Operations Department

Technical Report No. 77

ECMWF forecasts of the floods of January 1995

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December 1995

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Abstract

The performance of the ECMWF operational T213 forecast model and the Ensemble Prediction System (EPS) during the period of widespread flooding over western Europe in January 1995 is reviewed.

The ECMWF forecast system succeeded in providing valuable forecast guidance three to five days ahead through accurate prediction of area-averaged precipitation amounts and the separation of wet and dry periods. Forecasts more than a week ahead gave good guidance of the prevailing flow regime and indicated periods of intense precipitation over western Europe.

The EPS supported the operational high-resolution forecasts strongly during this period. Most members of the ensemble forecasts indicated the correct flow patterns, yielding consistently high probabilities of strong precipitation in the medium-range forecasts.

Introduction

Heavy precipitation over western and central Europe during the second half of January 1995 led to wide spread floods, first over Brittany, and later over the lower Rhine and Meuse regions of western Germany and the Netherlands, and over eastern Belgium.

From 17 to 23 January, Brittany and the surrounding regions received between 70 and 100 mm of rain with local maxima above 100 mm, and about the same amount again in the course of the following week. Large areas of western and central Europe received around 100 mm of precipitation between 20 and 30 January. At several locations of western Germany and especially in the Belgian Ardennes more than 150 mm and in places more than 200 mm was measured. For comparison, climatological January precipitation in the Rhine region is in the order of 50 mm.

Century record river levels, including the lower Rhine, and floods threatening to break some Dutch dikes, were caused by these excessive rainfalls combined with strong snow melt and soil conditions favouring rapid superficial runoff.

Synoptic description

January 1995 began with wintry weather over central Europe with widespread low temperatures and snowfall. Around 10 January a change to westerly weather caused warming and more precipitation, partly as rain. This was followed by a drier period with a ridge dominating until around 17 January, when a deep Atlantic low-pressure system approached Europe. In the following days a westerly regime was established, in which a succession of several frontal disturbances swept across western and central Europe. This led to abnormally large accumulated precipitation values during the second half of the month, as shown in Figure 1.

Pronounced warming in the Atlantic air mass regime caused snow melt up to relatively high altitudes. This, combined with the precipitation caused rapid swelling of rivers and devastating floods in many west and central European regions.

From 31 January onwards a more persistent high pressure ridge developed over central Europe and ended the prolonged period of strong precipitation over the Rhine catchment area, although more rain fell over northwestern Europe in the early days of February.

To summarize this sequence, Figure 2 shows analyses of mean sea level pressure, 850 hPa temperature and 500 hPa height from 16, 22 and 28 January. Figure 3 depicts time series of precipitation and two metre temperature averaged over SYNOP observations in the area indicated in Figure 1.

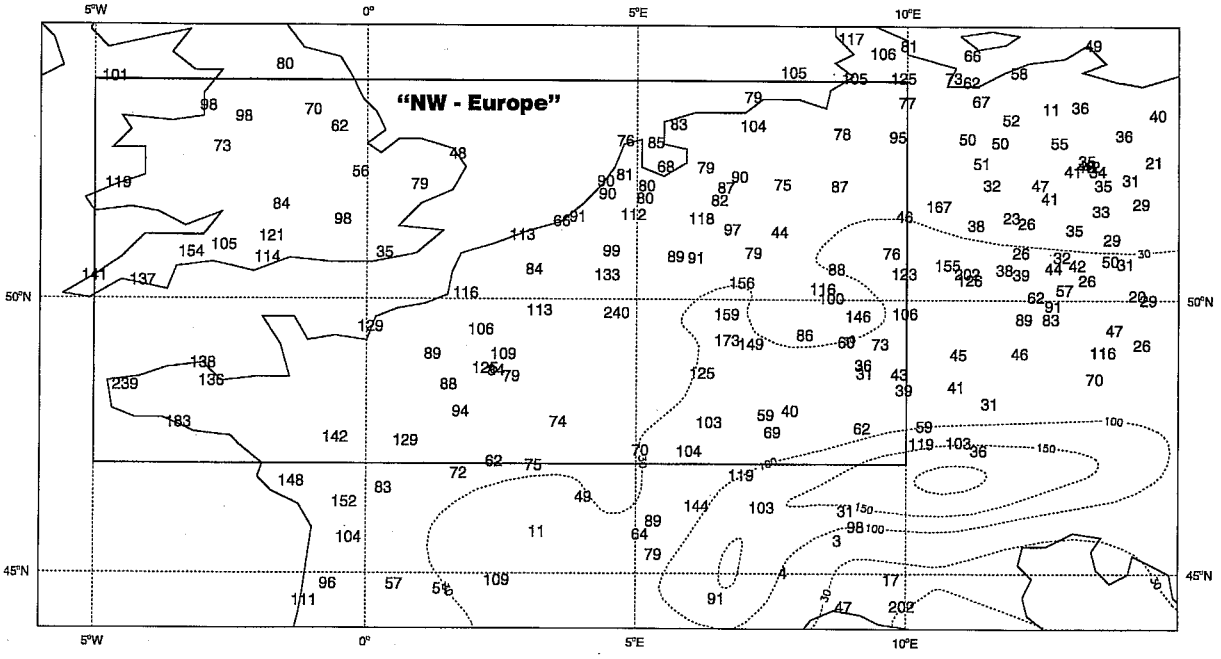


Fig. 1 Observed precipitation in mm, accumulated from 15 January 1995, 00 UTC, to 1 February 1995, 00 UTC, at SYNOP observation sites.

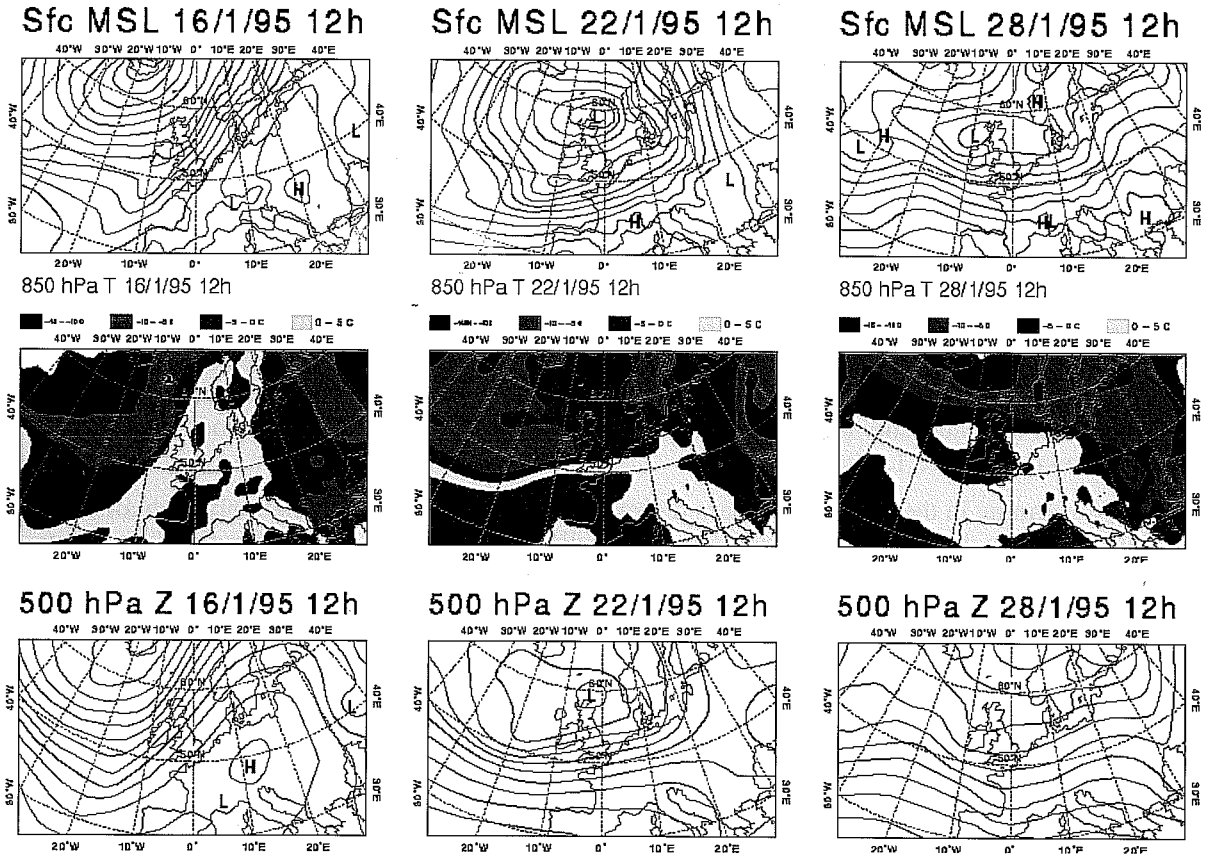


Fig. 2 Analyses of mean sea level pressure (top row), 850 hPa temperature (middle row), and 500 hPa geopotential height (bottom row) on 16, 22 and 28 January 1995, 12 UTC.

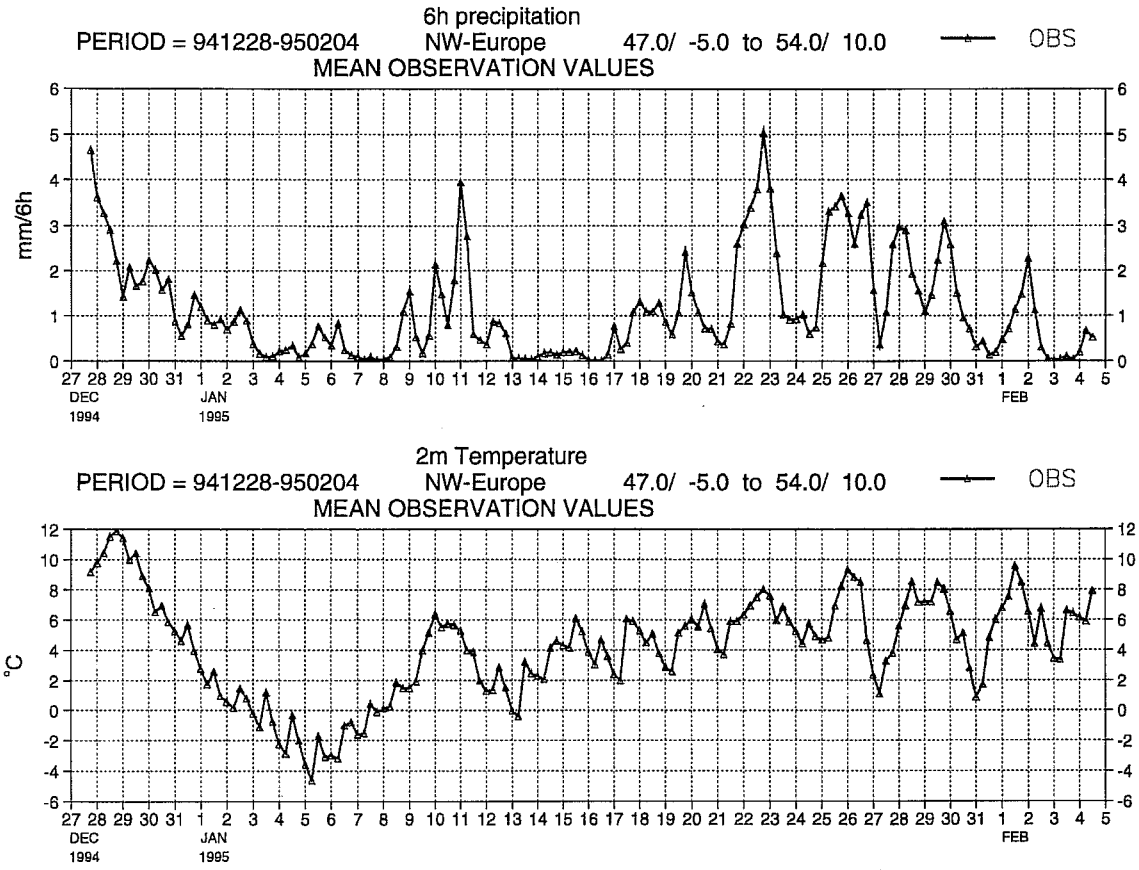


Fig. 3 Six-hourly time series of observed precipitation (top panel) and two metre temperature (bottom panel), averaged over the area marked "NW-Europe" in Fig. 1.

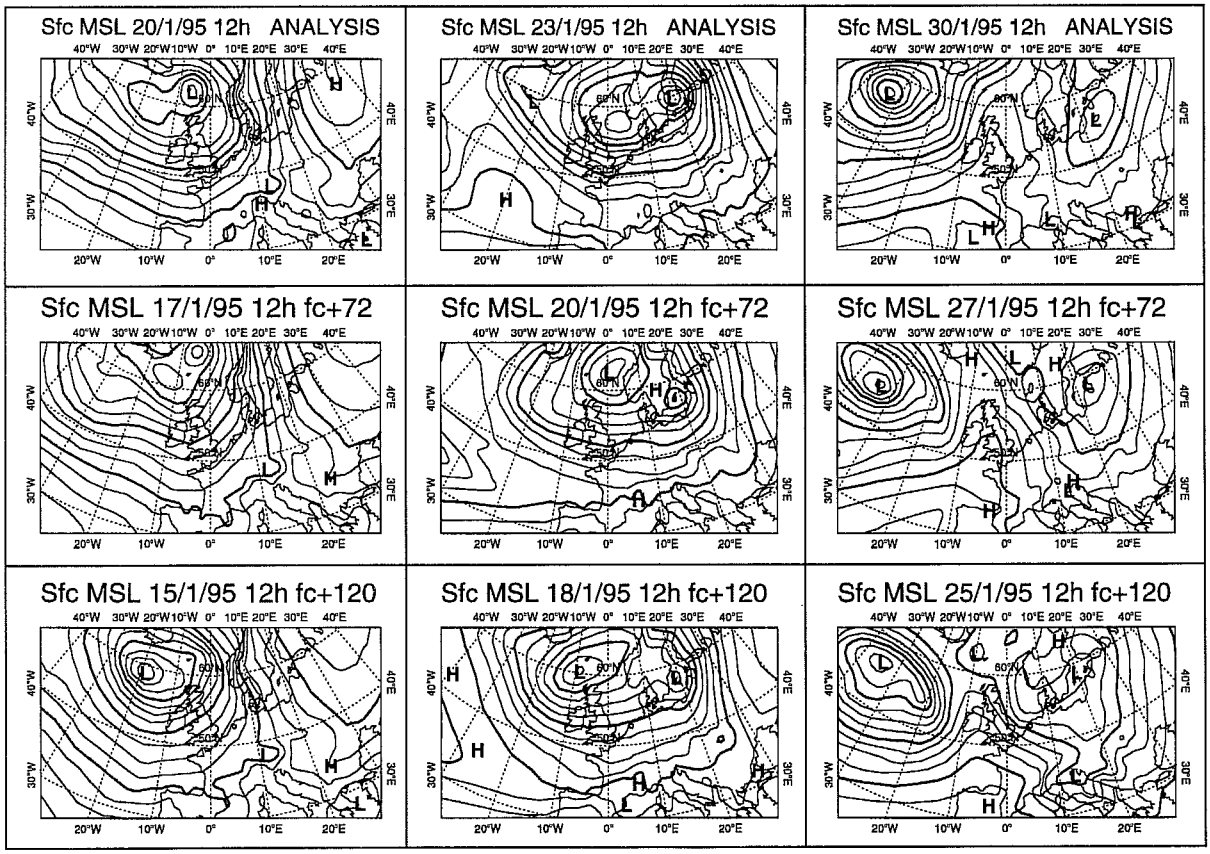


Fig. 4 Verification of mean sea level pressure on 20 (left column), 23 (middle column), and 30 (right column) January 1995, 12 UTC. Top row: verifying analyses; middle row: forecasts t+72 hours; bottom row: forecasts t+120 hours.

Operational forecast performance

The onset of the wet period around 17 January was marked by the progression of an Atlantic trough into western Europe, eroding a ridge of high pressure. This synoptic development was predicted well in the short range, but was slightly delayed in the medium range. The entire spell from 20 to 30 January yielded very good verification results in the medium range up to day 7 and 8. Some MSL pressure verification maps are shown in Figure 4.

Six-hourly precipitation time series for average observations and forecast values over the regions most severely hit by floods are presented in Figures 5 and 6 for the areas shown in Figure 7, Brittany and the extended catchment area of the Rhine and Meuse rivers.

The area mean verification for the Brittany region (Figure 5) shows remarkable skill of the 3-day forecasts in predicting the intensity and timing of rain events. Five-day forecasts of the accumulated precipitation amounts over periods of a few days were also good, except for the first short rain event. However, as can be expected, the timing of some rain events was not as good as in the shorter range. Verification for the greater Rhine catchment area (Figure 6) shows even more impressive results: timing and intensities were excellent in the 3-day range for all precipitation periods, including the forecasts for the precurrent events around 10 January. Five-day forecasts, although with some timing errors, gave superb medium range guidance.

Verification maps of 3-day forecast precipitation accumulated over the periods 17 to 24 January ("Brittany floods", Figure 8) and 20 to 31 January ("Rhine floods", Figure 9) demonstrate the model's performance in forecasting the geographical distribution of precipitation. During the first period, the areas of heaviest precipitation over Brittany and the region of the Ardennes and western Germany were captured well, with the magnitude perhaps slightly over-predicted (Figure 8). Over the map area the forecasts are virtually unbiased. The same is true for the second chosen period (Figure 9). In this case the observed distribution is quite complex, mainly due to complex orography over the region of eastern Belgium and western Germany (see Figure 7), which is not resolved in detail in the model. The accumulation was somewhat under-forecast for a few western German stations, whereas eastern France shows some over-prediction. The maximum values of more than 200 mm in the Ardennes were very well predicted.

Accumulated precipitation forecasts over the entire 10-day range of the forecast from 20 January (Figure 10) gave a very good indication that abnormally high amounts could be expected over the coming period, although values were generally over-predicted over France and Belgium and under-predicted over Germany, the Netherlands and Britain.

Runoff, also accumulated over the 10-day range from the forecast of 23 January, is depicted in Figure 11, together with the soil wetness in the top soil layer of the analysis from 25 January. The soil wetness analysis shows values above field capacity (at 22.6 mm for this layer) over the regions of strong precipitation, indicating little infiltration of rain into the ground and relatively high runoff. Peak values of runoff are greater than 100 mm over 10 days, which yields a runoff - precipitation ratio of around 50 percent. This very high figure indicates the ability of the surface parametrization scheme to simulate the saturation of the soil and subsequently high runoff values.

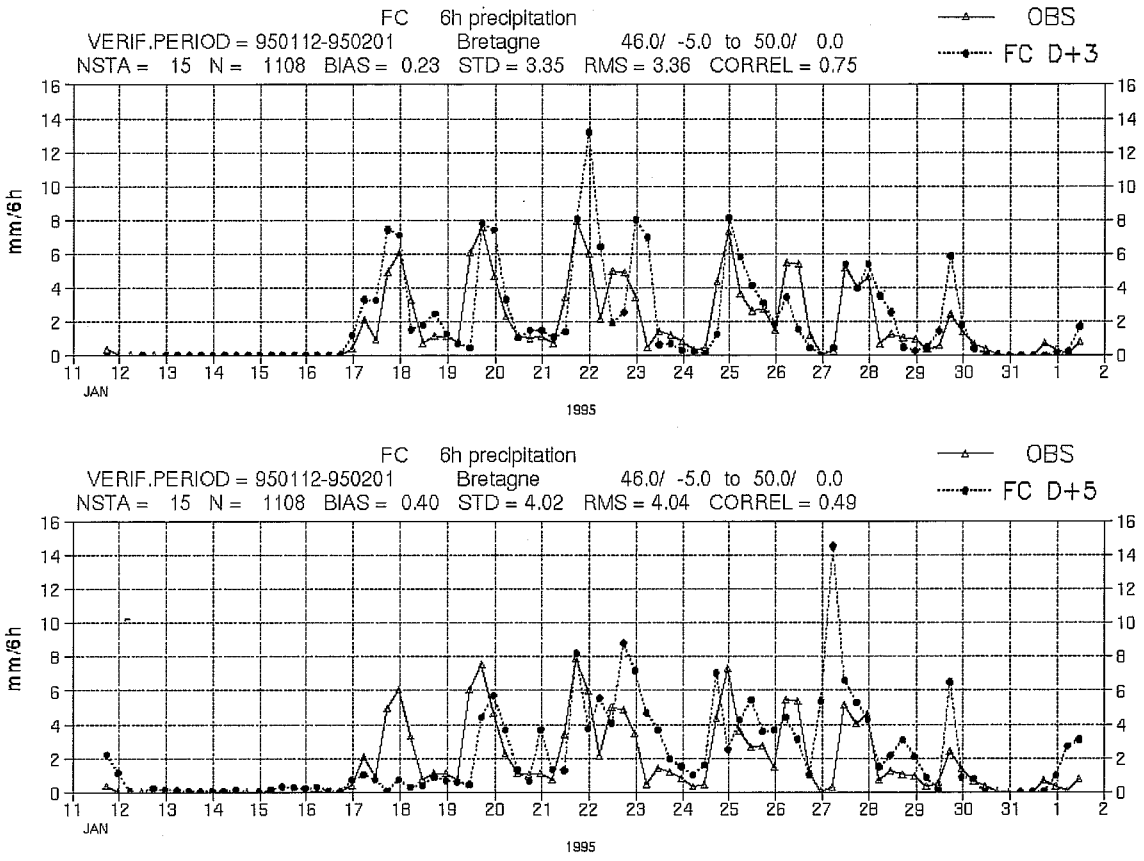


Fig. 5 Six-hourly time series of observed (red solid curves) and forecast (blue dotted curves) precipitation, averaged over the area of Brittany, see Fig. 7. Top: observed against day-3 (forecast steps t+ 54,60,66,72 hours); bottom: observed against day-5 (forecast steps t+ 102,108,114,120 hours).

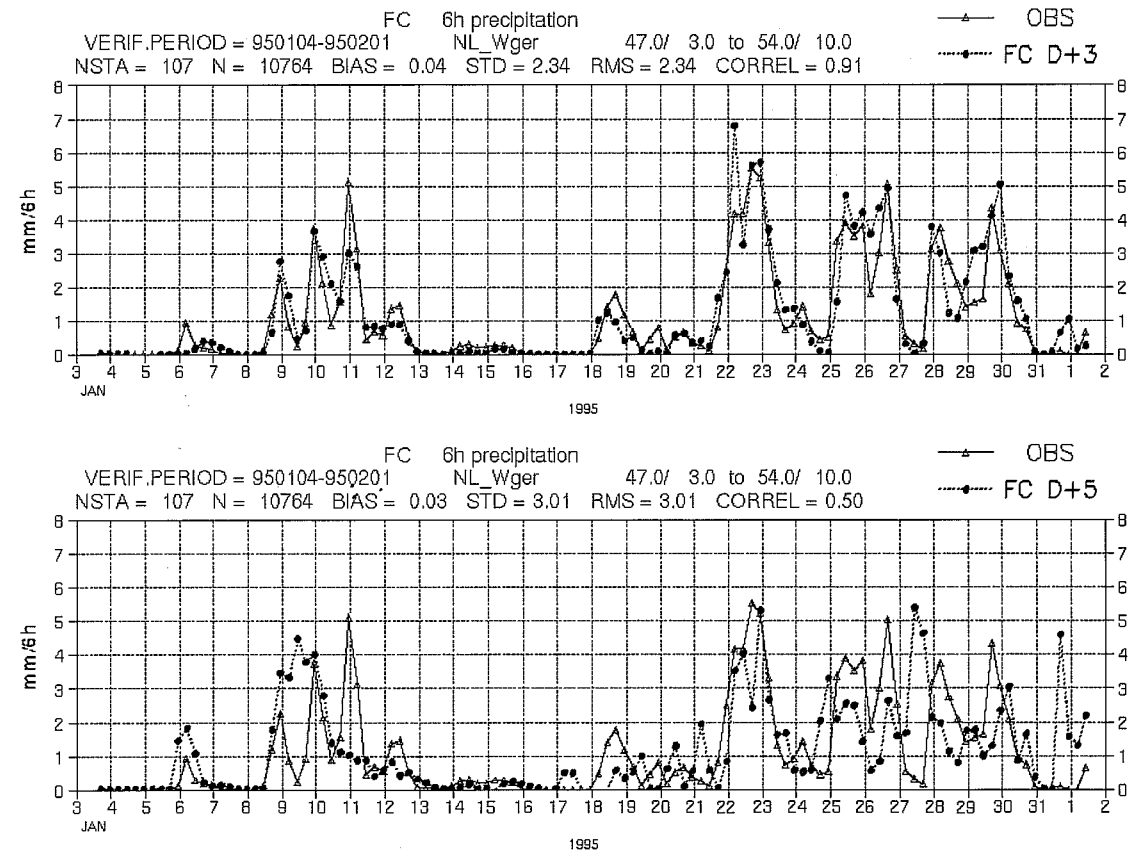


Fig. 6 As Fig. 5, but for the greater Rhine catchment area, see Fig. 7.

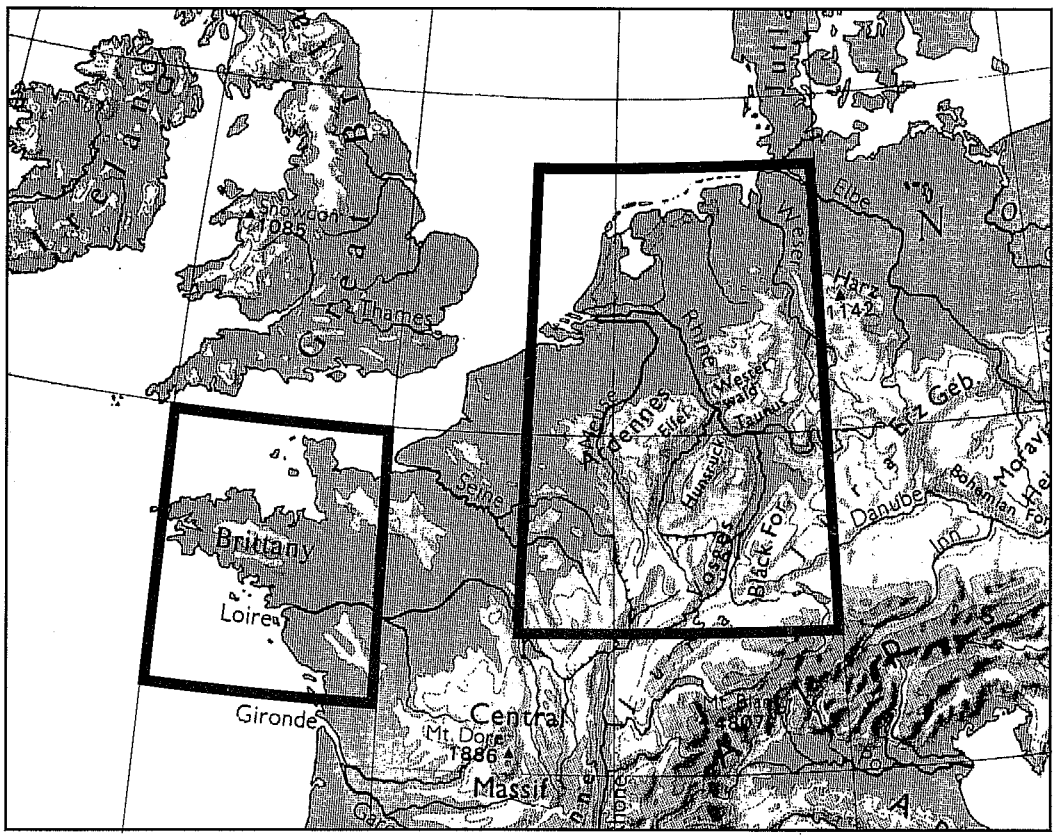


Fig. 7 Orographical map with areas used as verification domains in Figs. 5 and 6.

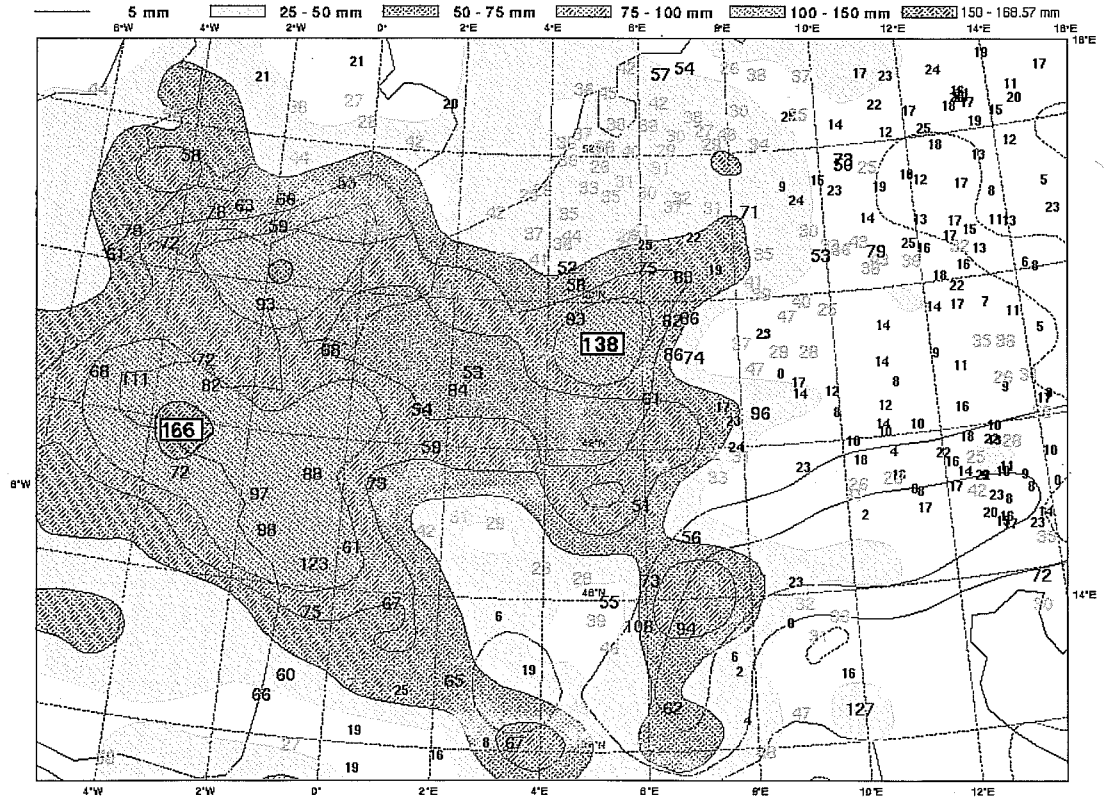


Fig. 8 Forecast precipitation from t+ 42 to t+ 66 hours, accumulated over the forecasts from 15 to 21 January 1995 (shaded field) against accumulated observed precipitation from 17 January 1995, 06 UTC, to 24 January 1995, 06 UTC (small numbers). The larger, framed, numbers are local forecast field maxima.

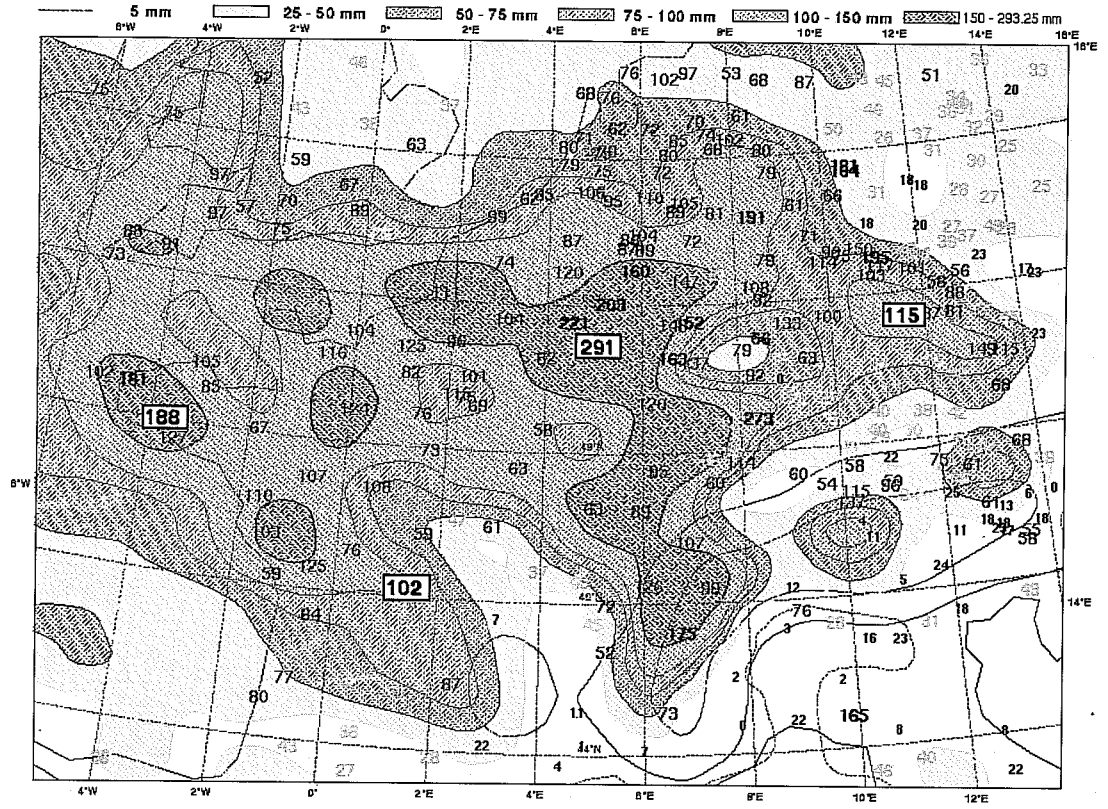


Fig. 9 As Fig. 8, but for the forecasts from 18 to 28 January 1995, and corresponding observation accumulation period from 20 to 31 January 1995.

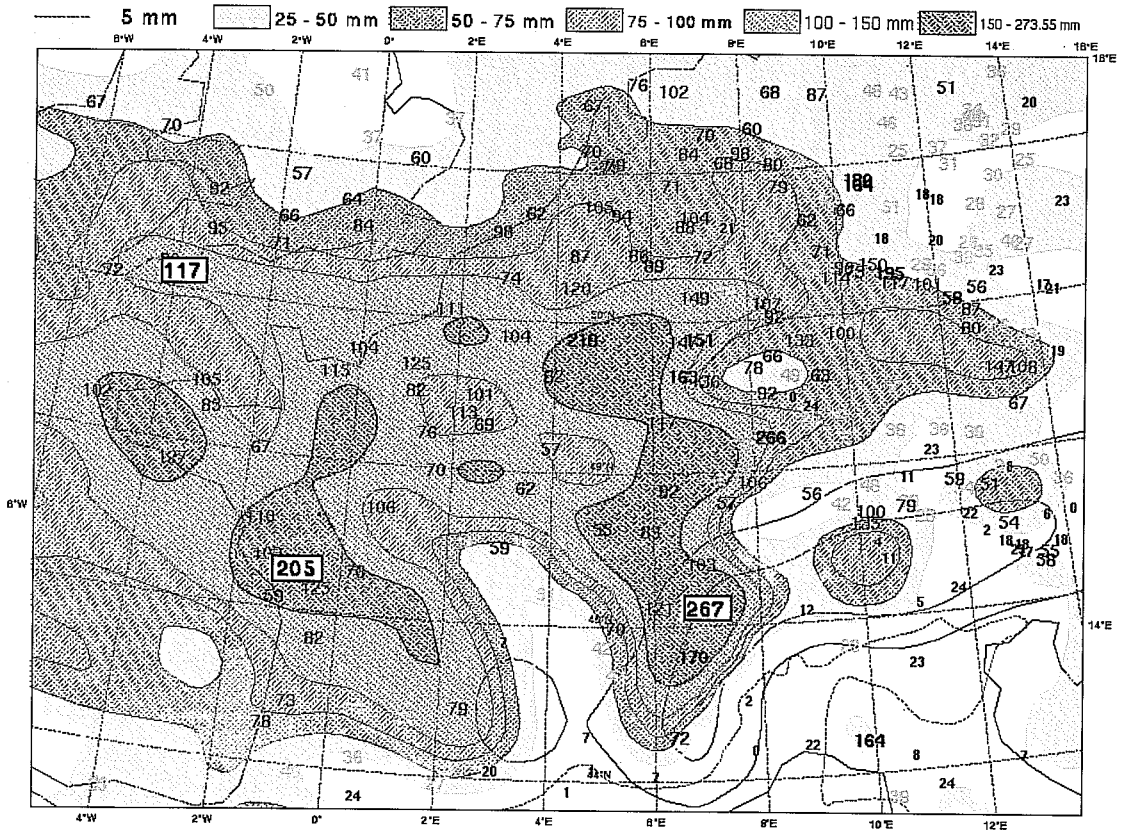


Fig. 10 Forecast precipitation accumulated over the entire 10-day range from one single forecast of 20 January 1995, 12 UTC, against accumulated observed precipitation. Plot layout as in Figs. 8 and 9.

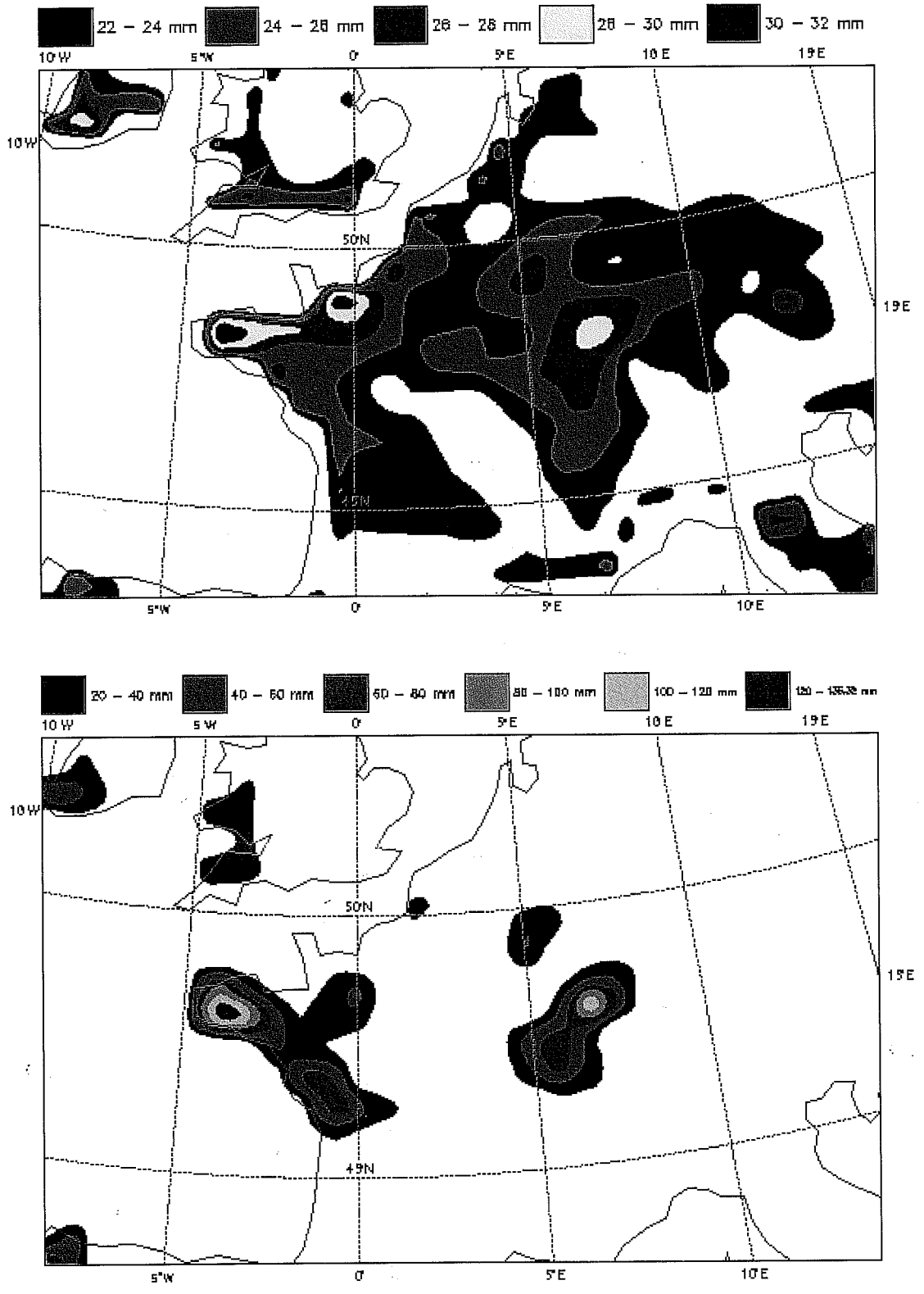


Fig. 11 Top: analysis of soil wetness, in mm, of the top model soil layer at 25 January 1995, 12 UTC; bottom: forecast runoff accumulated between t+ 0 to t+ 240 hours, in mm, from the forecast of 23 January 1995.

EPS forecast performance

The synoptic situation was captured well by the Ensemble Prediction System in the range of one week. During the relevant period the ensemble consisted of two or three clusters, all indicating the deep central low over the northeastern Atlantic or Britain and a westerly regime or progression of short wave troughs over western and central Europe. As an example, the 500 and 1000 hPa height clusters from 17 January are displayed in Figure 12.

The EPS consistently indicated high probabilities of strong precipitation during the period, as shown in Figure 13 for the day-7 probabilities for precipitation greater than 10 mm in 24 hours. Although the regions of high probabilities did not always coincide with areas of strong observed precipitation, or with the heaviest precipitation in the operational T213 forecasts, it is clear that EPS generally supported T213 well in predicting this prolonged period of anomalous rain amounts.

The T213 accumulated 10-day precipitation forecast from 20 January (Figure 10) was supported by virtually every member of the ensemble forecast (Figure 14). Several of the individual ensemble forecasts had maxima above 200 mm, which compares well with observed peak values.

Summary

During the second half of January 1995 large areas of western and central Europe received more than 100 mm of precipitation, with peak values of more than 200 mm. This resulted in widespread flooding, particularly over Brittany and the lower Rhine and Meuse regions.

The operational T213 forecast model showed consistently excellent performance over this period, in terms of forecasting the synoptic evolution and specifically the associated precipitation. At the 3-day range, the onset of the wet period, the precipitation amounts over these areas, and the timing of wet and intermediate dry periods were accurately predicted. In the range of five days there were difficulties with the onset around 17 January over western France as well as inaccuracies in the timing during the following period. However, precipitation amounts accumulated over several days were accurately predicted. The 7-day range still gave good guidance as to the synoptic regime and the main periods and magnitudes of intensity of precipitation over the area.

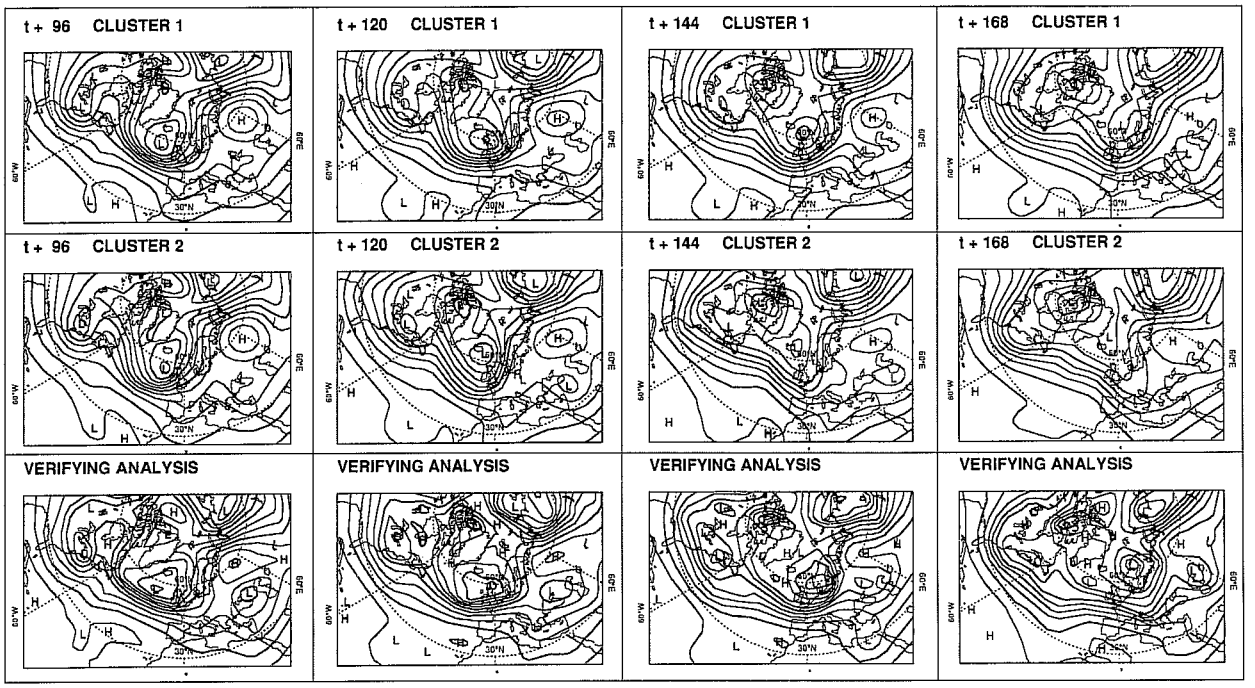
The accumulation of precipitation over several days of forecast, or even over the entire 10-day range, indicated well the amounts that were observed, with good estimation of peak values, but in some cases a shift of highest accumulations to the southwest. Associated high values of model soil wetness and runoff, although not strictly verified, indicate good performance of the surface parametrization scheme, at least in qualitative terms, and the potential usefulness for hydrological prediction of for example runoff.

The Ensemble Prediction Scheme also performed well during this period. Large scale flow patterns were correctly indicated in the medium range, with large majorities of the members of the ensemble supporting the high-resolution T213 forecasts. Consistently high probabilities of strong precipitation complemented the T213 forecast guidance.

500 hPa geopotential height

Control Forecast in cluster 1
Operational Forecast in cluster 1

Cluster 1 : 30 Forecasts
Cluster 2 : 3 Forecasts



1000 hPa geopotential height

Control Forecast in cluster 1
Operational Forecast in cluster 1

Cluster 1 : 30 Forecasts
Cluster 2 : 3 Forecasts

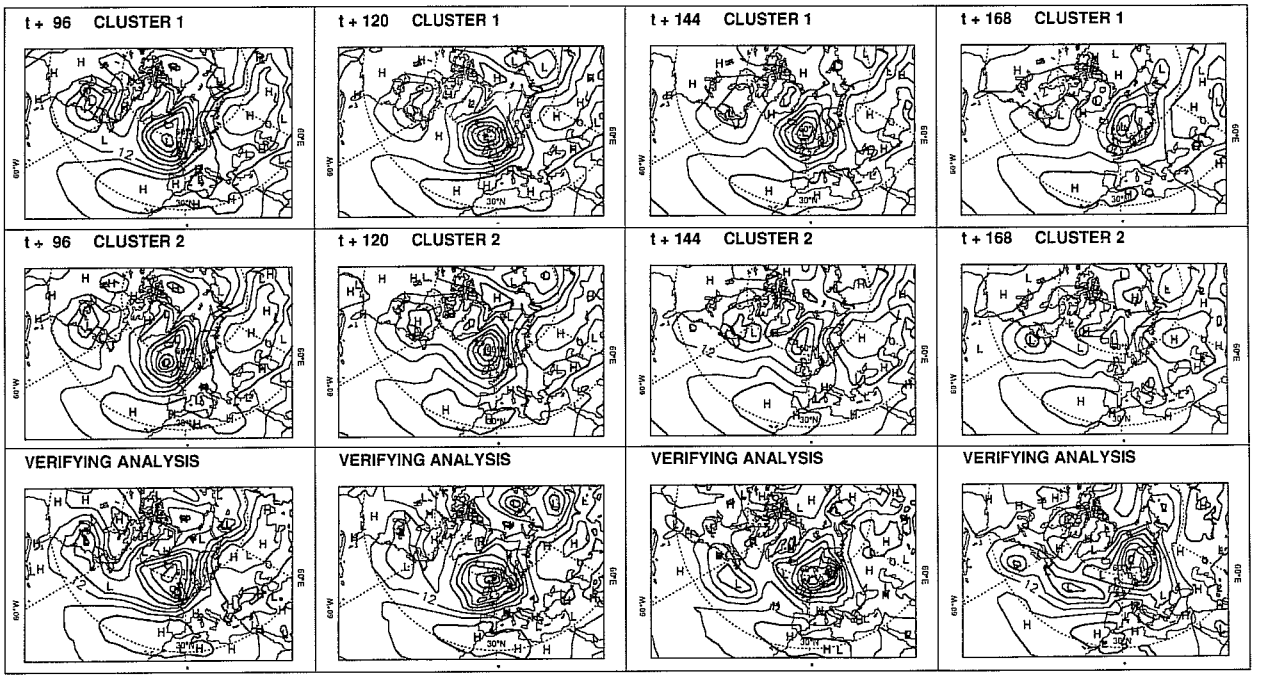


Fig. 12 EPS cluster mean fields from the forecast of 17 January 1995 and verifying analyses. Top row: cluster 1 means at forecast steps 96, 120, 144 and 168 hours, from left to right; middle row: cluster 2 means; bottom row: verifying analyses. Top set 500 hPa geopotential height; bottom set 1000 hPa geopotential height.

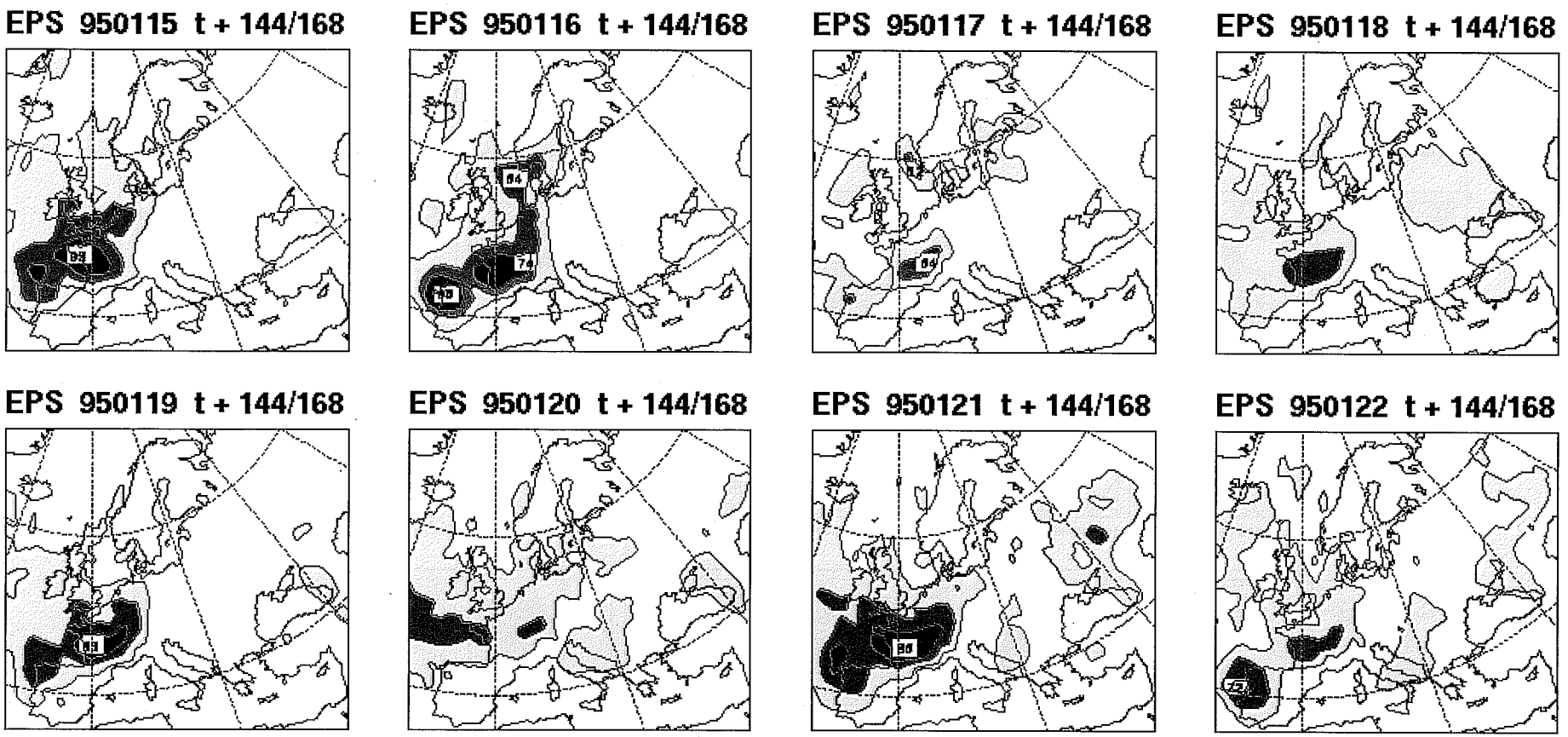


Fig. 13 Probability maps of 24-hour precipitation greater than 10 mm from the ensemble forecasts of 15 to 22 January 1995. Valid for forecast step t+ 144 to t+ 168 hours.

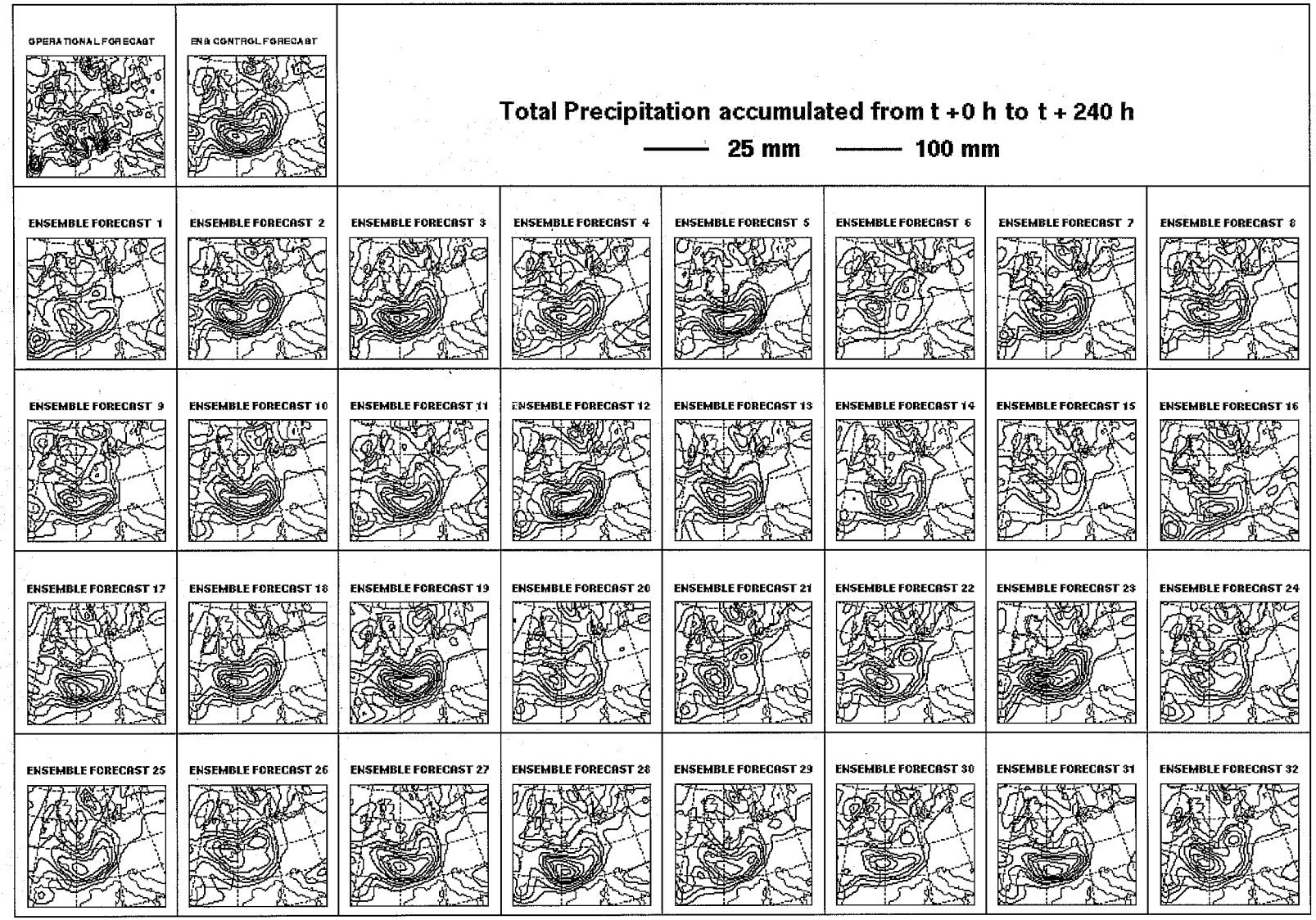


Fig. 14 Precipitation accumulated over the entire 10-day forecast range of the operational T213 model (top left), the T63 control forecast (top second from left), and all 32 ensemble forecasts from 20 January 1995. 100 mm contours are highlighted.