the main Atlantic low and there is some evidence of the double frontal structure (in fact the southern portion of one of the fronts appears to be incorrectly positioned). There is also an interesting area of enhanced cloud north of the Azores. The position of the front over Eastern Europe is apparent but the trough to the southeast of the UK is not well defined although its position can be readily identified on the original satellite picture.

We now consider the 36 hour forecasts of cloud - first those based on empirical relationships and then those which use the subgridscale condensation scheme. On each cloud forecast we also show the predicted position of the main rainbelts along with the pressure centres.

Figure 7 shows the results using the E(B-G) scheme. Clearly there is a marked overestimate of the cloud cover and this has the effect of masking the structure in the cloud field. This scheme produces unacceptable cloud forecasts and will not be considered further.

Figure 8 shows the results using the current operational scheme - E(O). Most of the features described earlier are in evidence but the most interesting aspect of the forecast is the cloud band (marked A) ahead of the main Atlantic front (marked B); this could be interpreted as being evidence of the double frontal structure seen in Figure 6. There is also an area of enhanced cloud to the north of the Azores (marked C) which corresponds to an observed area of cloud. The features marked D and E represent the trough and front that were observed over the continent. Finally there is an area of enhanced cloud over the southern parts of England and Ireland (marked F) which, along with the forecast rain in this area, suggests the existence of a frontal wave; however observations do not indicate such a well developed feature in this area. Overall E(O) produces reasonable results but it does tend to give large areas of almost complete cloud cover and in anticyclones it nearly always underestimates the cloud. This latter effect is probably due to the exclusion of the 950 mb relative humidity in the calculation of the low cloud.

Figure 9 shows the results using E(W). These are similar to those for E(O) although there are important differences. For example in the main Atlantic cloud band E(W) gives 100% cloud cover whenever any one of the 10-levels has 100% cloud cover, whereas for E(O) to give this we require all of the levels making up a cloud group to have complete cloud cover. Also E(W) tends to underestimate the low level convective cloud because of the combination of the high threshold humidity for which cloud forms and the fact that in the forecast the conditions for incorporating the Sc convection (see (3.6)) were never reached. This means that in the bottom right hand quarter of the chart there is little cloud forecast whereas the nephanalysis shows an area of mainly closed convective cells. Therefore these results suggest that either

(i) (3.6) is not applicable outside the tropics

(ii) (3.6) is correct but that the 10-level model does not adequately resolve the temperature structure in the lower levels of the atmosphere

(iii) the form of (3.6) is model dependent and so could not be expected to give good results for any model other than the one for which it was derived.

The origin of the inadequacy of the Sc correction has not been pursued. However because of this inadequacy and the similarity of the results from E(W) and E(O) elsewhere, we will not consider E(W) further. We now consider the forecasts which used subgridscale condensation.

Figures 10 and 11 show charts of f_T using S(1) and S(2) (Figure 6 is again used for verification). As with the best of the empirical scheme both S(1) and S(2) have reproduced all the main cloud features. The main differences between these two forecasts is that in S(2) the maximum cloud amounts are less than in S(1) (this also tends to apply to the minima) and the gradients of cloud cover are less severe. This means that for S(2) it is easier to pick out the axes of the cloud bands and for this reason it is probably preferable to use S(2) rather than S(1). However it should be noted that the ease with which features can be identified is closely linked to our choice of isopleths.

6. The other forecasts

For the remaining three forecasts we will only examine the best empirical scheme E(O) and the best scheme based on subgridscale condensation S(2). We will again concentrate upon the fields at T+36 and for each forecast the

the following charts are displayed

(i) a simplified nephanalysis valid at about T+36 along with the position of the main surface features

(ii) the forecast total cloud cover at T+36 using E(0); the forecast positions of the main surface features are also shown

(iii) similar fields to (ii) except that S(2) is used.

Figures 12, 13 and 14 show the results of the forecast based on 00Z 27/9/78. The predicted evolution of some of the features is not very good - the main Atlantic low is too shallow and displaced towards the southeast, and the speed of the associated warm front near the UK is underestimated. However both E2 and S(2) reproduced most of the main features although the S(2) forecast is much easier to interpret. This is particularly so in cloudy regions. For example with S(2) there is a definate indication of the position of the low near Greenland; also a wave on the trailing Atlantic front is indicated by an area of enhanced cloud. These features are not apparent in the E(0) forecast. The other main difference between the two methods is that for E(0) there tends to be little cloud in the high pressure regions whereas S(2) attempts to take into account the presence of St and Sc giving only limited areas of no cloud cover.

The results of the other forecast are shown in Figures 15 to 17. Both E(0) and S(2) produce reasonable forecasts although again there are differences in anticyclonic regions and in the vicinity of fronts.

7. Concluding remarks

Several cloud schemes have been examined and we have found that

(i) the Burridge and Gadd scheme E(B-G) produces a marked overestimate of cloud cover; this is such that the cloud forecasts are of little use.

(ii) the present operational scheme E(0) produces reasonable cloud forecasts although there is a tendency to underestimate cloud cover in anticyclonic regions. It may be possible to remedy this by including the 950 mb relative humidity in the calculation of the low cloud.

(iii) the tropical cloud scheme E(W) appears to be inadequate in its treatment of low level convective cloud in mid-latitudes; in other aspects the cloud scheme gives reasonable results.

(iv) the cloud schemes which use information from a subgridscale condensation scheme give reasonable results. Overall the version which first groups the cloud forecasts into cloud layers S(2) is preferable to the ungrouped version S(1) because it gives more information about the structure in the cloud bands. However with S(2) the maximum cloud cover seldom reaches 95%.

When evaluating the merits of these schemes we must take into account of the computation time. Use of the empirical expressions requires little extra computation since the cloud cover is derived from the relative humidity fields from the standard forecast. However when we use schemes based on subgridscale condensation it is necessary to change the dynamic rain parameterisation. This is done in such a way that the parameterisation scheme is more complex and is called more often than the standard version, and this results in an increase of between 10% and 20% in the CPU time of the forecast. Overall the slight improvement in quality of the cloud forecasts obtained by using S(2) instead of E(0) is probably not worth the computational effort. However if a subgridscale condensation scheme is going to be used to improve the rainfall forecasts then a desirable by-product would be a slight improvement in the cloud forecasts.

The experiments described here suggest that cloud forecasts using either a good empirical method of a method based on subgridscale condensation may be useful in identifying the position of non-frontal cloud bands as well as fronts; also frontal waves may be identified by an enhancement in the cloud cover. However neither type of method deals adequately with low level convective cloud.

Since it appears possible to derive reasonable cloud fields from relative humidities, it may be worthwhile investigating whether this process can be used in reverse. It may be practical to use a digitised satellite photograph to objectively estimate relative humidities.

Burridge, D M and A J Gadd	1977	"The Meteorological Office operational 10-level numerical weather prediction model (Dec 1975)." London Met Office, Sci Paper No 34.
Riddaway, R W	1978	"An investigation of various subgrid-scale condensation schemes." Met O 11 Tech Note No 122.
Ricketts, J N	1973	"An investigation into a relationship between upper relative humidity and cloud cover." Met Mag, 102, 146-156.
Walker, J	1978	"Interactive cloud and radiation in the 11-layer model. Part II: Cloud Scheme." Met O 2∅ Tech Note II/122.

		Relative Humidity				
		.5	.6	.7	.8	.9
(a) Burridge and Gadd	f_L	.00	.13	.37	.63	.87
	f_M	.10	.30	.50	.70	.90
	f_H	.25	.42	.58	.75	.92
	f_T	.33	.65	.87	.97	1.00
(b) Operational	f_L	.00	.20	.40	.60	.80
	f_M	.00	.20	.40	.60	.80
	f_H	.00	.20	.40	.60	.80
	f_T	.00	.49	.78	.94	.99
(c) Walker	f_L	.00	.00	.00	.00	.25
	f_M	.00	.00	.02	.18	.51
	f_H	.00	.00	.00	.00	.25
	f_T	.00	.00	.02	.18	.72

Table 1

Cloud cover of low, medium and high cloud (f_L, f_M and f_H) and the total cloud cover (f_T) for an atmosphere with constant relative humidity.

		Relative Humidity				
		50	60	70	80	90
(d) Subgridscale condensation scheme with o. overlapping cloud layers allowed	f_L	.00	.09	.31	.53	.76
	f_M	.14	.39	.60	.78	.91
	f_H	.27	.41	.56	.70	.85
	$\hat{f}_T$	.37	.67	.88	.97	1.00
(e) subgridscale condensation scheme with only 3 overlapping cloud layers allowed	f_L	.00	.05	.17	.31	.51
	f_M	.05	.15	.26	.39	.56
	f_H	.15	.23	.33	.45	.61
	f_T	.19	.38	.59	.77	.92

Table 1 (continued)

FORECAST SURFACE PRESSURE AND PRECIPITATION

OHOUR FORECAST.DATA TIME=OZ 26/9/78.VERIFICATION TIME=OZ 26/9/78

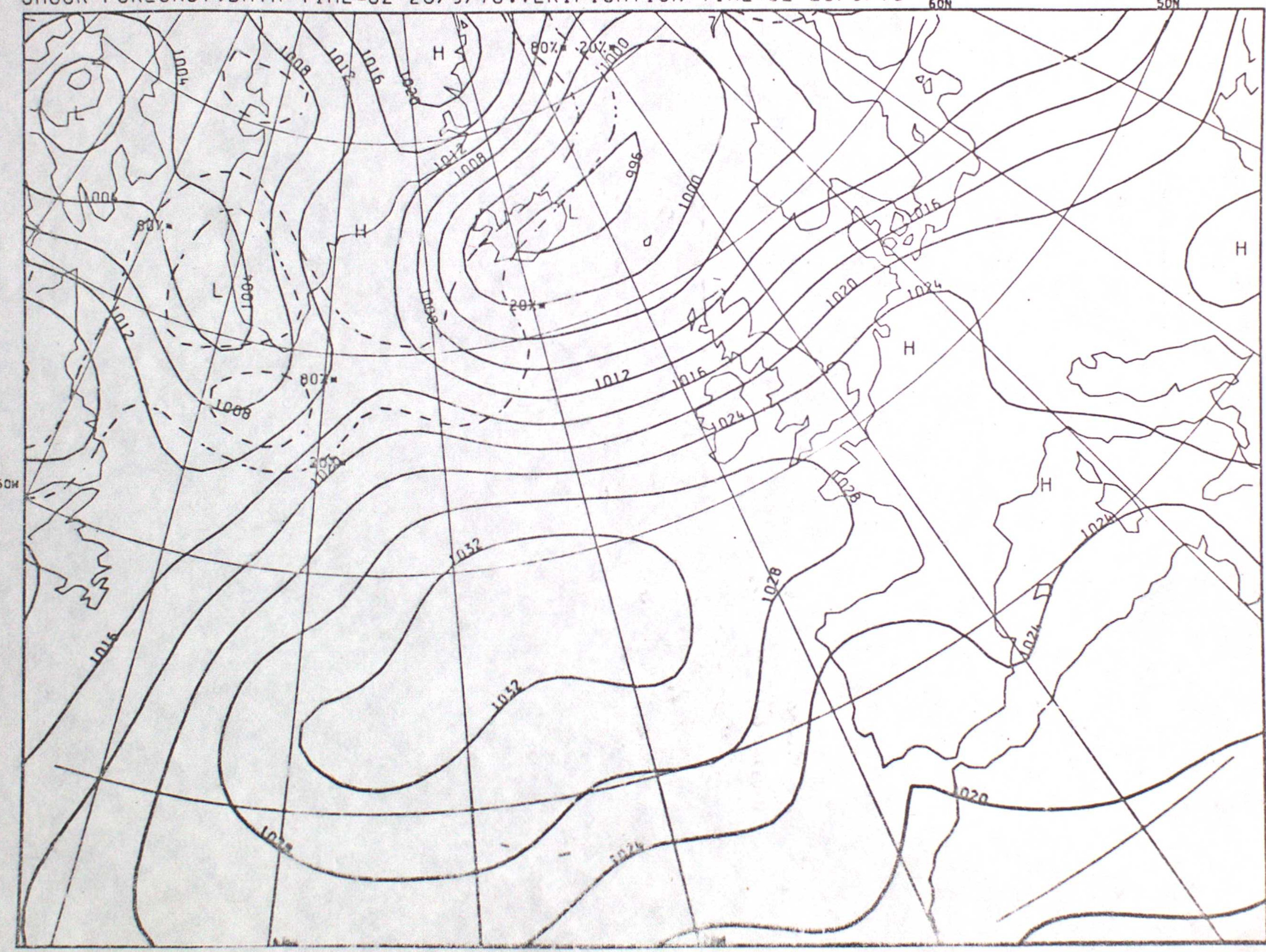

Figure 1 - initial surface pressure field for the first forecast (d.t. 00Z 26/9/78)

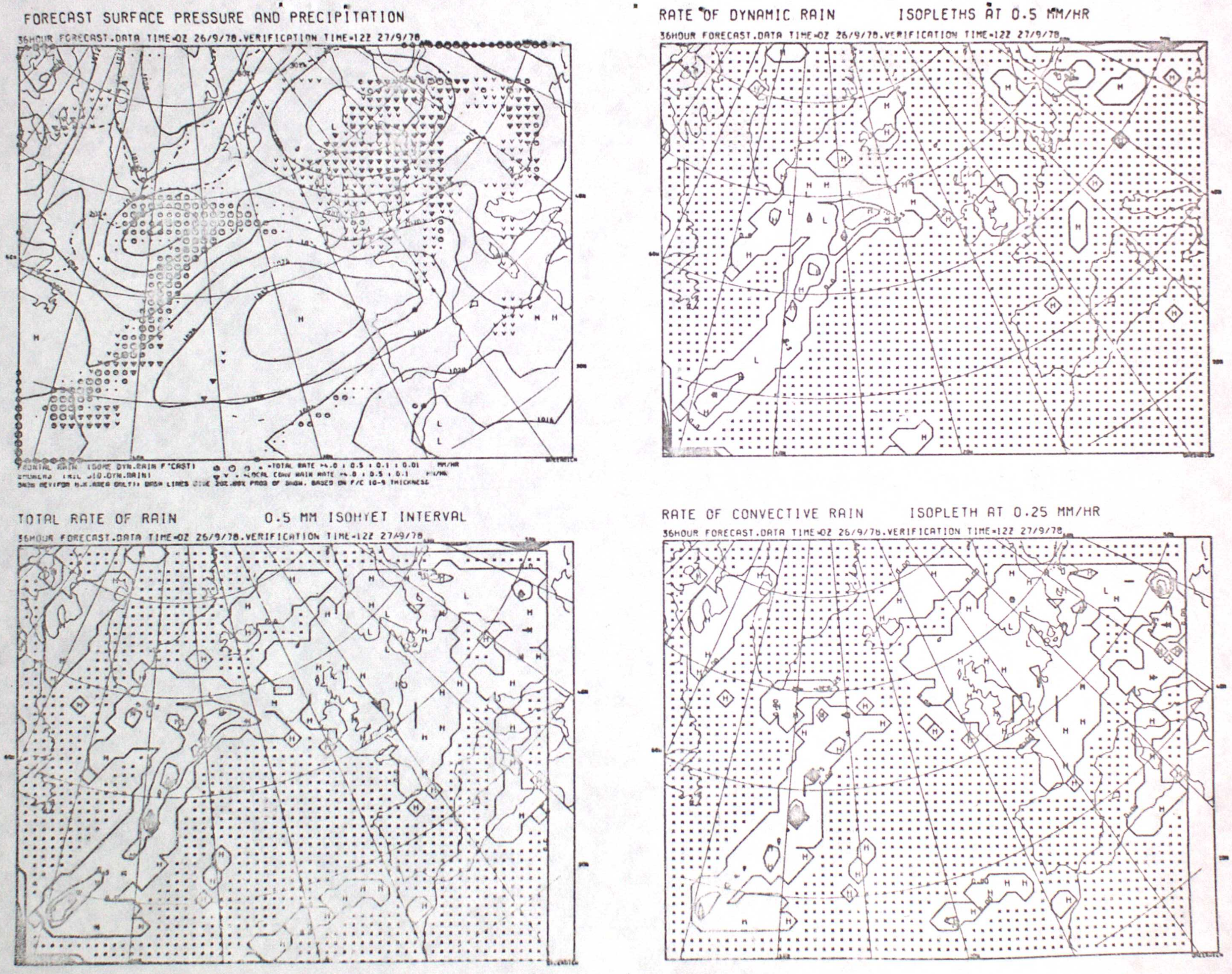

Figure 2 - 36 hr forecast using the operational condensation scheme

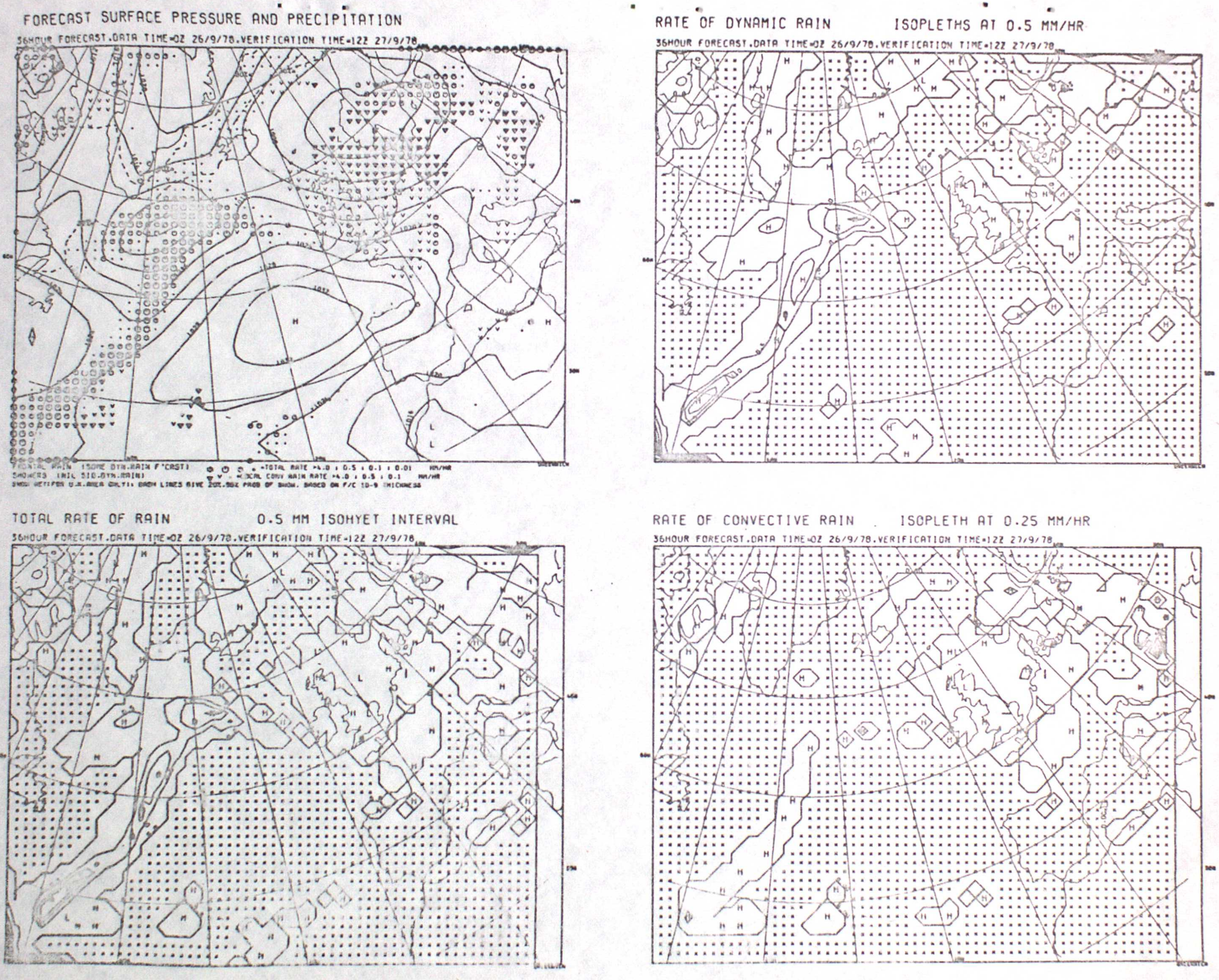

Figure 3 - 36 hr forecast using the subgridscale condensation scheme

FORECAST SURFACE PRESSURE AND PRECIPITATION (using subgridscale condensation)

36HOUR FORECAST.DATA TIME=0Z 26/9/78.VERIFICATION TIME=12Z 27/9/78

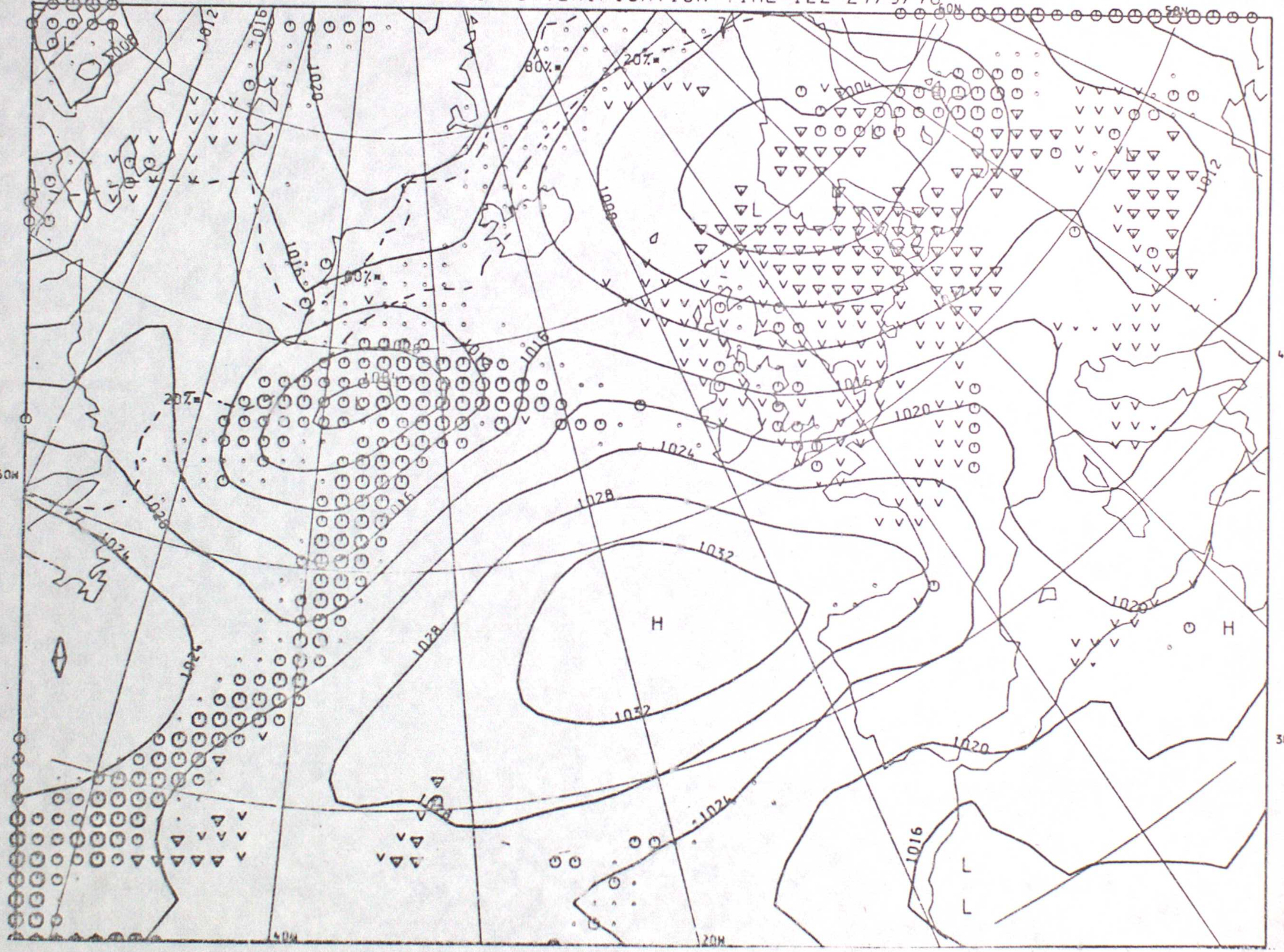

Figure 4 - enlarged version of the forecast shown in Figure 3

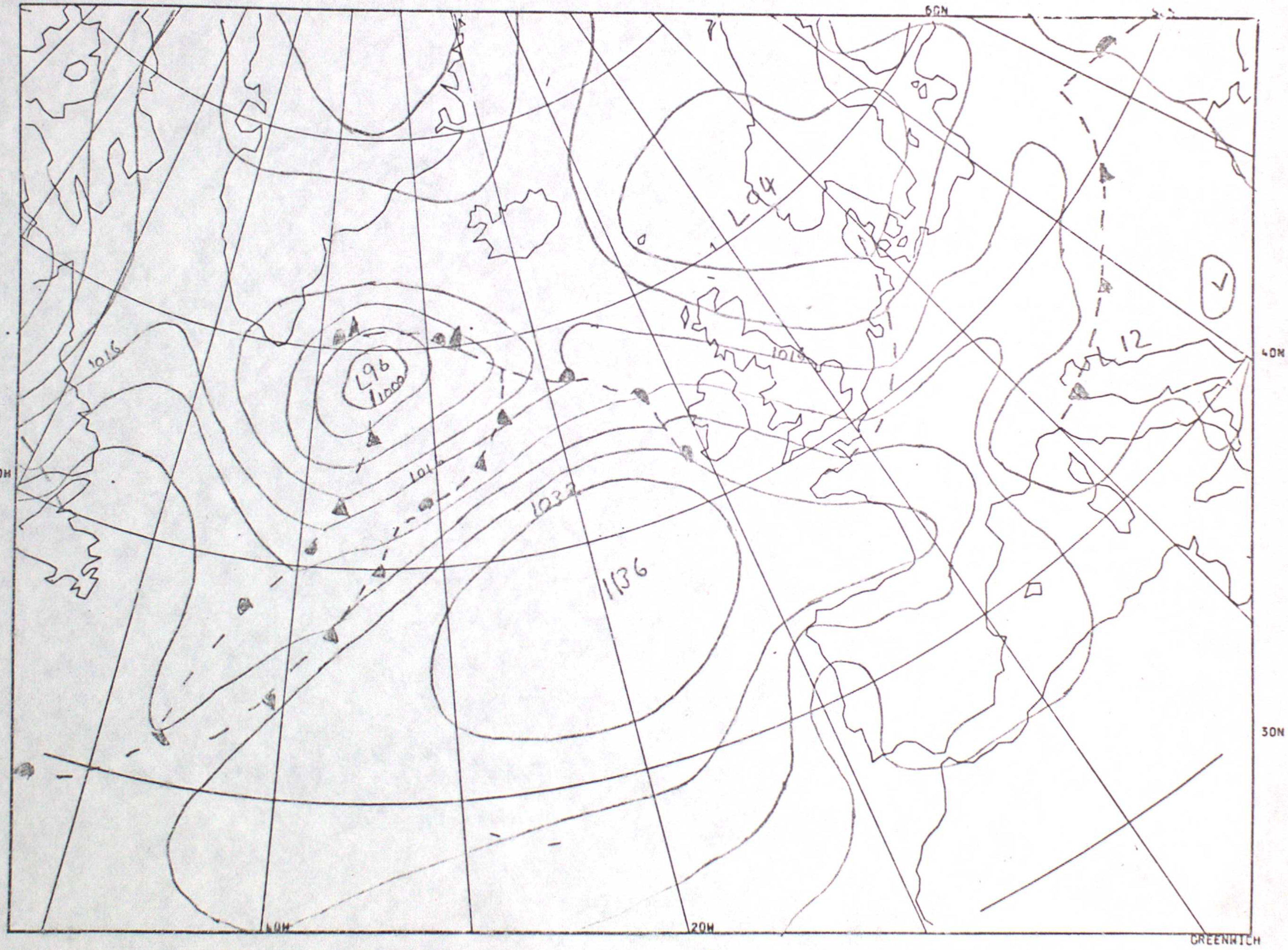

Figure 5 - CFO analysis for 12Z 27/9/78

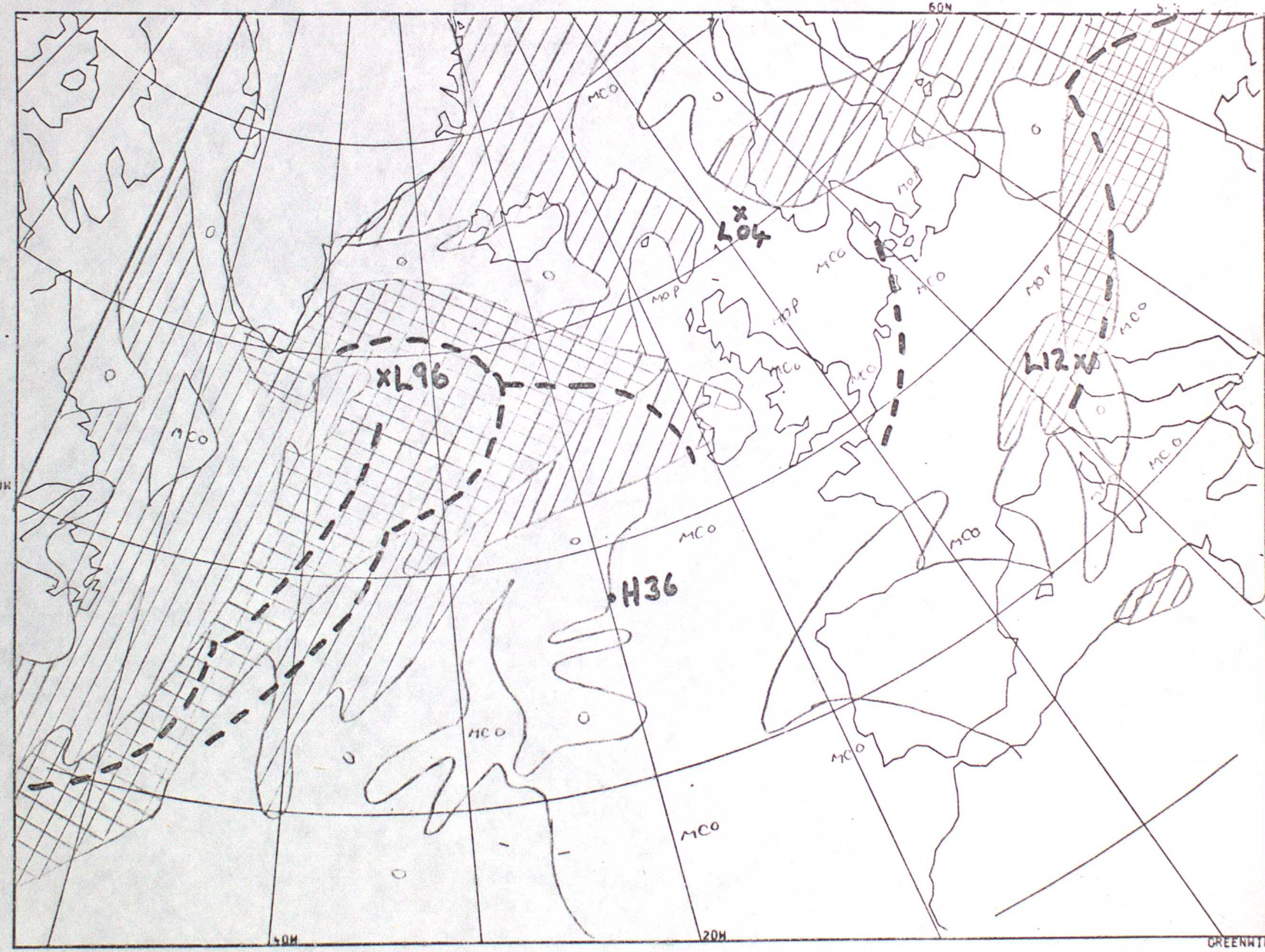

Figure 6 - nephanalysis at about 12Z 27/9/78 along with the positions of the main surface features

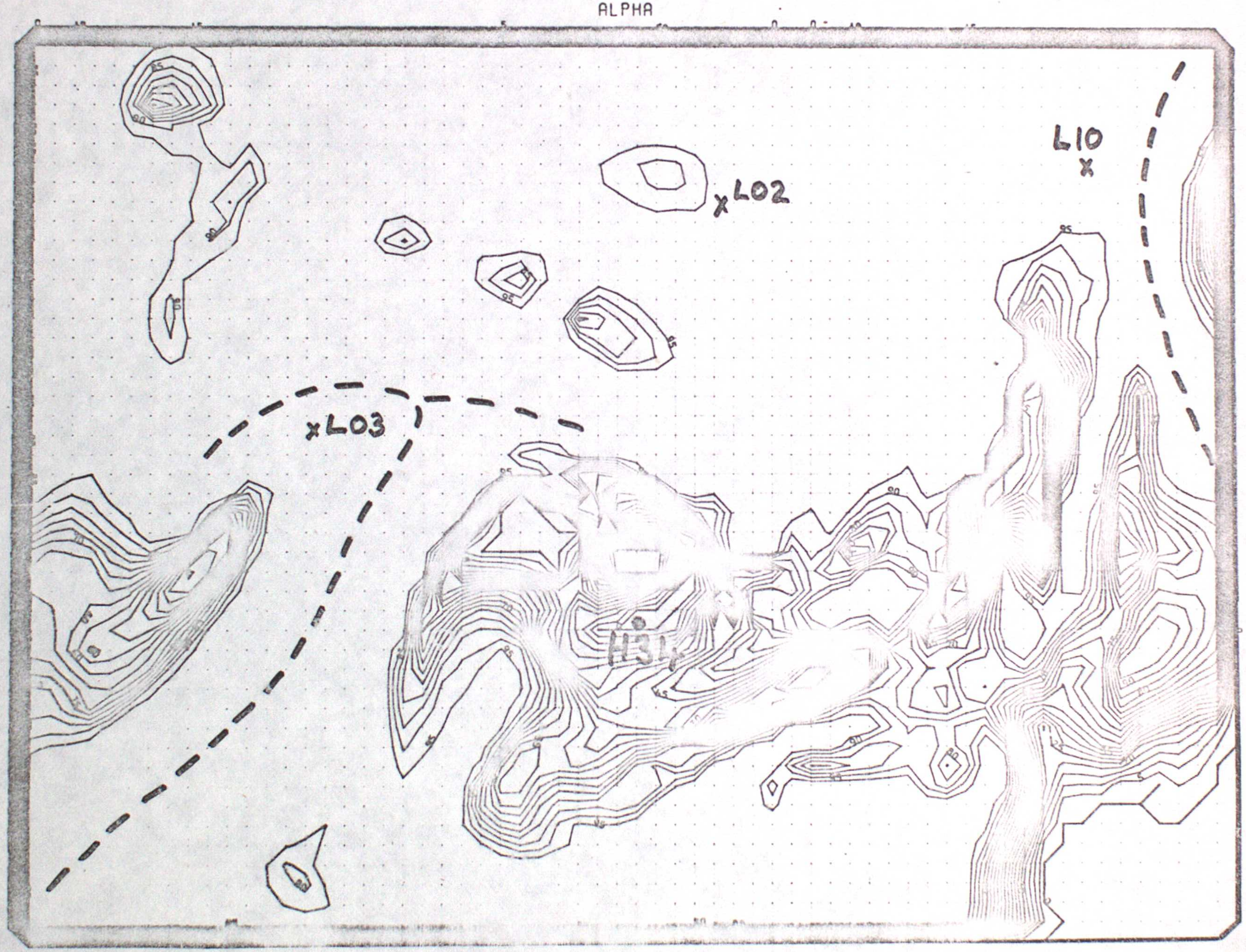

Figure 7 - 36 hr forecast of cloud cover and the main surface features (valid 12Z 27/9/78) using the Burridge and Gadd scheme - E (B-G)

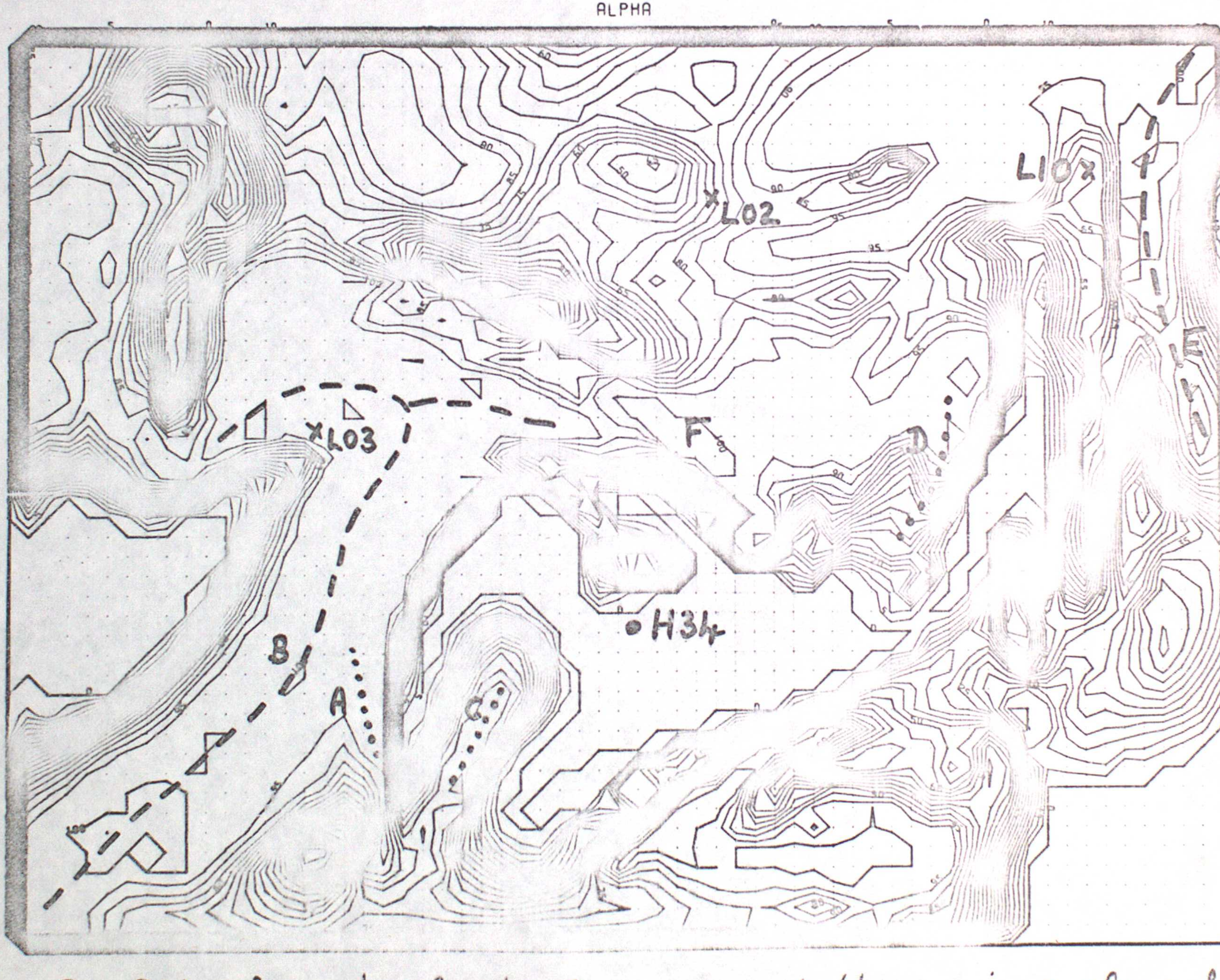

Figure 8 - 36 hr forecast of cloud cover and the main surface features (valid 12Z 27/9/78) using the operational scheme - E(0)

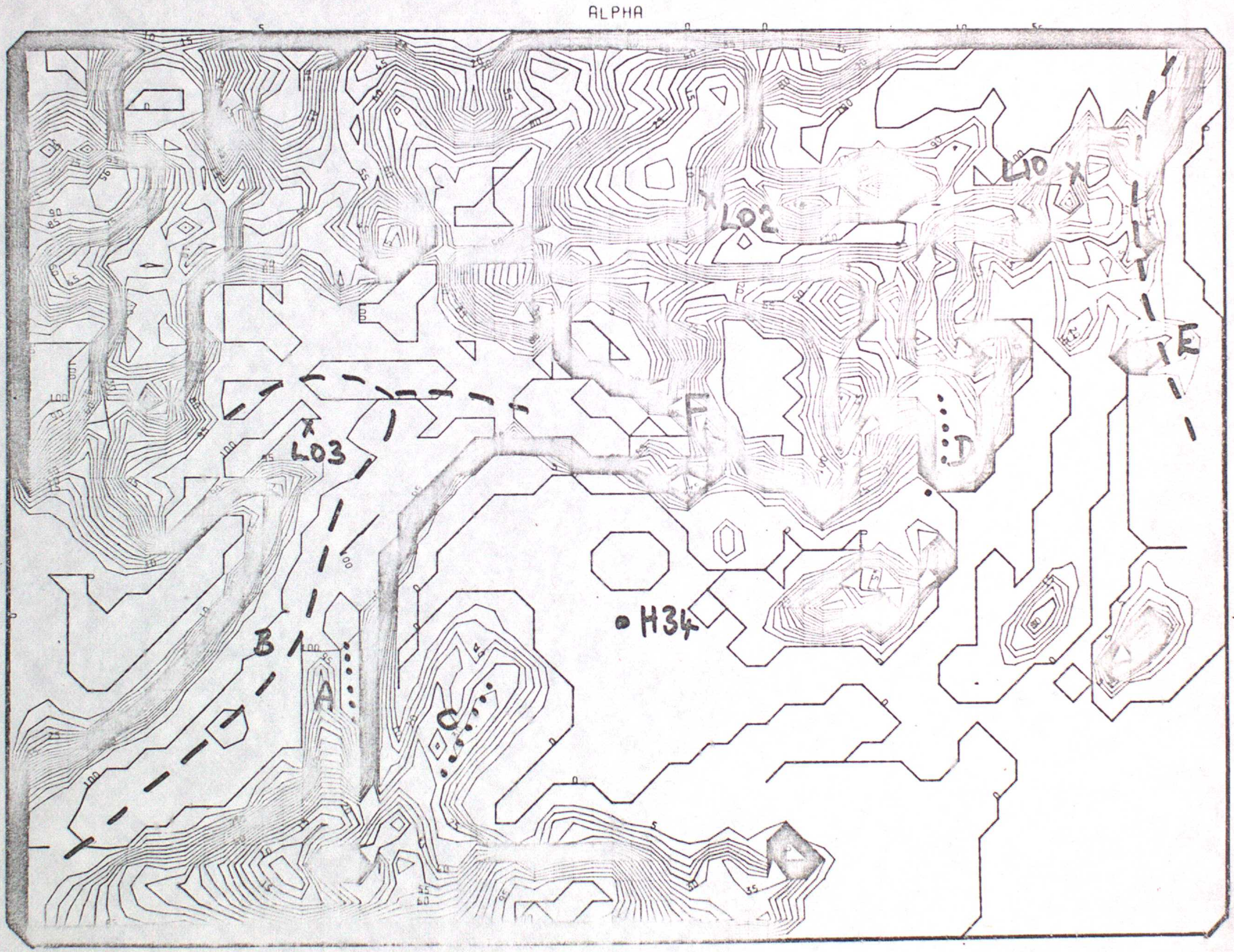

Figure 9 - 36hr forecast of cloud cover and the main surface features (valid 12Z 27/9/78) using the Walker scheme - E(W)

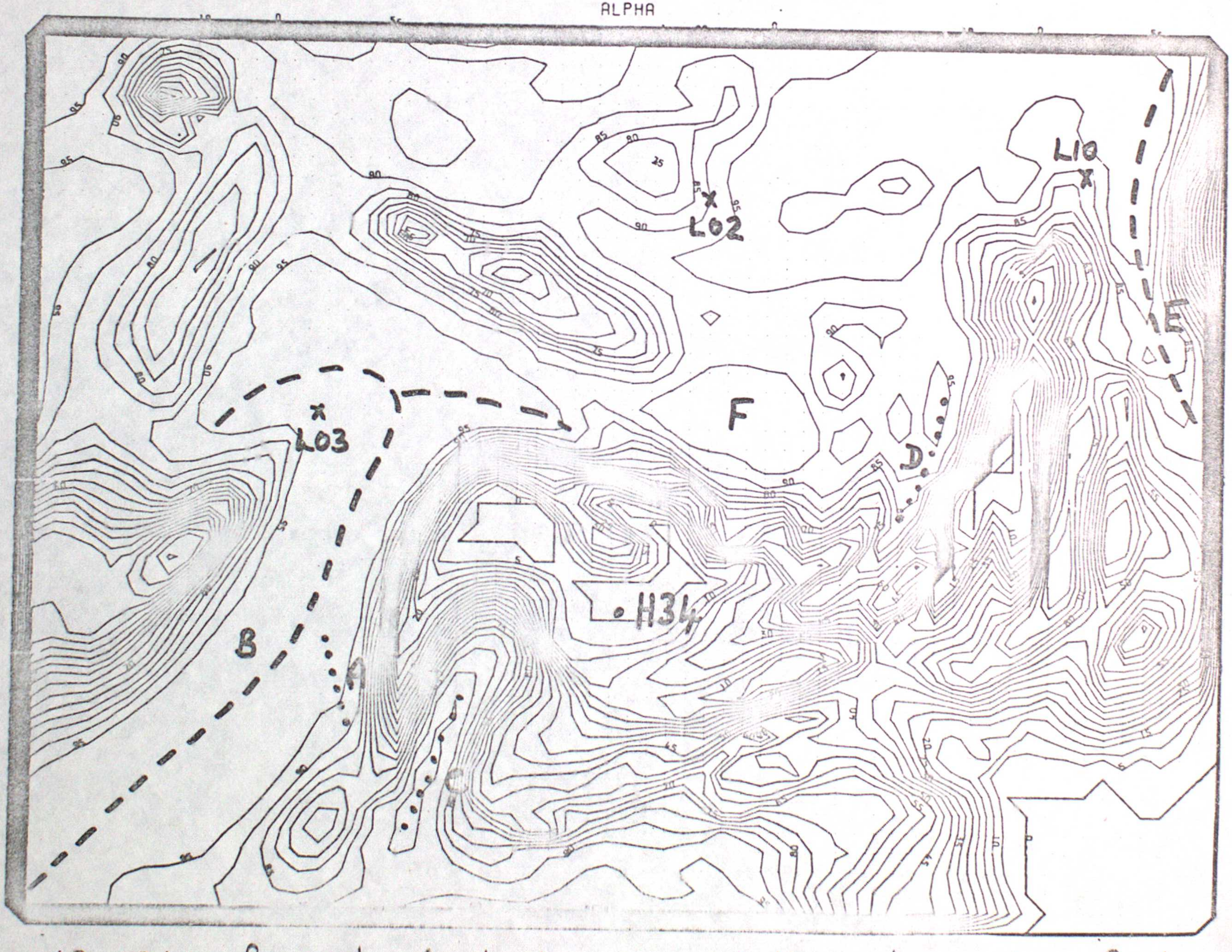

Figure 10 - 36hr forecast of cloud cover and the main surface features (valid 12Z 27/9/78) using the subgridscale condensation scheme - SC1)

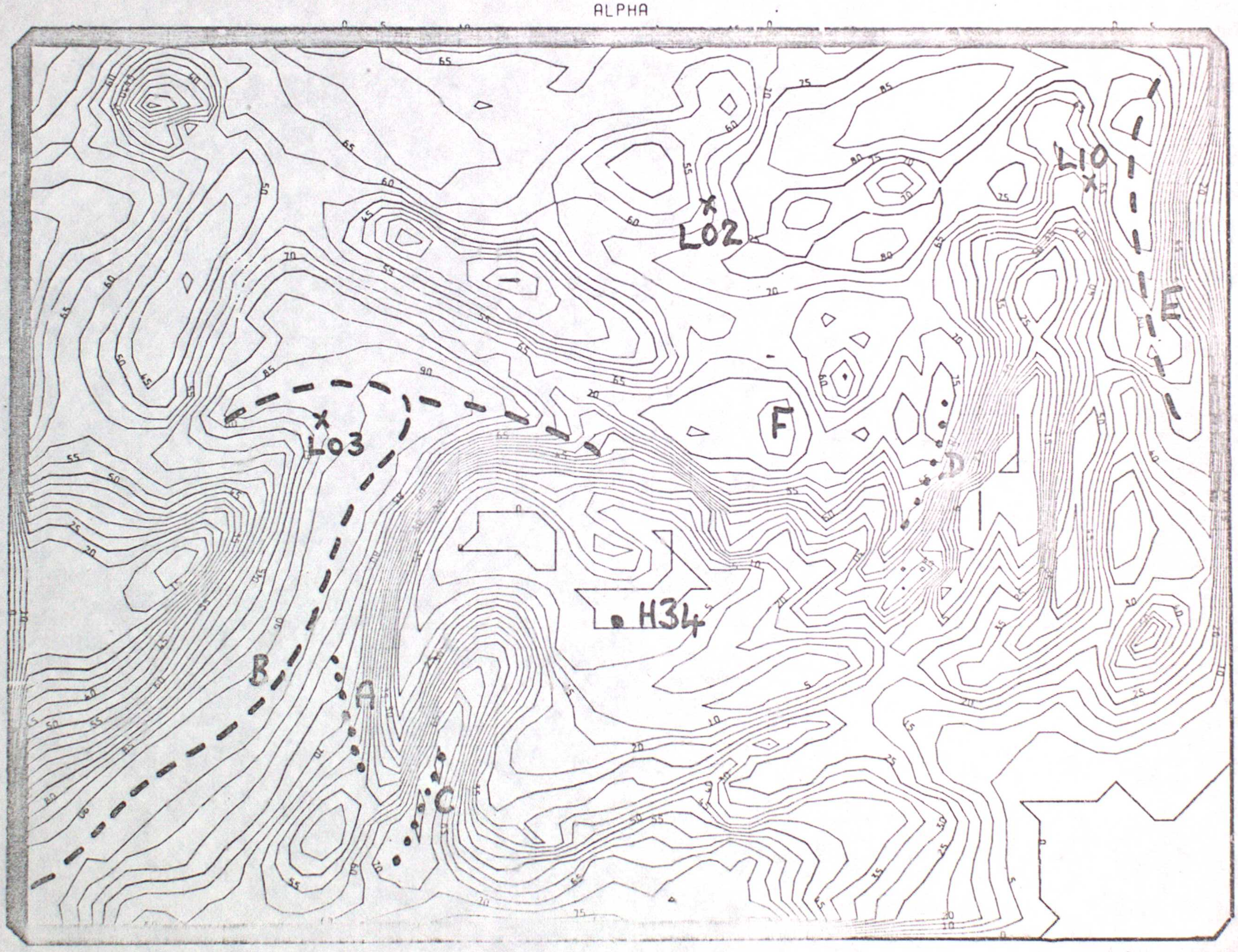

Figure 11 - 36hr forecast of cloud cover and the main surface features (valid 12Z 27/9/78) using the subgridscale condensation scheme - S(2)

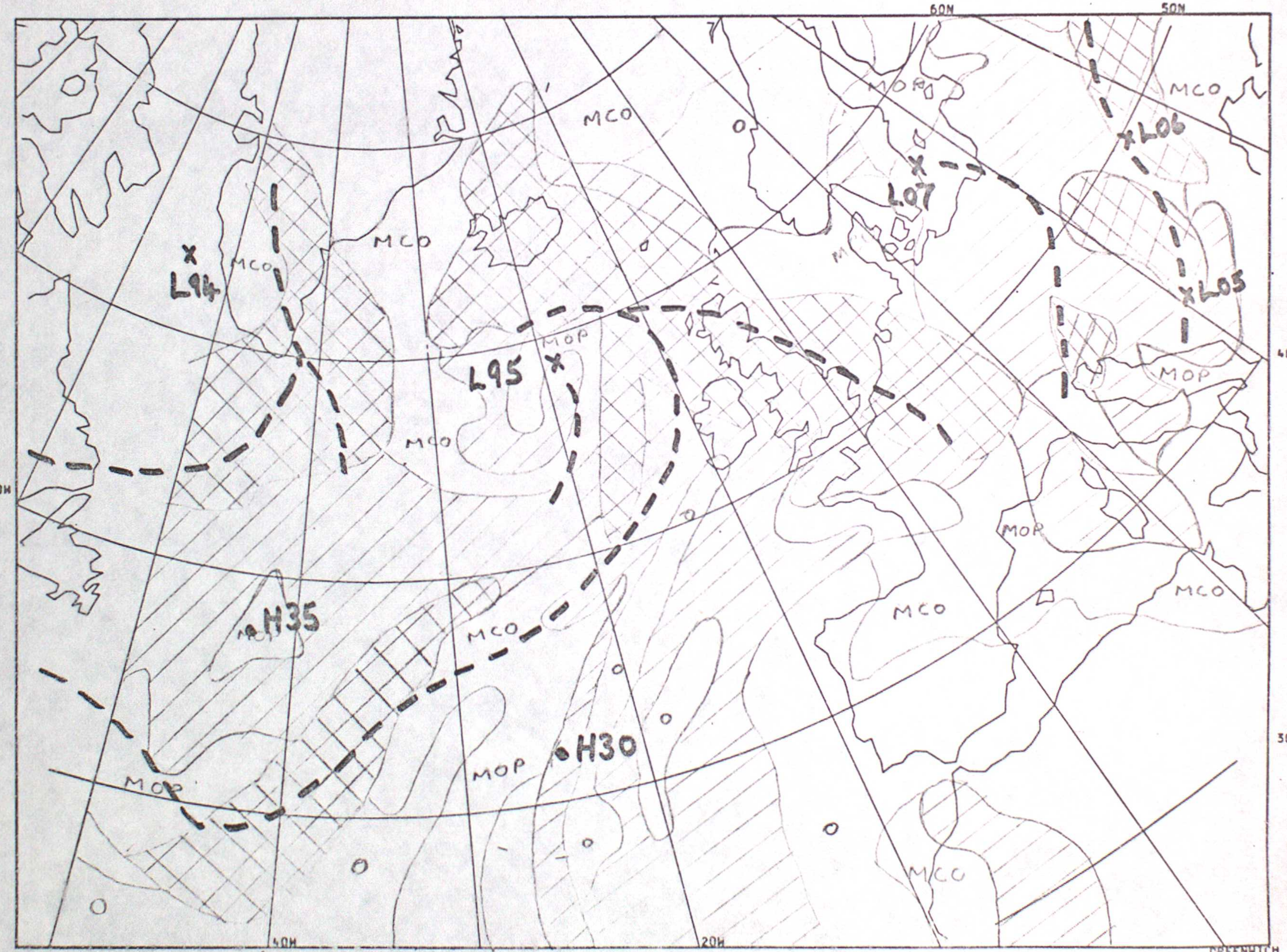

Figure 12 - nephanalysis at about 12Z 28/9/78 along with the positions of the main surface features

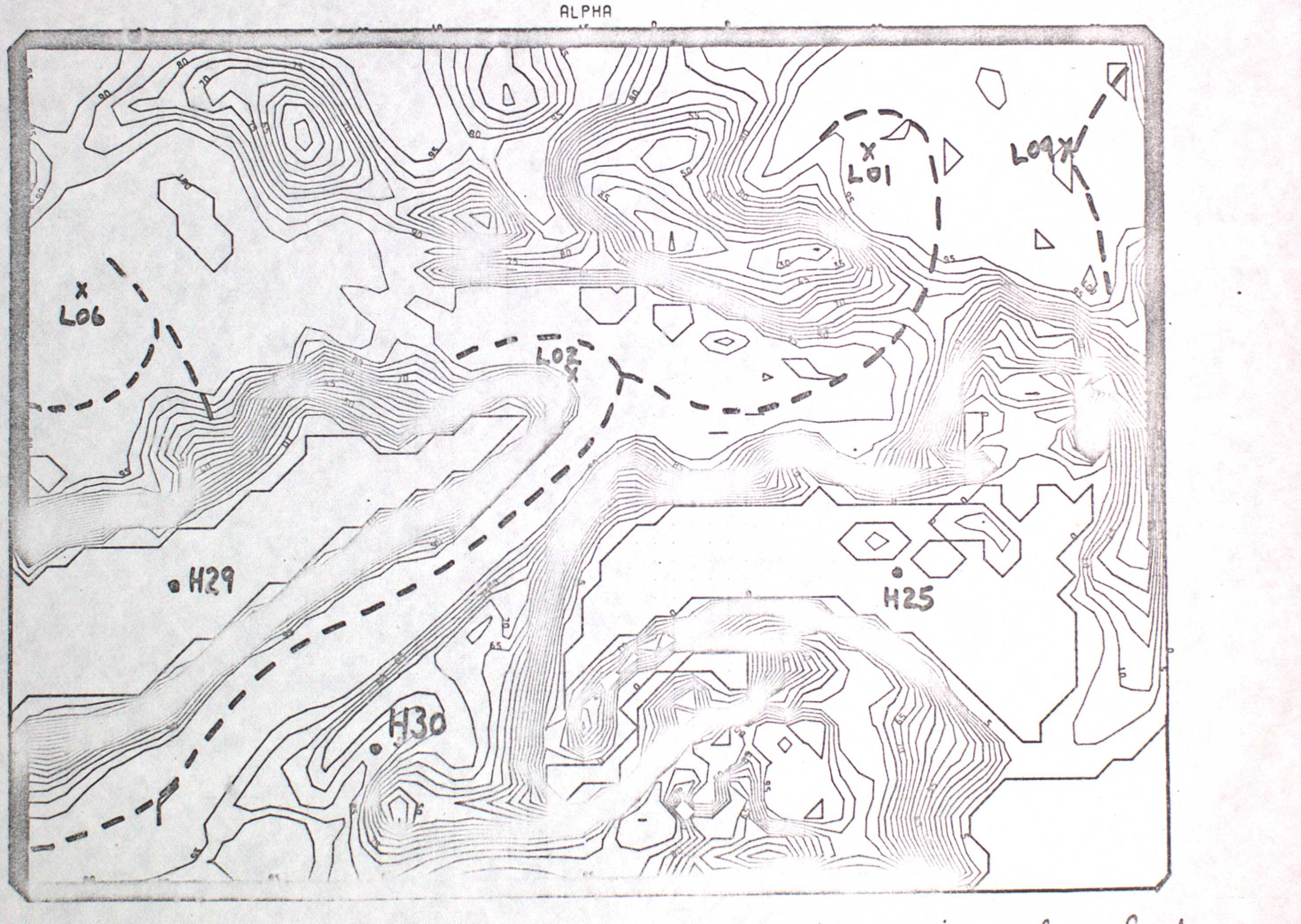

Figure 13 - 36 hr forecast of cloud cover and the main surface features (valid 12Z 28/9/78) using the operational scheme - E(0)

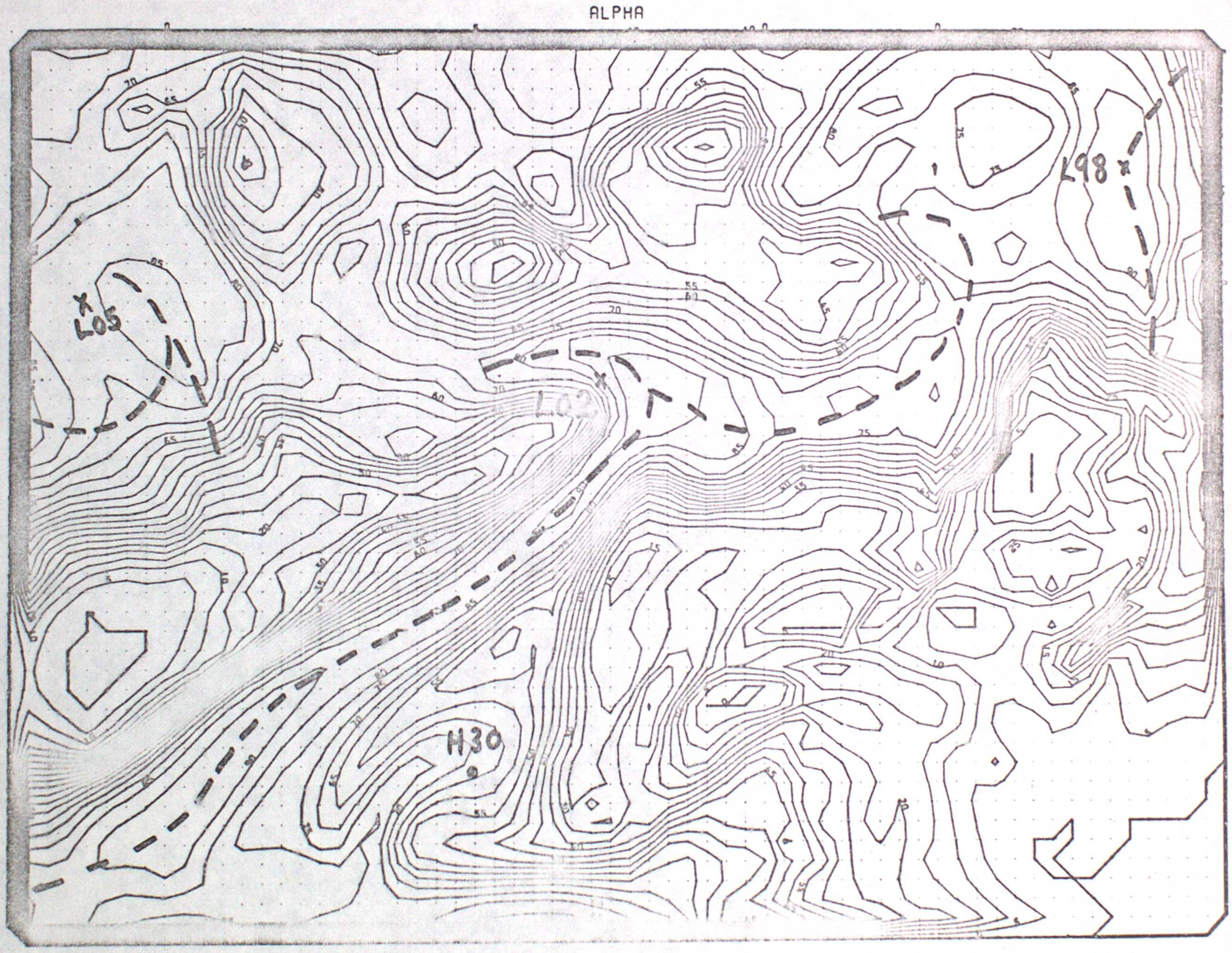

Figure 14 - 36 hr forecast of cloud cover and the main surface features (valid 12Z 28/9/78) using the subgridscale condensation scheme - S(2)

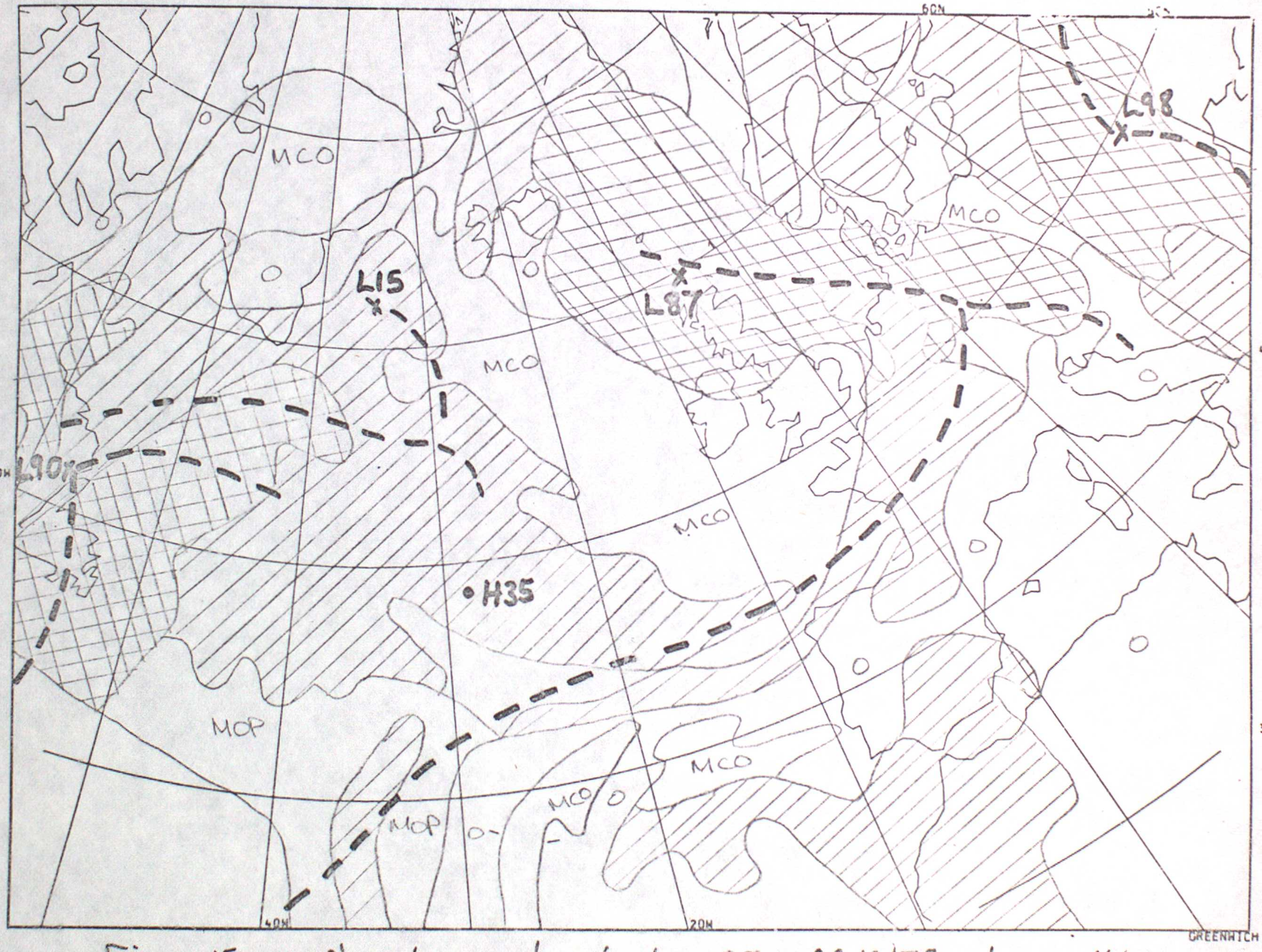

Figure 15 - nephanalysis at about 12Z 29/9/78 along with the positions of the main surface features

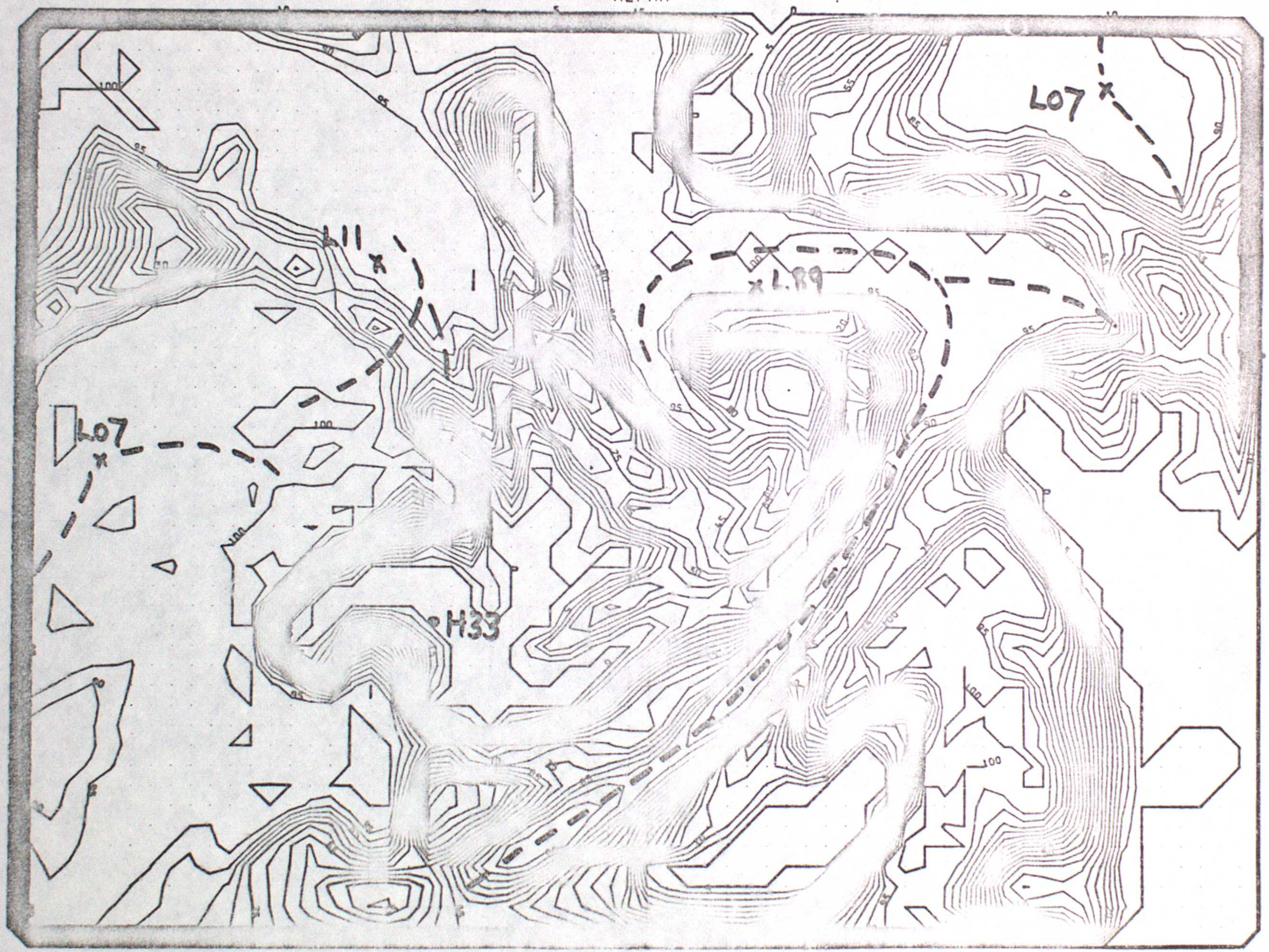

Figure 16 - 36 hr forecast of cloud cover and the main surface features (valid 12Z 29/9/78) using the operational scheme - E(0)

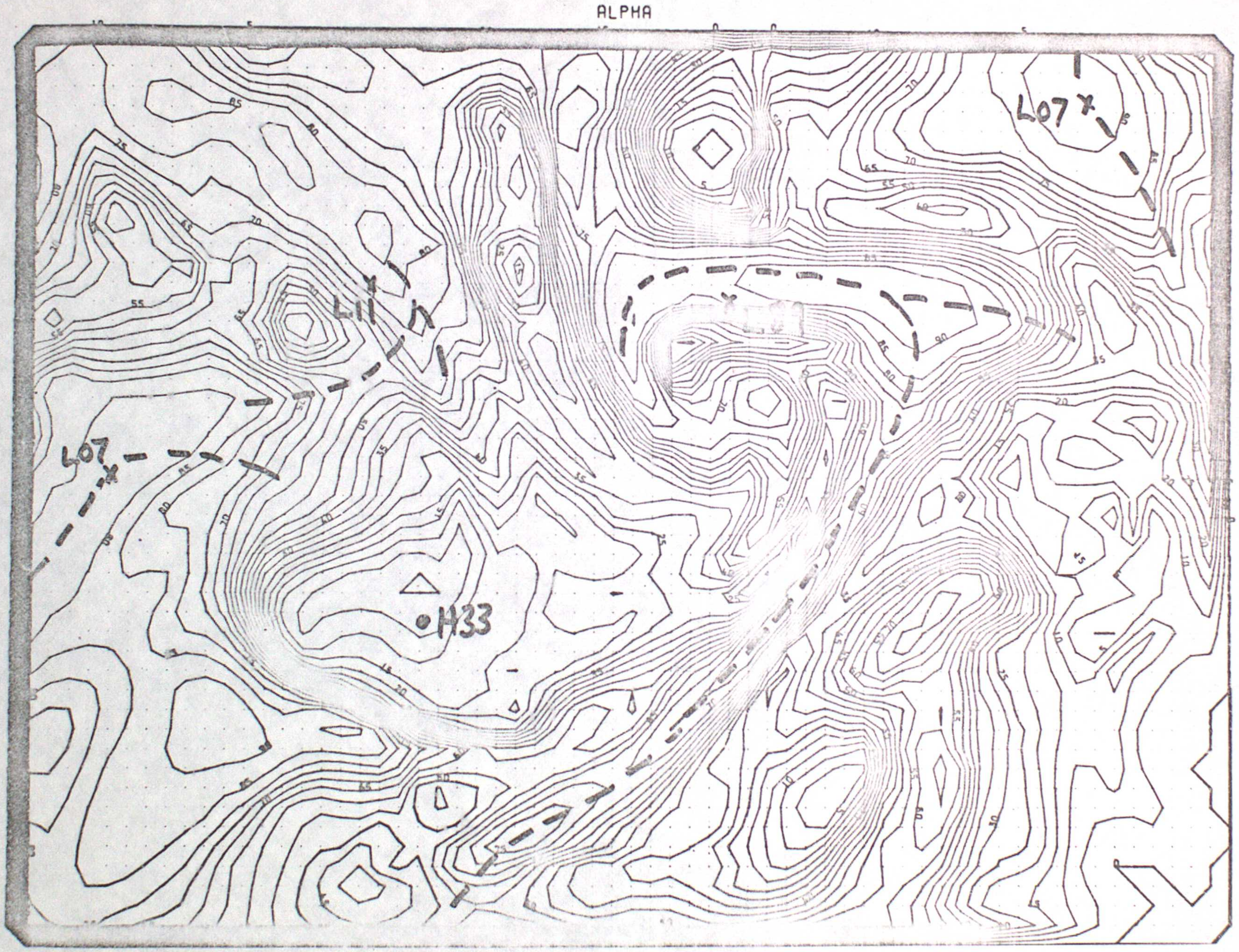

Figure 17- 36 hr forecast of cloud cover and the main surface features (valid 12Z 29/9/78) using the subgridscale condensation scheme - S(2)