# Forecasting Research

Forecasting Research Division
Technical Report No. 163

## Report on tests of merging extrapolation and Mesoscale model cloud forecasts for Nimrod

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## 1. Introduction

The Nimrod system is required to produce cloud amount forecasts for up to six hours ahead in a number of atmospheric layers together with related products such as cloud base and cloud top heights. Cloud amounts will be generated by merging forecasts using extrapolation (Pamment, 1994) with forecasts from the Mesoscale model. A linear combination has been proposed and tested with the extrapolation technique dominating near the beginning of the forecast period and the model near the end. Performance targets for the merged forecast are specified in the Nimrod User Requirement (UR), which states that forecasts should achieve a Hit Rate (HR) greater than 70% at T+1, 60% at T+3 and 50% at T+6, and False Alarm Rates (FAR) less than 30% at T+1, 50% at T+3 and 60% at T+6 with HR and FAR being calculated for cloud amount thresholded at 4 oktas. This report will describe the merging technique, and assess the performance in eight case studies.

## 2. The Merging Technique

The inputs to the merging process are extrapolation forecast cloud fraction fields (X) and model forecast cloud fraction fields (M). A merged field (G) is calculated for each forecast lead time at each cloud level as follows:

$G_{T+1} = X_{T+1}$
$G_{T+2} = 0.8X_{T+2} + 0.2M_{T+2}$
$G_{T+3} = 0.6X_{T+3} + 0.4M_{T+3}$
$G_{T+4} = 0.4X_{T+4} + 0.6M_{T+4}$
$G_{T+5} = 0.2X_{T+5} + 0.8M_{T+5}$
$G_{T+6} = M_{T+6}$

At pixels where the extrapolation forecast produces no-data, for example, beyond the advected boundary of the model, the full model cloud fraction is used to derive a merged value.

## 3. Objective Evaluation of the Merged Forecast

Merged forecasts were produced for each of the eight cases used by Pamment in developing the extrapolation forecast technique. The forecasts were assessed against hourly MOPS analyses (Wright,1993) already available from the previous study. Following Pamment, the forecast and analysis for each time were divided into three height bands of cloud; below 1000 feet above sea level, below 5000 feet above sea level and total cloud. Cloud amount was assigned to the three layers by choosing the maximum cloud fraction from all the levels which overlapped a particular band. The forecast and analysis in each height band were thresholded at 4 oktas, then smoothed using a Gaussian function with a half width of 25km as described in the UR. HR and FAR for the thresholded and smoothed cloud fields in each band were calculated within the area of radar coverage for each time, (see Pamment for further details and explanation of the verification procedure).
In calculating HR and FAR for the two deeper cloud layers, regions less than half cover were used as opposed to those greater than half cover by Pamment. This was to overcome the problem noted by Golding, 1994, where the percentage occurence of cloud greater than 4/8 cover was 11% for low cloud, 83% for cloud below 5000 feet and 90% for total cloud. Using regions less than half cover as the significant ones for the deeper layers ensures that the forecasting problem is equally difficult for all three layers and the same success measure can be used for each. Of the eight cases, four had very little low cloud so they were not used in calculating the composite statistics for that layer. The cases are listed and described in section 4. HR and FAR for each forecast lead time from the extrapolation, model and merged forecasts are shown in Table 1.

**Table 1.** Hit rate and false alarm rates expressed as percentages for all cases for each forecast lead time and for three cloud categories. X = forecasts using extrapolation only, M = forecasts direct from Mesoscale model, G = merged model and extrapolation forecast. Figures are presented in bold type where they meet the UR.

| Hit Rate | | T+1 | T+2 | T+3 | T+4 | T+5 | T+6 |
|---|---|---|---|---|---|---|---|
| >4 oktas below 1000’ | X | **75** | 68 | **68** | 52 | 57 | 42 |
| | M | 64 | 68 | **71** | 62 | 55 | **66** |
| | G | **75** | 64 | **71** | 57 | 59 | **66** |
| <4 oktas below 5000’ | X | **85** | 62 | 58 | 50 | 50 | 48 |
| | M | 70 | 68 | 58 | 57 | 56 | **62** |
| | G | **85** | 66 | **64** | 57 | 58 | **62** |
| <4 oktas total | X | **81** | 62 | **61** | 53 | 56 | 50 |
| | M | 64 | 64 | 55 | 48 | 52 | 46 |
| | G | **81** | 62 | **66** | 52 | 55 | 46 |
| Nimrod UR | | >70 | | >60 | | | >50 |

| False Alarm Rate | | T+1 | T+2 | T+3 | T+4 | T+5 | T+6 |
|---|---|---|---|---|---|---|---|
| >4 oktas below 1000’ | X | **10** | 21 | **36** | 44 | 50 | 67 |
| | M | **28** | 20 | **24** | 25 | 34 | **36** |
| | G | **10** | 19 | **20** | 24 | 23 | **36** |
| <4 oktas below 5000’ | X | 42 | 47 | 58 | 62 | 63 | 68 |
| | M | 58 | 58 | 65 | 63 | 63 | **58** |
| | G | 42 | 48 | 58 | 63 | 63 | **58** |
| <4 oktas total | X | 34 | 39 | 57 | 60 | 68 | 69 |
| | M | 60 | 55 | 61 | 61 | 61 | **53** |
| | G | 34 | 43 | 57 | 62 | 61 | **53** |
| Nimrod UR | | <30 | | <50 | | | <60 |

These results clearly show the benefit of the merged forecast. For low cloud the merged forecast met the UR at all times whereas neither the extrapolation nor the model forecasts achieved this.
For HR the merged forecast failed to meet the UR on one occasion (total cloud/ T+6). Beyond T+3 the model generally performed better than extrapolation except for (HR/ total cloud). Up to T+3 extrapolation was generally the best. At T+3 the merged forecast was the best for each cloud category and both success measures. At other times the merged forecast results were mainly either, closest to extrapolation or model, whichever was the best, or was itself the best result. On **only one occasion** (HR/ low cloud/ T+2) was the merged forecast the worst.

Also evident from the table is that all the forecast methods for the two deeper cloud layers performed better as measured by HR than by FAR. This was because of too many cloud gaps being predicted in some cases. These will be indicated in the subjective assessments.

## 4. Subjective assessments of cases

The cases used for the assessment are listed in table 2.

**Table 2.** List of cases used for the assessments. Analysis times in bold type indicate cases used for both low cloud and the two deeper layers. Analysis times in ordinary type indicate cases where very little low cloud was present and so were not included in the assessment.

| Date | Analysis time(s) | Description |
|---|---|---|
| 02 November 1993 | **10 UTC** | Stratocumulus sheet, frontal cloud to south |
| 29 November 1993 | **04 and 14 UTC** | Active frontal systems moving slowly east. |
| 07 December 1993 | 04 UTC | Waving cold front in SE |
| 16 January 1994 | 04 and 14 UTC | Cold unstable northerly |
| 25 January 1994 | **08** and 16 UTC | Organised convection and frontal system |

The synoptic conditions for these cases have been described in Pamment, and so are not repeated here. Maps of cloud cover have been produced for each case using four shades of grey (including white). For low cloud white represents 0 - 2/8 cover, light grey >2/8 - 4/8, grey >4/8 - 6/8 and dark grey >6/8 cover. For total cover the meaning of the colours has been reversed to prevent the maps from coming out too dark. Thus for the <5000 feet and total cloud categories; white represents 6/8 - 8/8 cover, light grey 4/8 - <6/8, grey 2/8 - <4/8, and dark grey 0 - <2/8 cover.
The important thing to remember in looking at the maps is that ***for both low and total cloud the significant regions as far as the UR is concerned are those shaded either grey or dark grey.***

### 4.1 2nd November 1993 DT 1000 UTC

The low cloud forecast is shown in figure 1 and the total cloud forecast in figure 2. The low cloud forecast is good right through from T+1 to T+6. The retention of the small cloud gap over Brittany, and the decrease in cloud cover over the southern North Sea near Holland during the forecast are particularly impressive. Obviously there are small errors in detail as well, such as the too large cloud gap in the Channel north of the Channel Islands at T+1, which does, however, get corrected when the model is merged in at T+3. In the SW approaches there is not enough significant cloud early in the forecast, however, the increasing contribution of the model with time improves this, thus showing the value of merging. The total cloud forecast is not as good as the low cloud prediction. The greatest difference between the forecast and analysis occurs at T+3, with an area of 4/8 - 6/8 forecast cloud cover over parts of England and Wales compared to 6/8 - 8/8 in the analysis. This is due to both the extrapolation forecast and the model forecast becoming slightly deficient in cloud in this region, fortunately it is not significant. By T+6 there is a large significant gap in the model forecast cloud over the Irish Sea which does not verify.

### 4.2 29$^{th}$ November 1993 DT 0400 UTC

The low cloud forecast is shown in figure 3 and the total cloud forecast in figure 4.
The low cloud forecast is again quite good with no major errors apart from there being too little cloud forecast over Cornwall at T+6. However, there are more problems with the total cloud. The model has too much cloud at T+6 over E.Anglia, Kent, and NE France, the same strip is also evident further west at T+3, but here only 0.4 of the model cloud is used so it comes out grey instead of white in figure 4. At T+1 the line discontinuity in the forecast cloud cover in the west is the same as that noted by Pamment, where cloud identified as precipitating, (which is moved with a single object vector), starts to become separated from non-precipitating cloud (which is advected with cloud level winds). By T+3 pixels in the west with no-data values have been replaced by full model cloud fractions which in this case are 6/8 - 8/8.

### 4.3 29$^{th}$ November 1993 DT 1400 UTC

The low cloud forecast is shown in figure 5 and the total cloud forecast in figure 6.
The main region of low cloud in the western English Channel and over SW England is handled reasonably well in the forecast with the region becoming smaller and tending to break up with time.
By T+3 the main error is that the cloud has been advected too far east in the Channel with also too much cloud over SW England compared to MOPS. The small patch of cloud in the southern North Sea near Holland at T+1 has been advected too far west, and then fragments at T+3 because the model has not represented it. However, the T+3 forecast generally is a good compromise between model and extrapolation solutions. In the total cloud forecast, the eastern regions have been handled well albeit with a tendency for too little cloud in the North Sea. In the extreme west, the model has too little cloud and this clearer slot is advected slowly eastwards.

### 4.4 7$^{th}$ December 1993 DT 0400 UTC

The forecast for total cloud is shown in figure 7.
This forecast is rather poor, particularly after T+1. The clearer areas are overdone and often in the wrong place. For example, compare Ireland and the Irish Sea at T+3. The main problem is that, although the model handled the frontal cloud in the southeast reasonably well, the showery air in the west and northwest is too clear. This is clearly evident at T+6 and at T+1 where the line of broken cloud at the western edge is where the model cloud has been used to fill in no-data regions after extrapolation.

### 4.5 16$^{th}$ January 1994 DT 0400 UTC

The total cloud forecast is shown in figure 8.
This forecast is quite good, particularly in the early stages. However, the model does have too clear conditions advecting south from the northern boundary. At T+1 there are two spurious lines of clearer regions near northern Ireland which coincide with object boundaries in the extrapolation forecast.

### 4.6 16th January 1994 DT 1400 UTC

The total cloud forecast is shown in figure 9.
This was a forecast noted by Pamment, where medium/high cloud layers were becoming separated because of vertical wind shear. Combining the model and extrapolation forecasts has alleviated this problem. This forecast is now very good with most of the significant clear regions in and around the UK being well forecast. However, there remains too little cloud predicted over the sea to the SW of the UK.

### 4.7 25th January 1994 DT 0800 UTC

The low cloud forecast is shown in figure 10 and the forecast for total cloud in figure 11.
In figure 10 the MOPS analysis clearly shows the significant low cloud associated with a frontal system lying west - east along the English Channel curling northwards into Scandinavia then wrapping round the surface low to the northwest of Scotland. The cloud was well forecast throughout the period. Noteworthy is the forecast of low cloud in the Bristol Channel at T+1 and the decrease in cloud amount in the south between T+3 and T+6. The model forecast alone would not have captured the cloud in the Bristol Channel, and the extrapolation forecast alone would not have dissolved the cloud in the later stages of the forecasts. Combining extrapolation and model forecasts produces a good solution. The total cloud forecast was also quite good with the clear zone to the rear of the frontal system being well handled, at least up to T+3. By T+6 the model forecast had too little cloud between Scotland and Scandinavia and too much cloud over southern England.

### 4.8 25th January 1994 DT 1600 UTC

The total cloud forecast is shown in figure 12.
The main error in this forecast is that the model has too little cloud in the west and north . However, the broken cloud in the MOPS analysis at T+3 between SW England and Ireland is not represented in the forecast and leads to a substantial error over southern and eastern England by T+6.

## 5. Conclusions and recommendations

1). A method of combining extrapolation and model cloud forecasts for Nimrod has been described.

2). The method has been tested on the cases used by Pamment in developing the extrapolation component. The performance of the merged forecast has been assessed against the standards laid down in the UR. Cloud was assessed in three height bands: below 1000 feet above mean sea level (amsl), below 5000 feet amsl and total cloud. The low cloud forecasts satisfied the UR completely and the subjective assessment indicated just small errors in detail at the longer ranges. The forecasts for the two deeper cloud layers were less good with too little cloud being predicted in several cases, however, the scores for HR only failed to meet the UR at one time (total cloud/ T+6).

3). The model forecasts used for the merging process for the cases with data times after 1200 UTC were those from data times at 0600 UTC since these were the latest available. This means that model forecasts in some cases at T+6 were T+14 forecasts from the model data time. In Nimrod the model forecast will have a shorter lead time and hopefully less errors. An improved model forecast will then lead to an improved merged cloud forecast.

4). The problems of cloud separation noted by Pamment have been alleviated in the merged forecast. Where the extrapolation forecast leaves pixels with no-data the model forecast is used to supply values, this has proved to be successful. However, there are still some problems near object boundaries at T+1 where cloud becomes broken in an otherwise cloudy field.

5). Given the good performance of the low cloud forecasts and the reasonable representation of total cloud in most cases, it is recommended that the cloud merging scheme is now ready for implementation into Nimrod for further trials. It is anticipated that refinements of the scheme will need to be made, for example, the treatment of object boundaries before it can be accepted for operational use.

## 6. References


Golding, B.W. (1994) "A proposed technique for merging extrapolation and mesoscale model cloud forecasts". *Nowcasting Development Group Working Paper No. 90.*

Pamment, J.A. (1994) "Summary Report on the Tests of the Automated Cloud Extrapolation Forecast for Nimrod". *Forecasting Research Division Technical Report No. 130.*

Wright, B.J. (1993) "The Moisture Observation Processing System (MOPS)". *Forecasting Research Division Technical Report No. 38.*

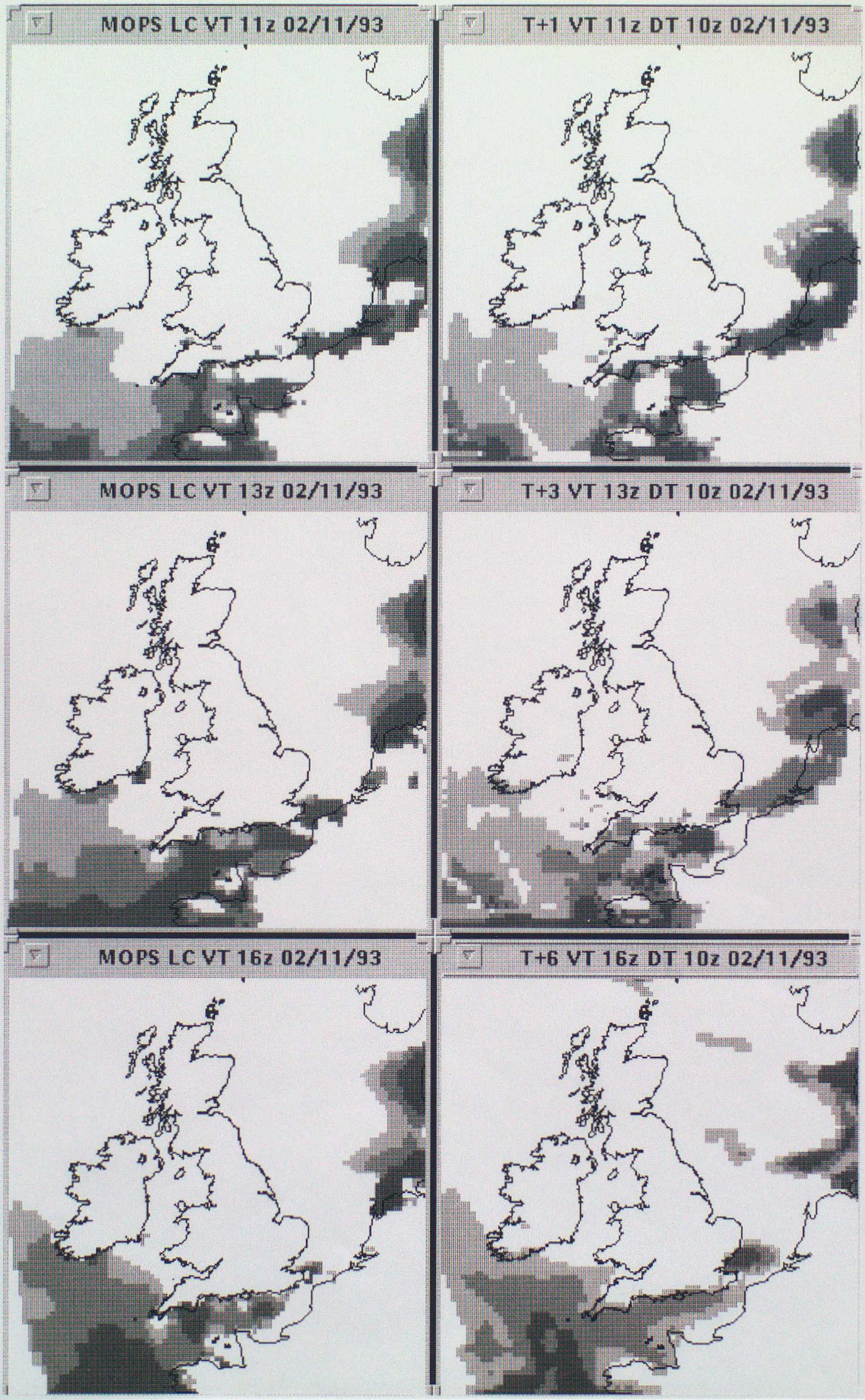


**Figure 1.** MOPS analyses and corresponding merged cloud amount forecast for low cloud at T+1, T+3 and T+6 from data time 2/11/93 1000 UTC. White = 0 - 2/8, light grey >2/8 - 4/8, grey >4/8 - 6/8 and dark grey >6/8 cover.

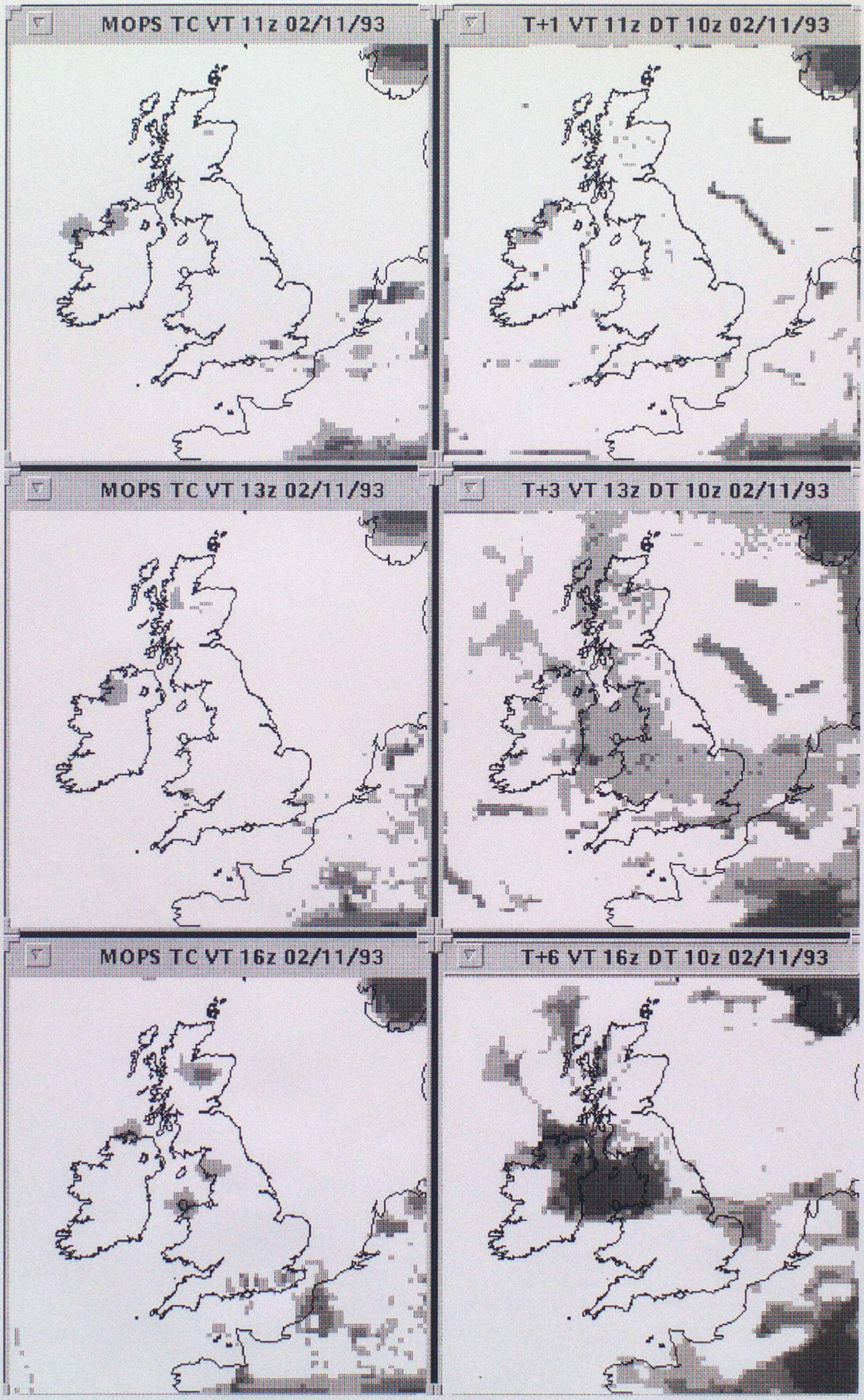


**Figure 2.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 2/11/93 1000 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.

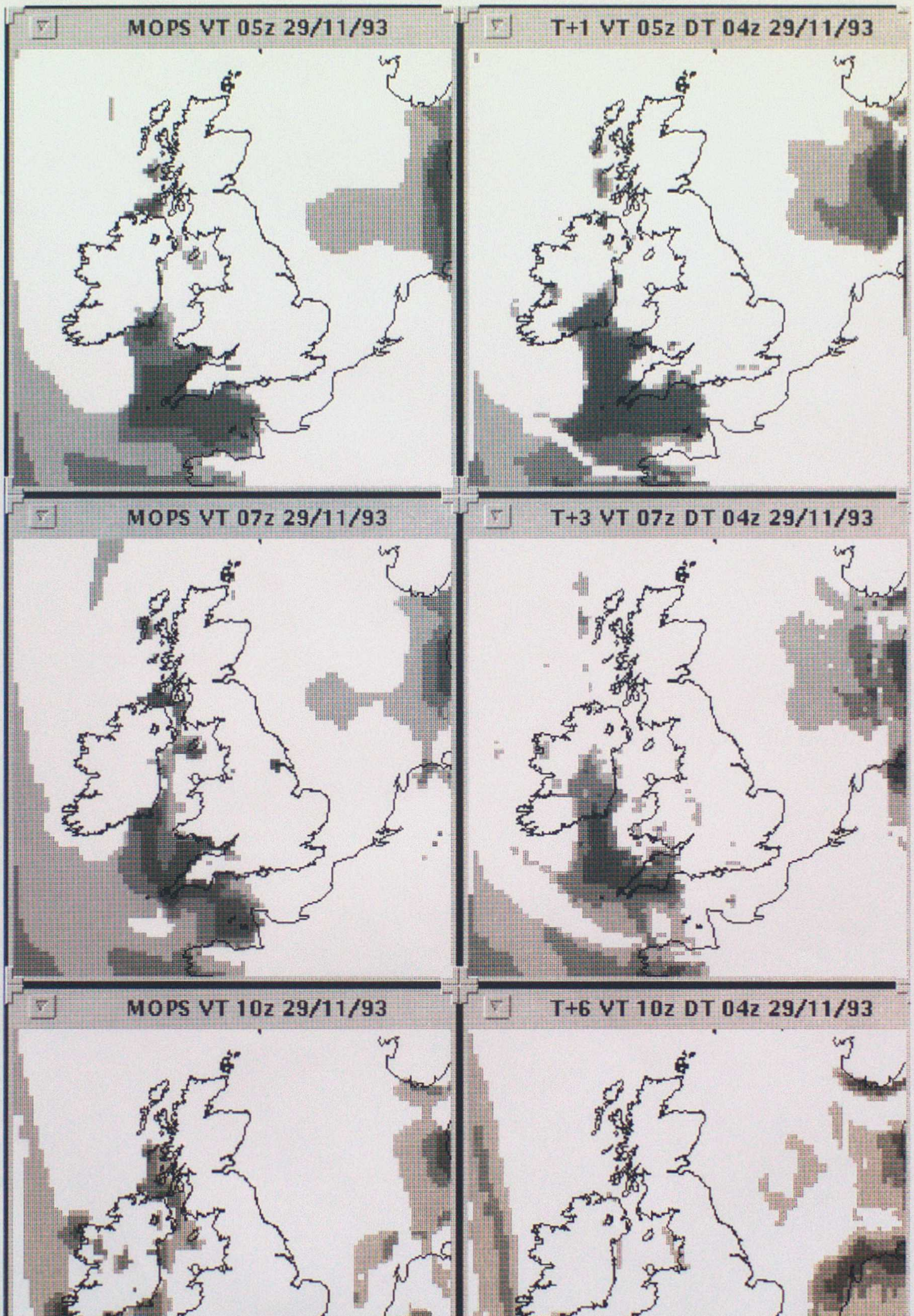


**Figure 3.** MOPS analyses and corresponding merged cloud amount forecast for low cloud at T+1, T+3 and T+6 from data time 29/11/93 0400 UTC. White = 0 - 2/8, light grey >2/8 - 4/8, grey >4/8 - 6/8 and dark grey >6/8 cover.


**Figure 4.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 29/11/93 0400 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.

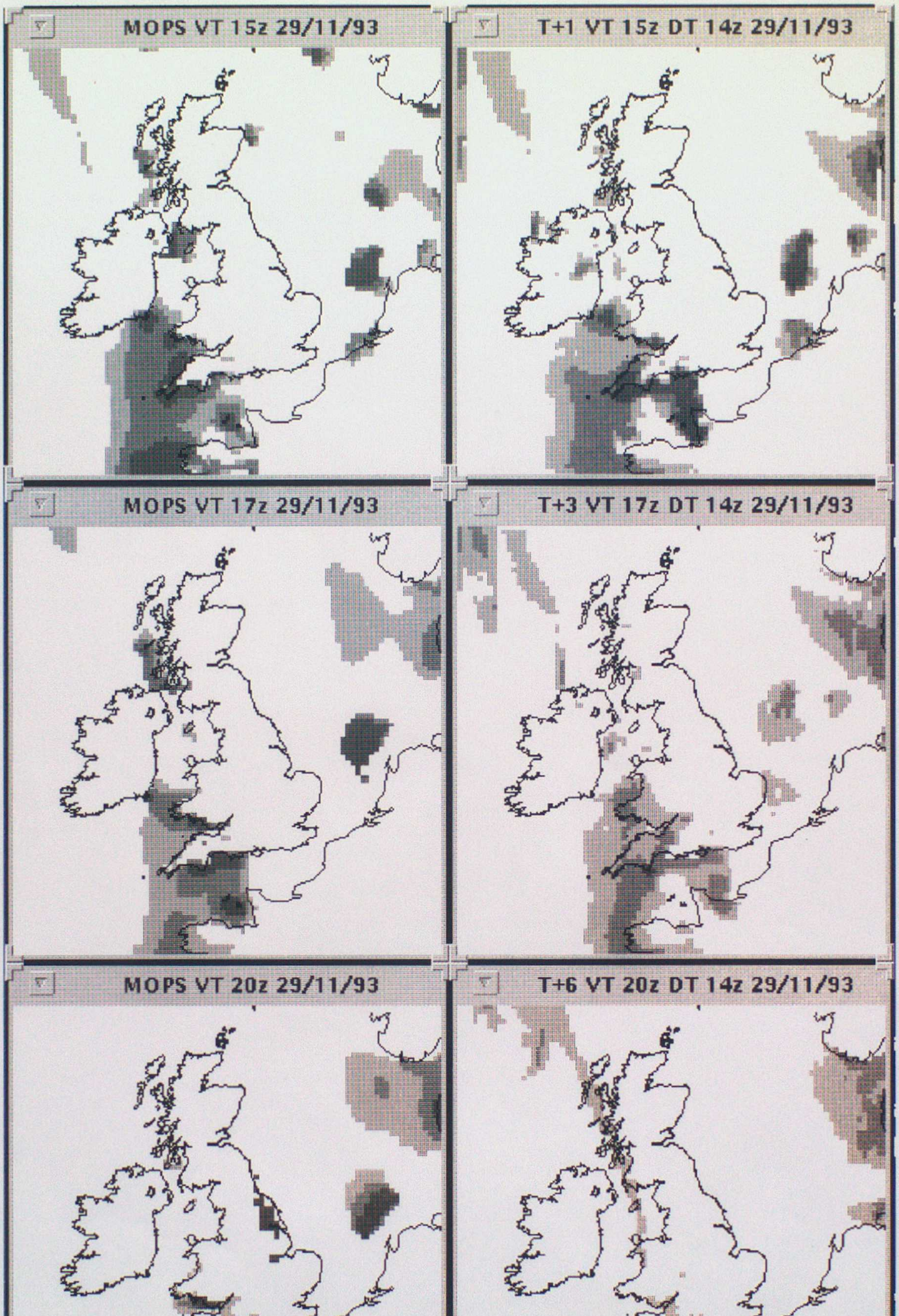


**Figure 5.** MOPS analyses and corresponding merged cloud amount forecast for low cloud at T+1, T+3 and T+6 from data time 29/11/93 1400 UTC. White = 0 - 2/8, light grey >2/8 - 4/8, grey >4/8 - 6/8 and dark grey >6/8 cover.


**Figure 6.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 29/11/93 1400 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.

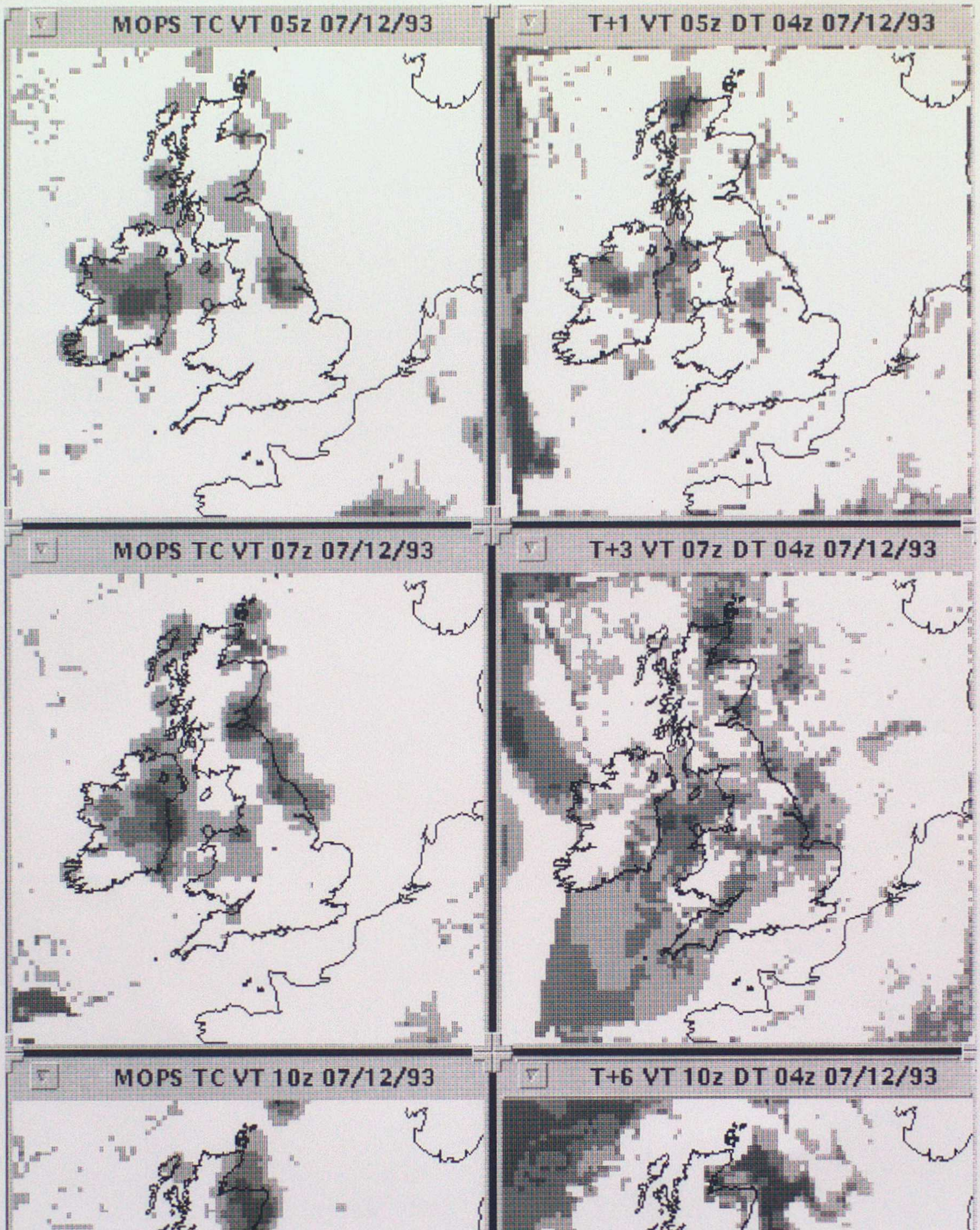


**Figure 7.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 7/12/93 0400 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.

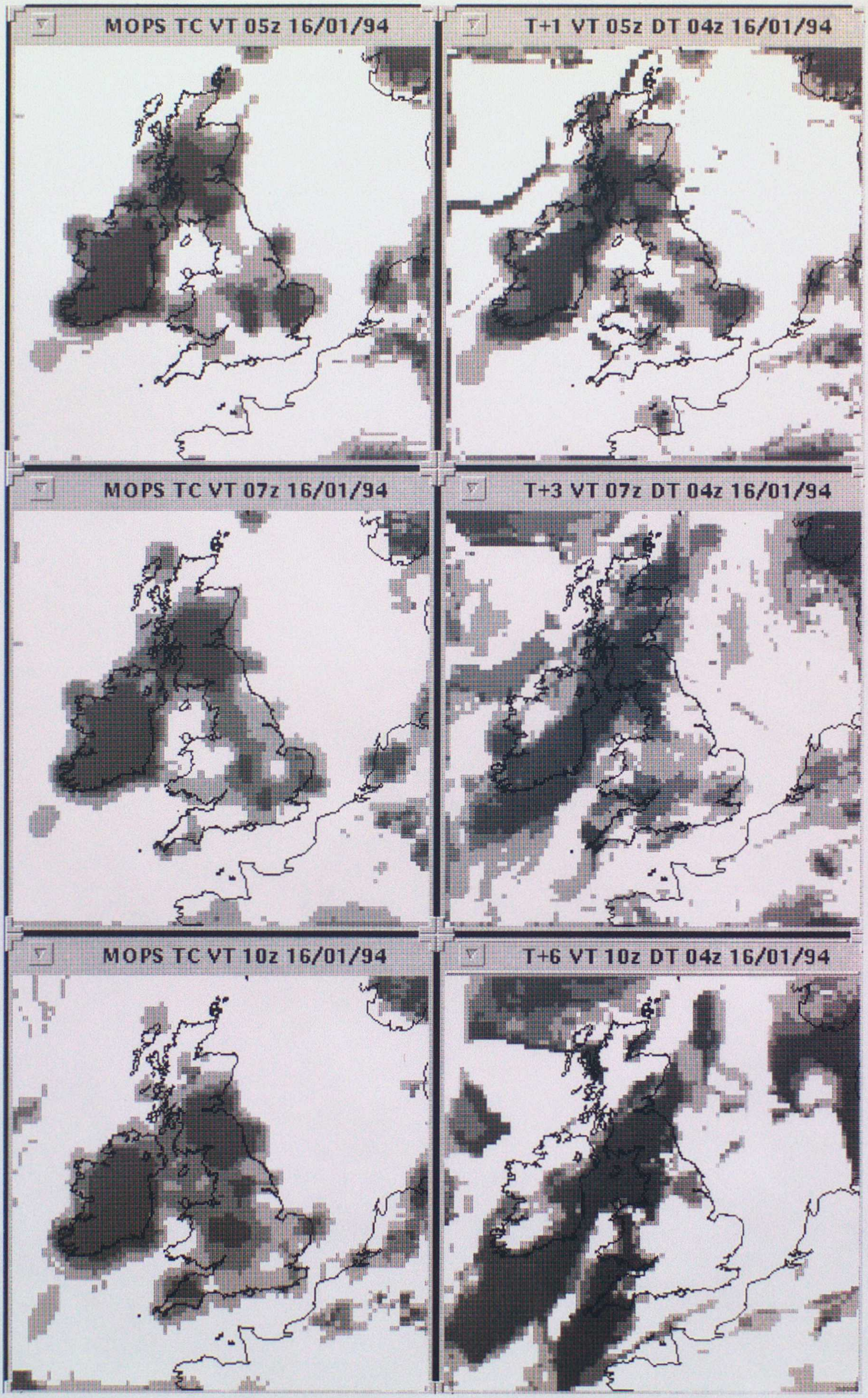


**Figure 8.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 16/01/94 0400 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.

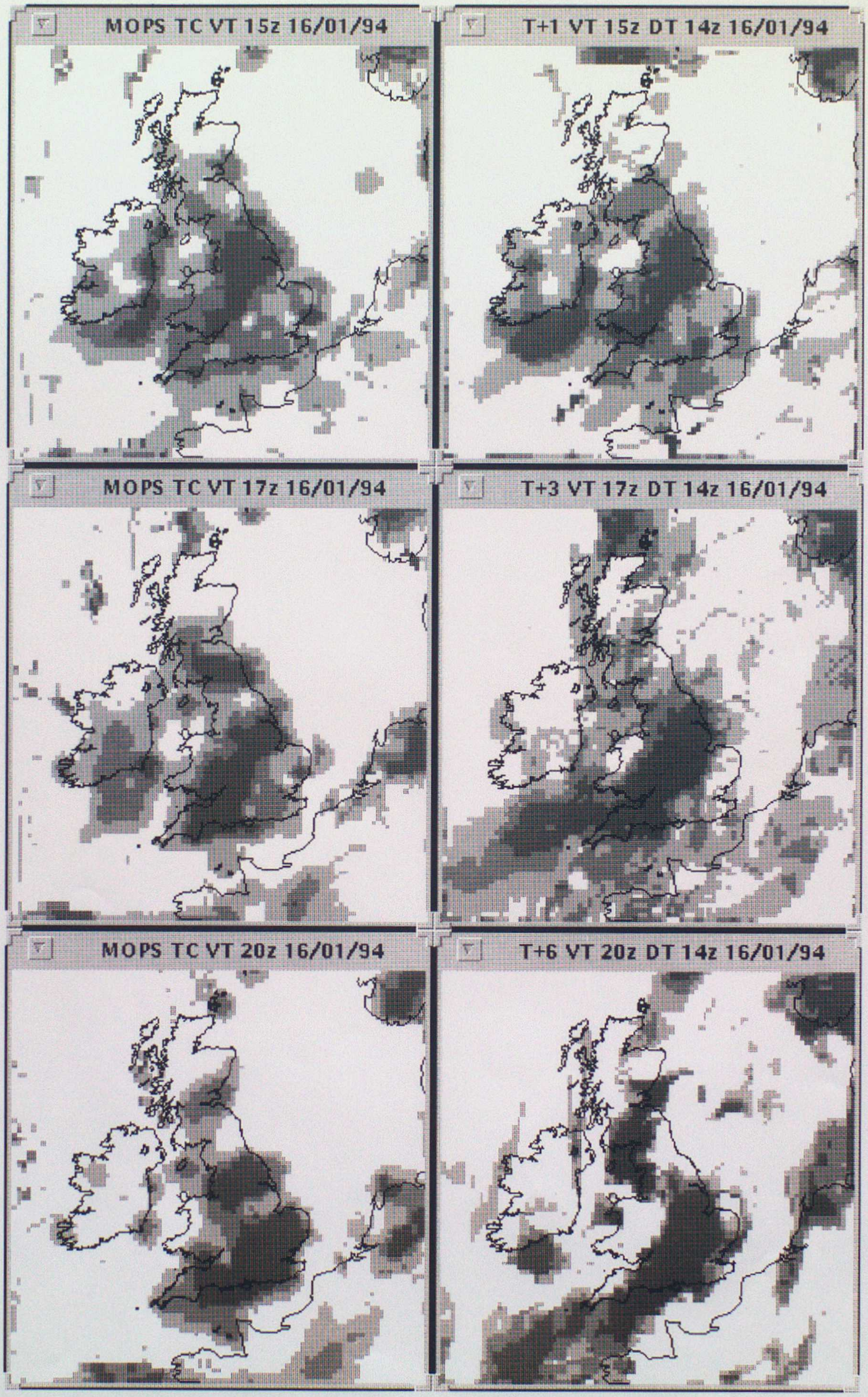


**Figure 9.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 16/01/94 1400 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.


**Figure 10.** MOPS analyses and corresponding merged cloud amount forecast for low cloud at T+1, T+3 and T+6 from data time 25/01/94 0800 UTC. White = 0 - 2/8, light grey >2/8 - 4/8, grey >4/8 - 6/8 and dark grey >6/8 cover.

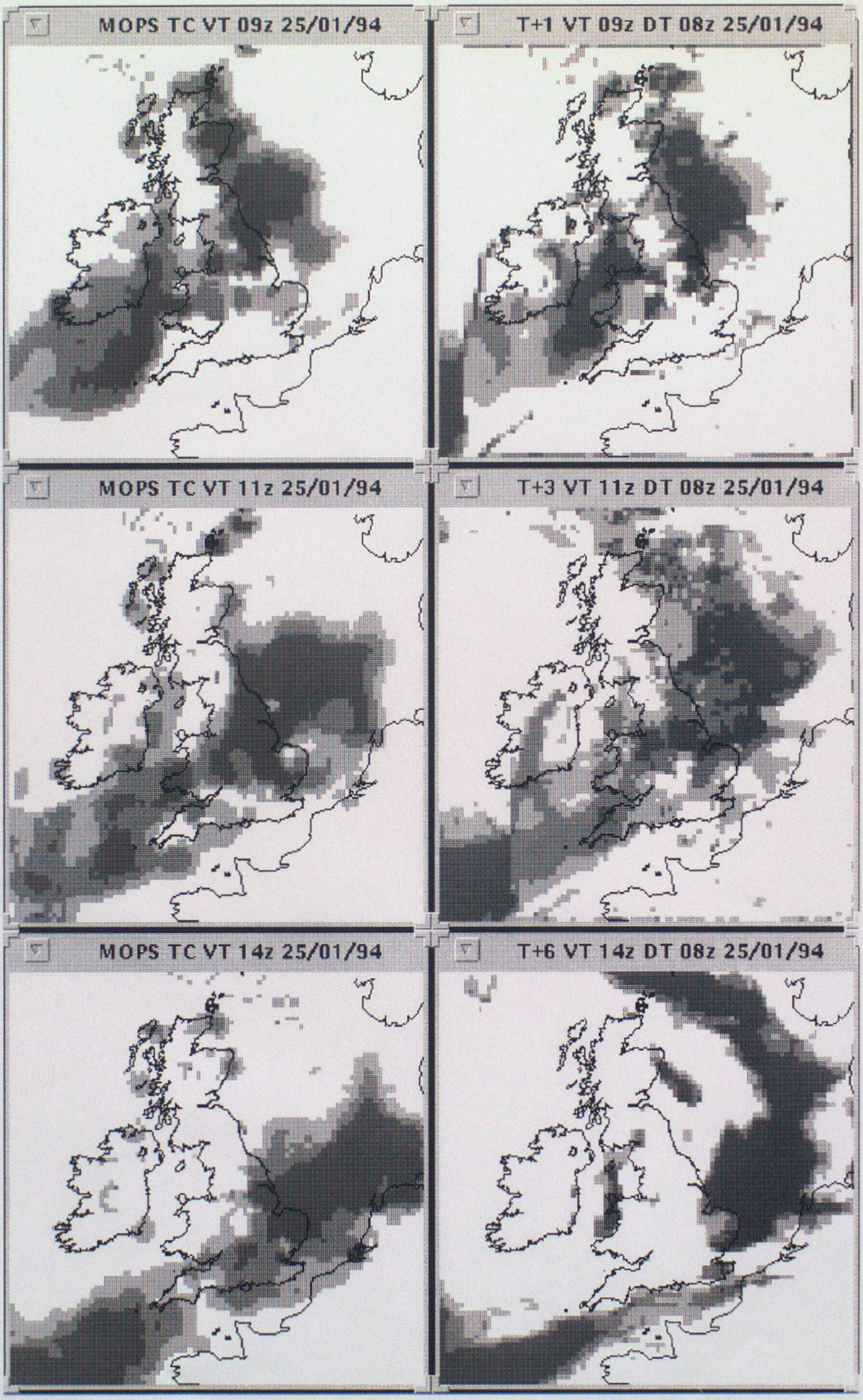


**Figure 11.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 25/01/94 0800 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.

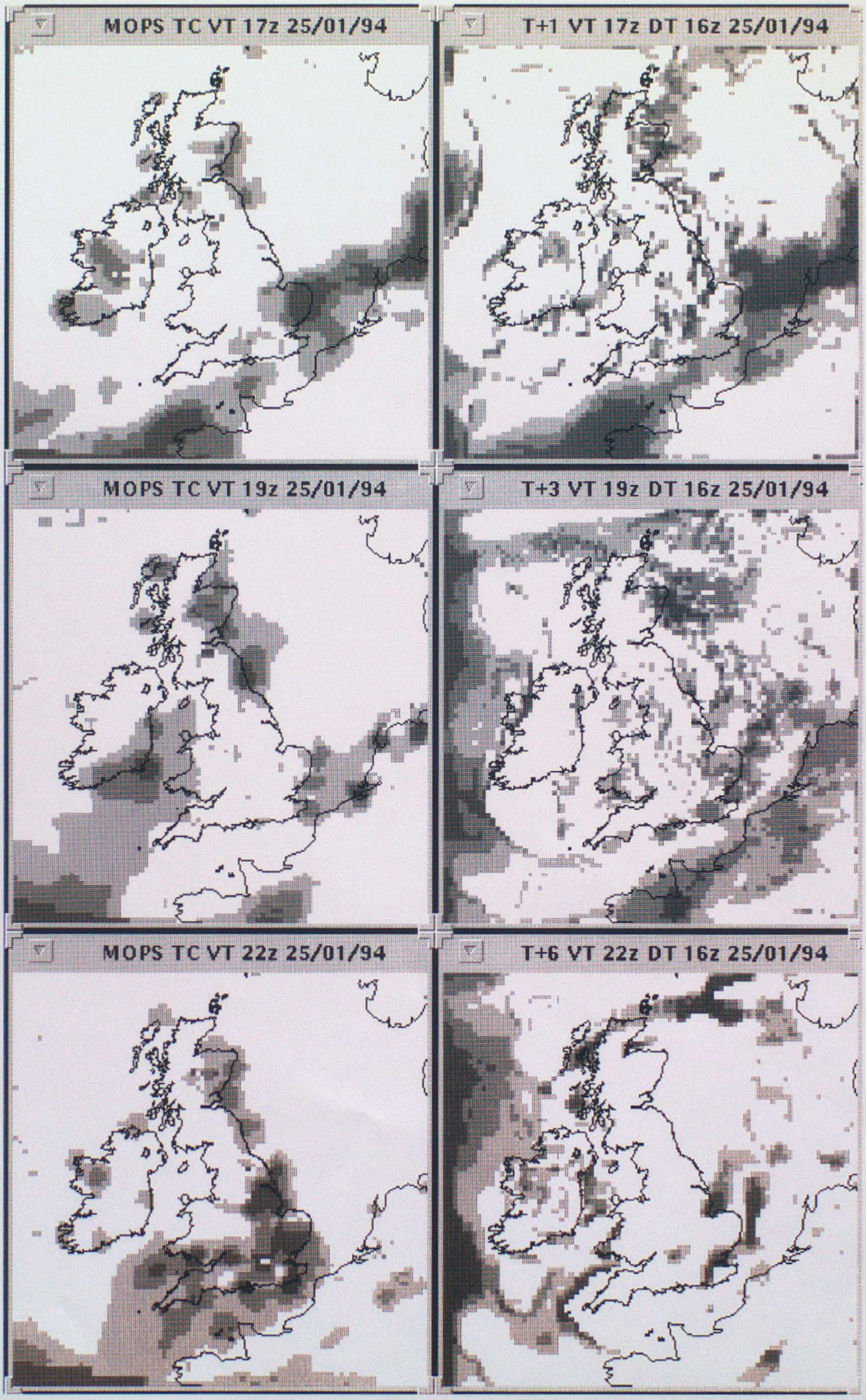


**Figure 12.** MOPS analyses and corresponding merged cloud amount forecast for total cloud at T+1, T+3 and T+6 from data time 25/01/94 1600 UTC. White = 6/8 - 8/8, light grey 4/8 - <6/8, grey 2/8 - <4/8 and dark grey 0 - <2/8 cover.