HURRICANE CHARLIE

Modelling a Severe Storm with the HIRLAM System

by

Peter Lynch and Ray McGrath.

Introduction

The weather of August, 1986 was memorable for a number of reasons:

- It was the coldest August on record at most stations in Ireland (about two degrees below the normal value)
- Rainfall was generally double the normal values (more than three times the normal at Roche's Point)
- There were record 6, 12 and 24 hour rainfall amounts
- Severe storms caused widespread damage and flooding.

A major storm occured on Monday, 25th August. This developed as an offshoot of a hurricane originating off South Carolina in mid-month, and the storm became known in Ireland as Hurricane Charlie. It was one of the worst storms in living memory. Here are some of its consequences:

- A number of lives were lost in the storm (an old man died in Ballsbridge, a canoeist drowned in Kilkenny, and several other accidents occured)
- Over 400 houses were flooded, some with up to eight feet of water, and 35 commercial premises were innundated
- The Dodder and Dargle rivers burst their banks, causing severe flooding in Ballsbridge and Bray
- Superquinn's supermarket in Bray suffered £0.5M worth of water damage
- Total insurance claims amounted to some £26M.

The meteorological characteristics of the storm were extreme in a number of respects:

- Storm force 10 winds were reported at the Kish Lighthouse and at Wicklow Head.
- New rainfall records for 24 hour falls were established at the synoptic stations at Dublin Airport (65.5 mm) and Casement Aerodrome (89.4 mm)
- Heaviest rainfall was in the mountains south of Dublin; an estimated 280 mm fell at Kippure (750 m high), while amounts approaching 200 mm were reported from a number of lowland stations in Dublin and Wicklow.
- A storm of such severity might be expected on average only once in 100 years.

In the wake of the storm an emergency Cabinet Meeting was held on Thursday, 28th, for which the Taoiseach flew home from holiday in Cyprus. The farming organisations called for a financial rescue package.

Development of the Storm

GENESIS

Hurricane Charlie originated off the eastern seaboard of the United States around the 15th of the month. It caused storm force winds and torrential rain during the following days, as it moved north and then northeast. Around the 20th it passed south of Newfoundland, developing into an extra-tropical depression. The track of the depression as it crossed the Atlantic is shown in Figure 1. On the 23rd the depression split into two parts, one of which deepened rapidly and moved northeastward towards Ireland. By midday on Sunday, 24th it lay about 1200 km west-southwest of Kerry. The Meteosat picture in Figure 2 shows the situation at about this time. The nation was enjoying a beautiful sunny Sunday, unmindful of the approaching tempest.

MONDAY, 25TH

An analysis of the surface pressure for 00Z on Monday, 25th August is shown in Figure 3(a). This is the situation which we take as the initial data for the model forecasts described below. The storm is about 600 km southwest of Ireland, with a central pressure of 1002 mb. It moved rapidly ENE during the next 24 hours, the centre passing south of Ireland to a position near St. David's Head in SW Wales. The surface analyses each six hours from 06Z on 25th to 00Z on 26th are given in Figure 4. They show the very strong gradient which developed over Ireland during the day, particularly in the south and east. Heavy rain in the Cork/Kerry area during the morning eased off later, but not before 84 mm had fallen at Roche's Point. Winds on the east coast backed from southeast at 06Z to east in the afternoon and northeast by evening. The wind at Dublin Airport remained at gale force for several hours. The east-to-northeast flow interacted strongly with the Wicklow mountains, resulting in pronounced orographic enhancement of rainfall in the river catchments south of Dublin. [A detailed analysis of the rainfall records has been carried out (O'Reilly, 1986: Unpublished Note, Irish Met. Service)].

AFTERMATH

During Tuesday 26th, as the mopping-up operation got under way in Dublin and Bray, the storm continued to track across England. By midday on the 27th it had moved out over the North Sea and slowed down. It remained there for several more days, gradually filling.

Numerical Forecasts of the Storm

We have carried out two 24 hour forecasts, both starting from the analysis of 00Z on Monday, 25th August. The analysed surface pressure field was shown in Figure 3(a). The field after initialization by the HIRLAM system is shown in Fig 3(b). The two forecasts were made with the HIRLAM model. The first used a grid spacing of 1.5 degrees; the second used a much finer grid with a resolution of 0.25 degrees. The coarse grid has about 150 km between gridpoints; for the fine grid this is reduced by a factor of six to about 25 km.

OROGRAPHY

The principal aim of refining the grid in the present case is to achieve a better representation of the mountains. The observed rainfall pattern clearly showed that the mountains south of Dublin played a crucial role in enhancing precipitation. Figures 5(a) and 5(b) show the orography as

represented on the fine and coarse grids. It is clear that the fine grid (Fig. 5(a)) enables the main mountainous areas to be represented. In contrast, the coarse orography in Fig. 5(b) is virtually structureless over Ireland, and is below 100 m throughout the island. Despite the improvement with resolution, the finegrid orography is far from perfect. Figure 6 shows an enlargement of this orography over Ireland. The maximum elevation is about 250 m in the southwest. There is another maximum of 162 m in the Wicklow area. However, the representation is still very crude compared to the actual orography, plotted in Figure 7.

SURFACE PRESSURE FORECASTS

Two 24 hour forecasts of surface pressure, valid at 00Z on 26th August, are shown in Figure 8. The coarsemesh forecast in Fig. 8(a) has the low centre near the southwest tip of Wales, with a minimum pressure of 986 mb. Comparing this to Fig. 4(d), the forecast position is very good; the central pressure is about 6 mb too high. The finemesh forecast in Fig. 8(b) has the low in approximately the same position. The central pressure is now 983 mb, which is an improvement. Overall, the two forecasts are very similar, and both are reasonably good.

WIND FORECASTS

The two forecast windfields valid at 00Z on 26th are seen in Figure 9. (These are the 10 metre winds diagnosed from the model level forecasts). Both show strong cyclonic flow with northeasterly winds of about 40 knots over the east coast of Ireland. There does not appear to be any substantial difference between the forecasts, although obviously more detail is discernable on the finemesh forecast, Fig. 9(b).

The forecast dynamical fields of mass and wind did not vary greatly as the grid spacing was refined. However, physical processes, particularly those in the atmospheric boundary layer, are likely to be much more sensitive to grid resolution. We look next at the precipitation forecasts.

RAINFALL

The total rainfall accumulated over the 24 hours of the forecast is plotted in Figure 10. The coarsemesh forecast in Fig. 10(a) has a maximum of 74 mm in the southwest of the country. The overall pattern of rainfall is very smooth and lacks any fine-grain structure. The corresponding map of accumulated precipitation for the finemesh model is shown in Fig. 10(b). It is much more detailed, with significantly greater maxima in the south and east of Ireland and in Wales and Cornwall. Enlarged plots of the coarse and fine mesh rainfall over Ireland are displayed in Figs. 11(a) and 11(b). The latter has a maximum of about 100 mm south of Dublin (compared to about 50 mm for the coarse mesh). There are other maxima in the southwest (65 mm) and in the Tipperary/Waterford area (126 mm).

The observed rainfall between 09Z on 25th and 09Z on 26th is plotted in Figure 12. The maximum in Wicklow is over 200 mm. There is no pronounced maximum in the south or southwest. However, much of the rainfall in these areas fell before 09Z on 25th. Recall that the total for the 25th at Roche's Point was 84 mm.

The rainfall predicted by the finemesh model (Fig. 11(b)) is more realistic and more accurate than that of the coarsemesh run (Fig. 11(a)). The maximum in Wicklow is much less than was actually observed in mountain stations, but is very much better than for the coarse mesh. It indicates that the process of orographic enhancement is being simulated more faithfully with finer resolution. The maximum in the Tipperary/Waterford area is probably too high. The finemesh model orography in this region is relatively pronounced: four ranges (Galtees, Knockmeldowns, Sliamh-

na-mBan and Comeraghs) in Figure 7 appear as one in Figure 6. In reality, the hills in this region are lower and less extensive than the Wicklow plateau, and are relatively exagerated in the model orography.

Summary

The forecast dynamic fields of surface pressure and 10 m winds are very similar for both grid resolutions, with a slightly deeper low for the fine mesh. The rainfall patterns predicted on the two grids are markedly different. The coarsemesh precipitation is too weak and lacks detail. The finemesh forecast is more intense and more realistic. While it is not accurate in every detail, it gives a much better indication of the precipitation as actually observed, and has a better representation of orographic enhancement.

The above experiment was a preliminary test of the behaviour of the HIRLAM System with enhanced resolution. It showed that the use of a refined grid can lead to improvments in the forecast. Much more work remains to be done. The development of a mesoscale model is one of the goals of the HIRLAM Group. Such a model should enable us to provide much more detailed and accurate warnings of extreme events such as Hurricane Charlie.

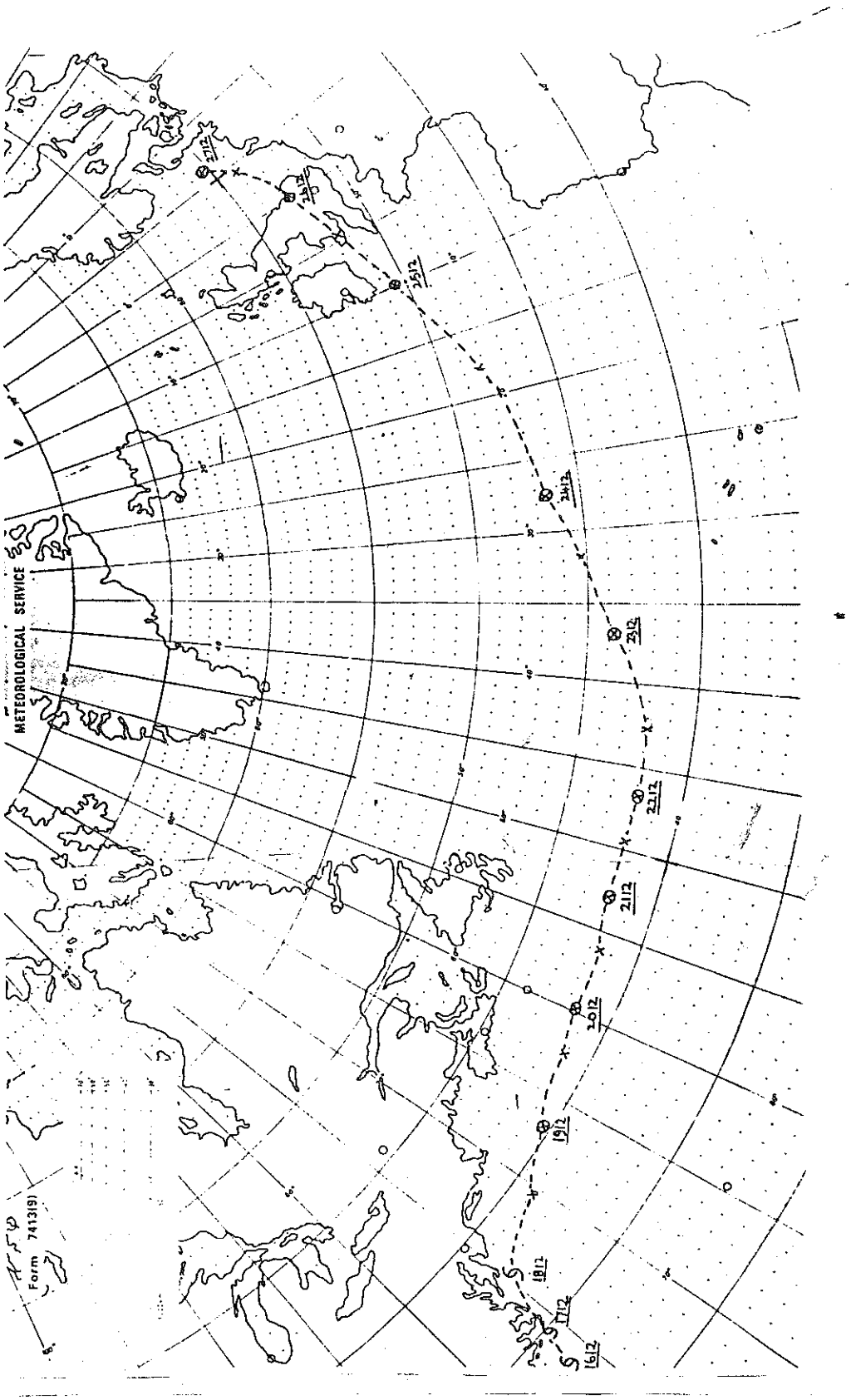
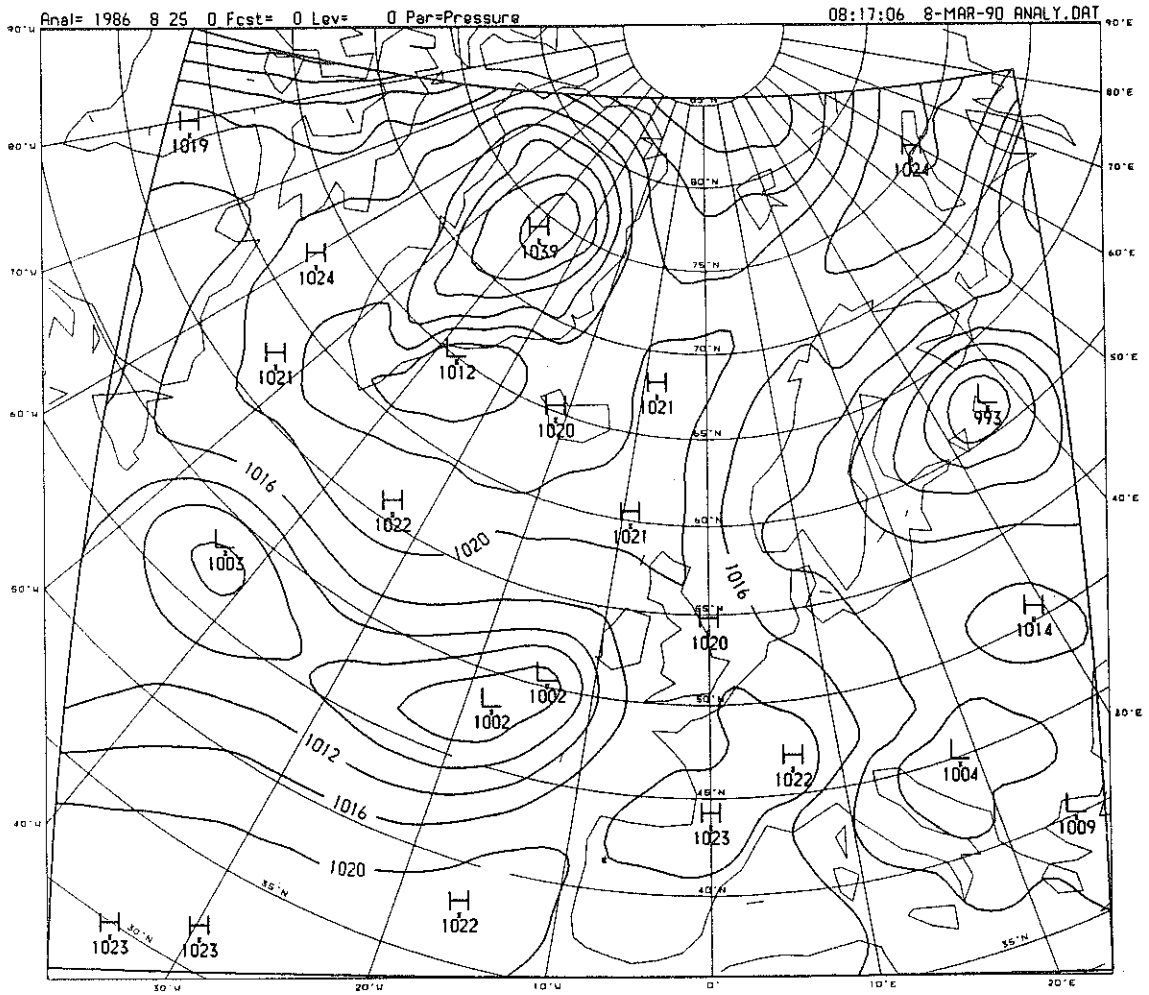


Figure 1. Path of the storm from its inception as Hurricane Charley to the point where it began to fill over the North Sea. Position marked at midday each day from 16th to 27th August, 1986.

Figure 2. Meteosat image (visible channel) at 1230 UTC on 24th August, showing the storm approaching Ireland from the southwest.



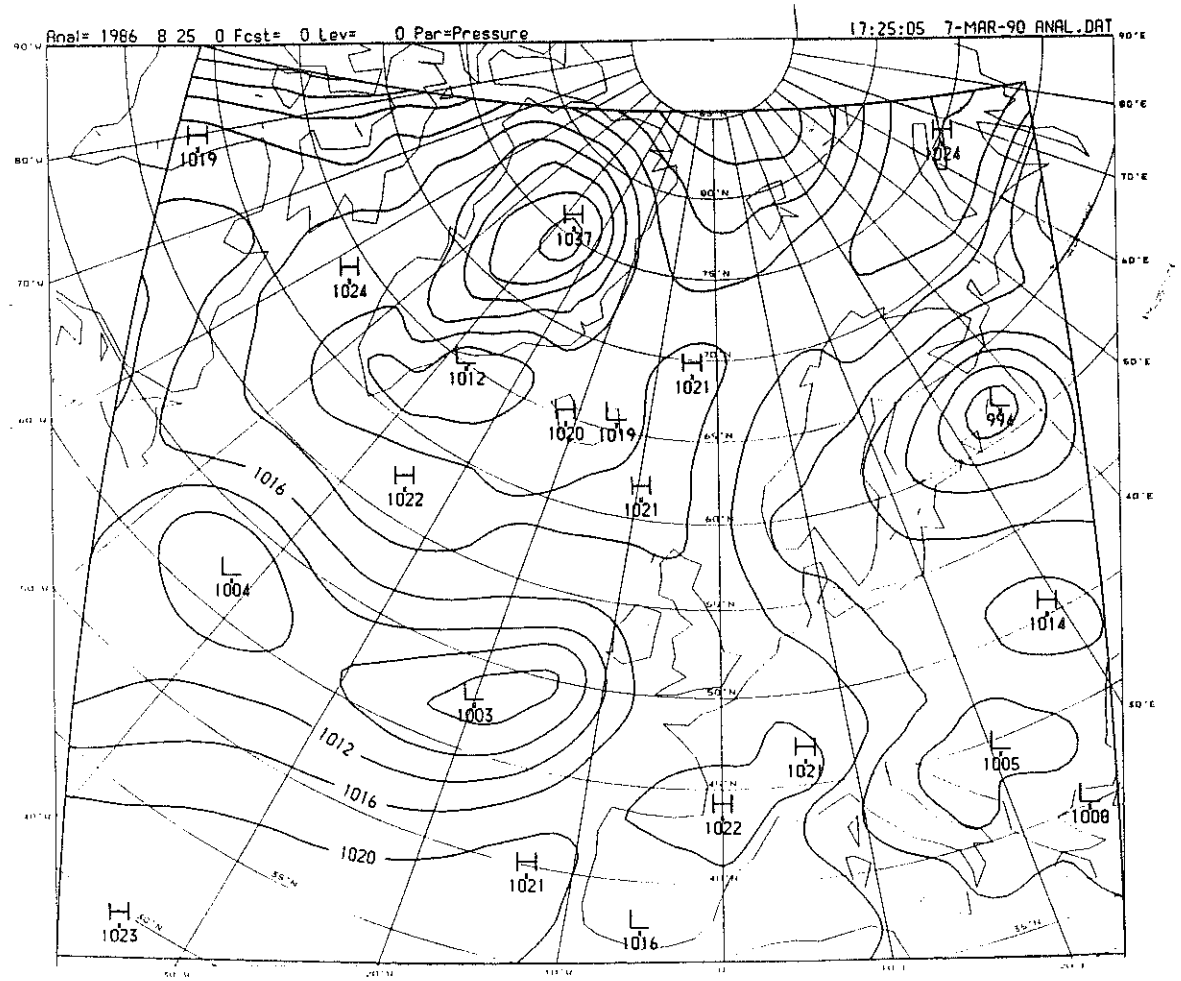


Figure 3. (a) Analysis of surface pressure valid at 0000 UTC, Monday 25th August, 1986. (b) Surface pressure field after initialization.

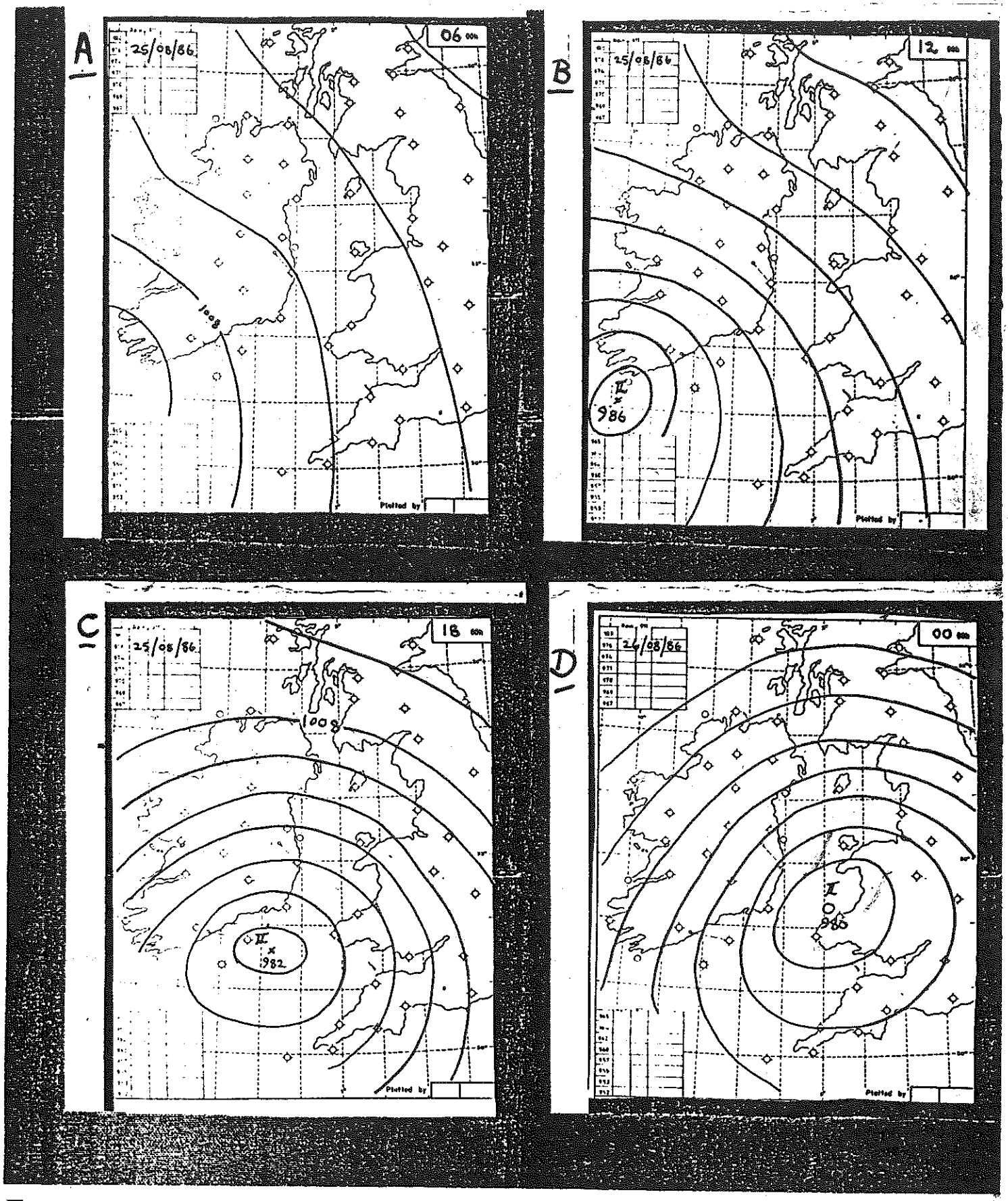


Figure 4. Surface pressure pattern over Ireland every six hours: (a) 25th, 06Z (b) 25th, 12Z (c) 25th, 18Z (d) 26th, 00Z.

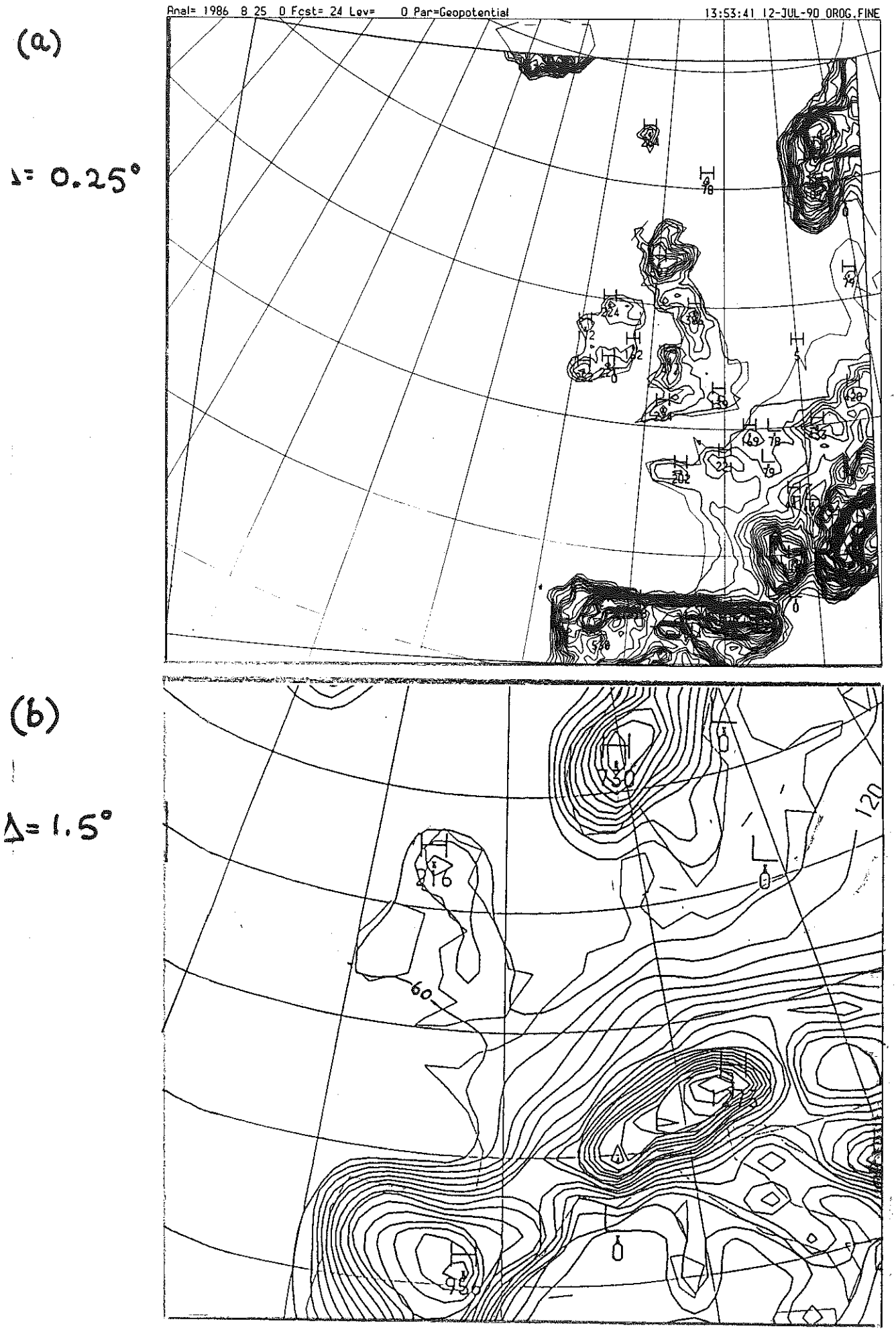


Figure 5. Orography as represented in the models. (a) Fine grid, resolution 0.25 deg. (b) Coarse grid, resolution 1.5 deg.

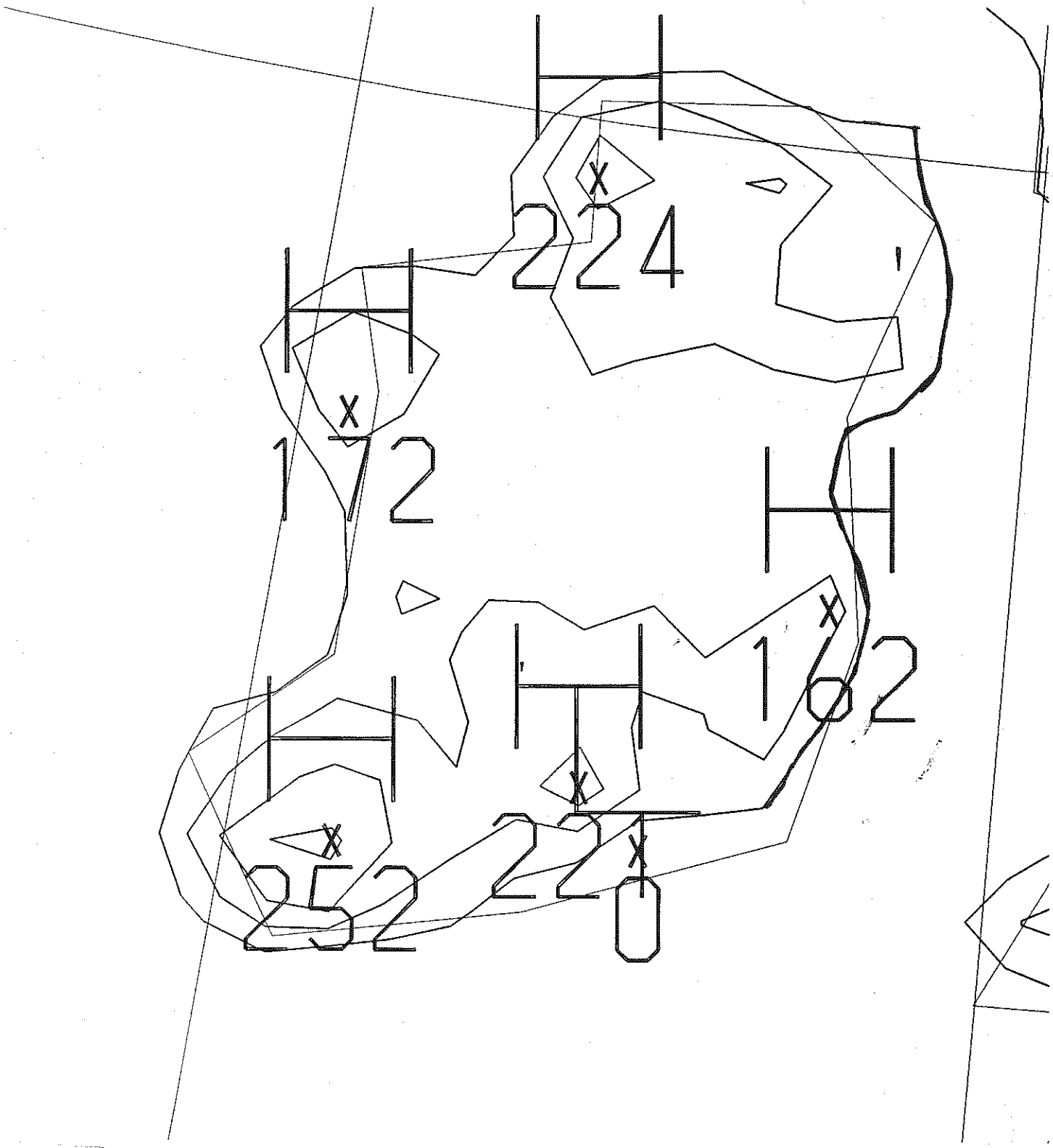


Figure 6. Enlargement of orography over Ireland on the Fine Grid.

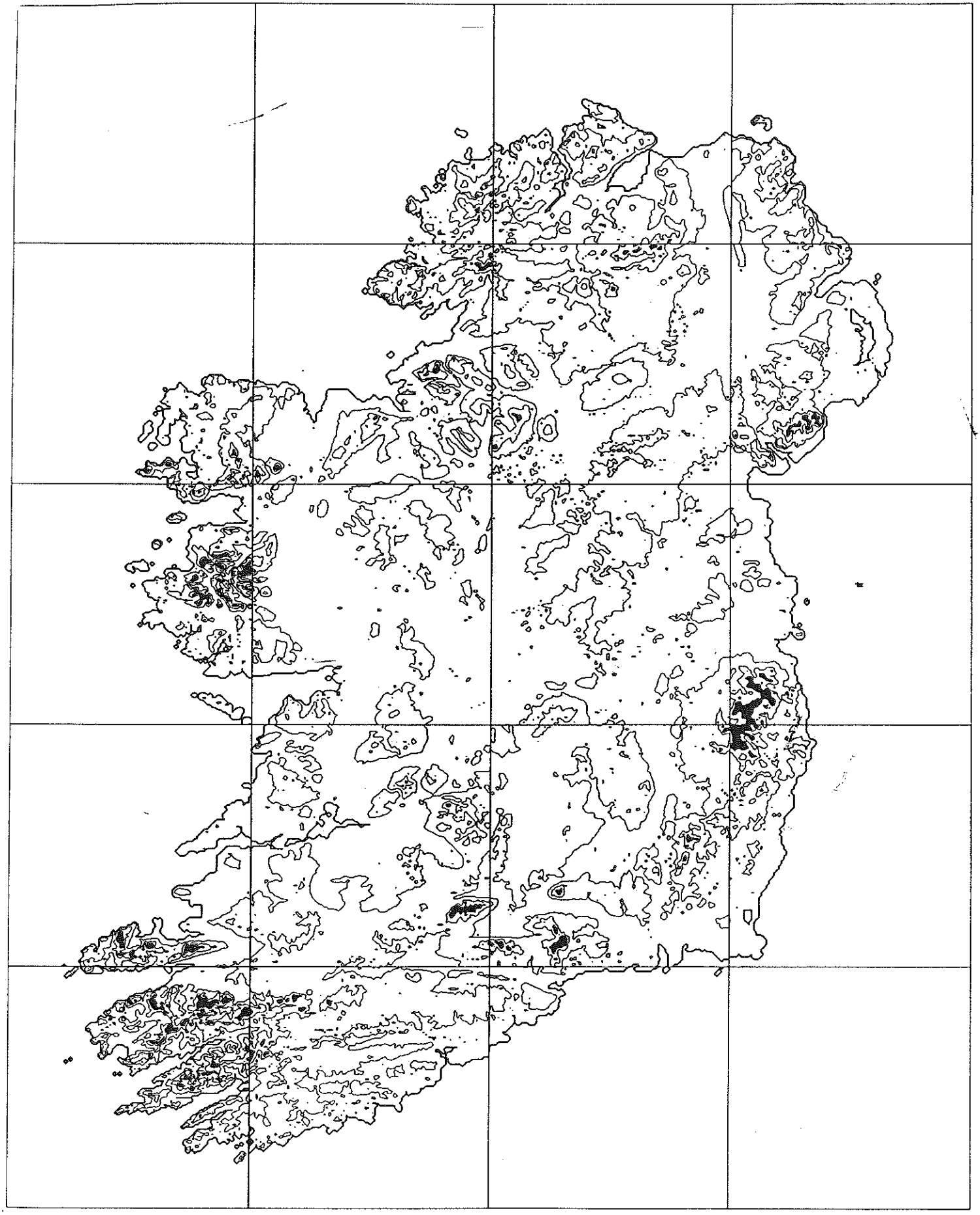


Figure 7. Orography of Ireland based on a dataset with 1 km resolution.

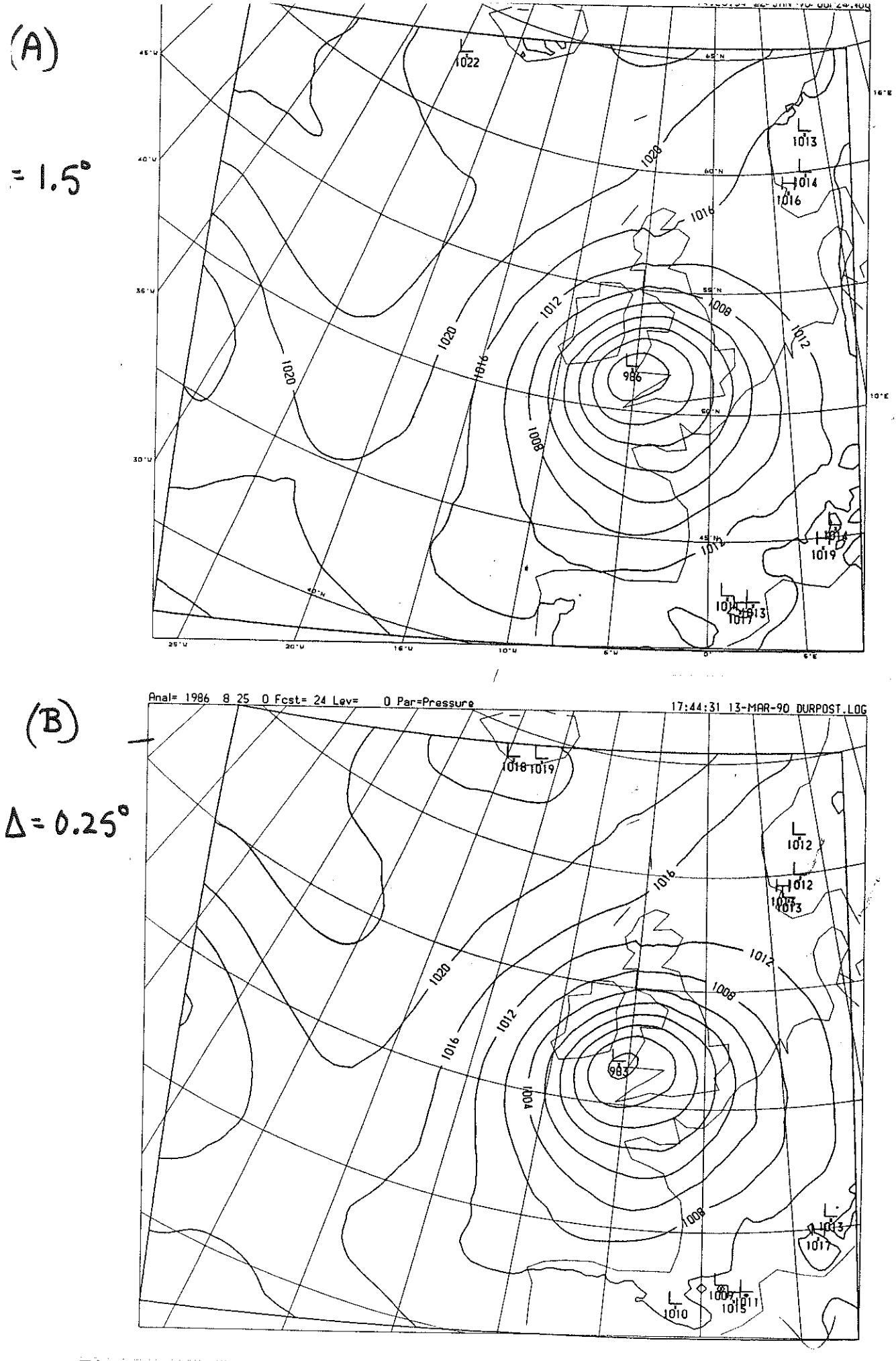


Figure 8. 24 hour forecast of surface pressure valid at 0000 UTC, Tuesday, 26th August. (a) Coarse mesh forecast, (b) Fine mesh forecast.

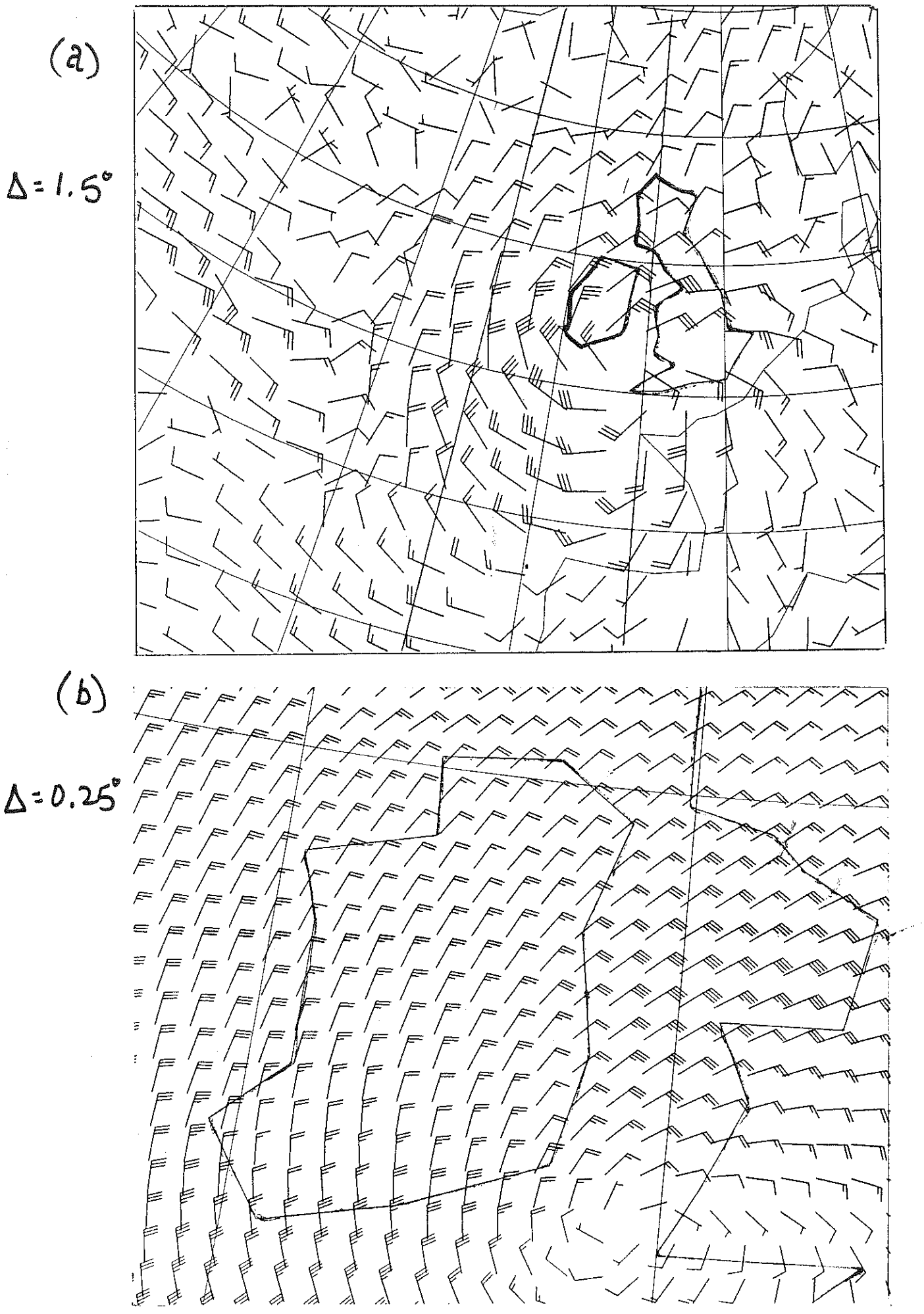
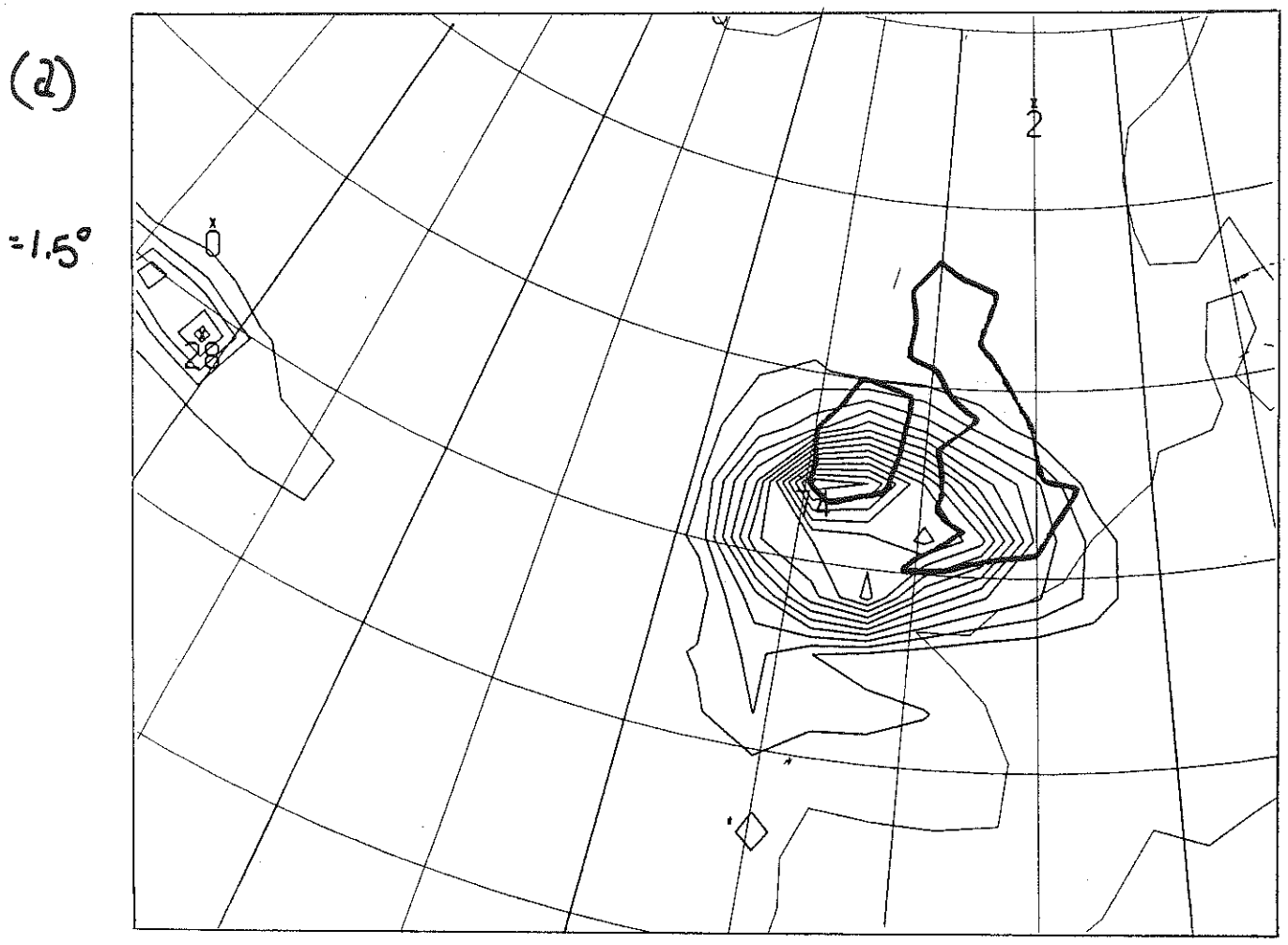


Figure 9. 24 hour forecast of 10 metre winds valid at 0000 UTC, Tuesday, 26th August. (a) Coarse mesh forecast, (b) Fine mesh forecast.



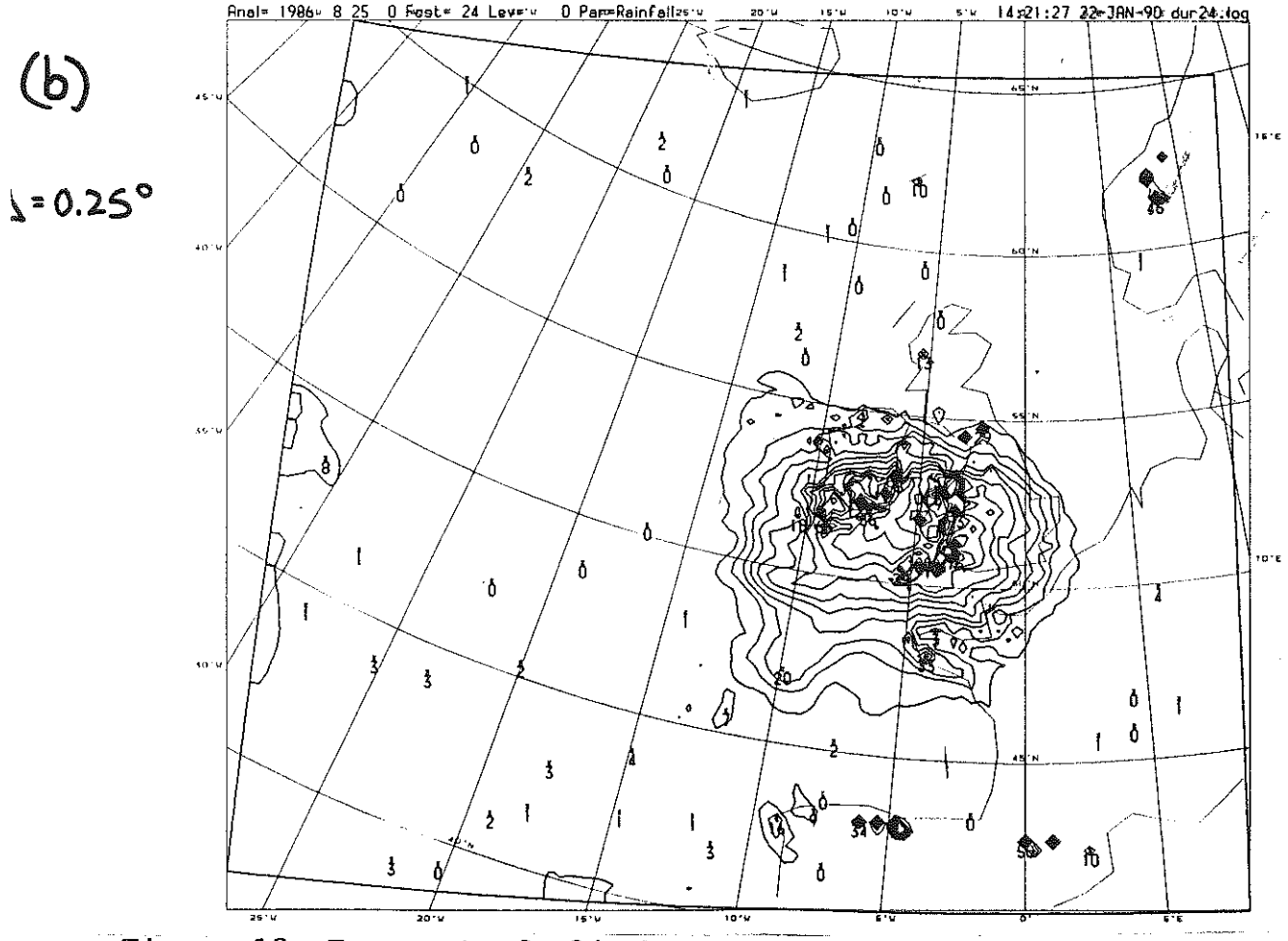


Figure 10. Forecast of 24 hour accumulated precipitation between 00Z on 25th and 00Z on 26th August. (a) Coarse mesh forecast, (b) Fine mesh forecast.

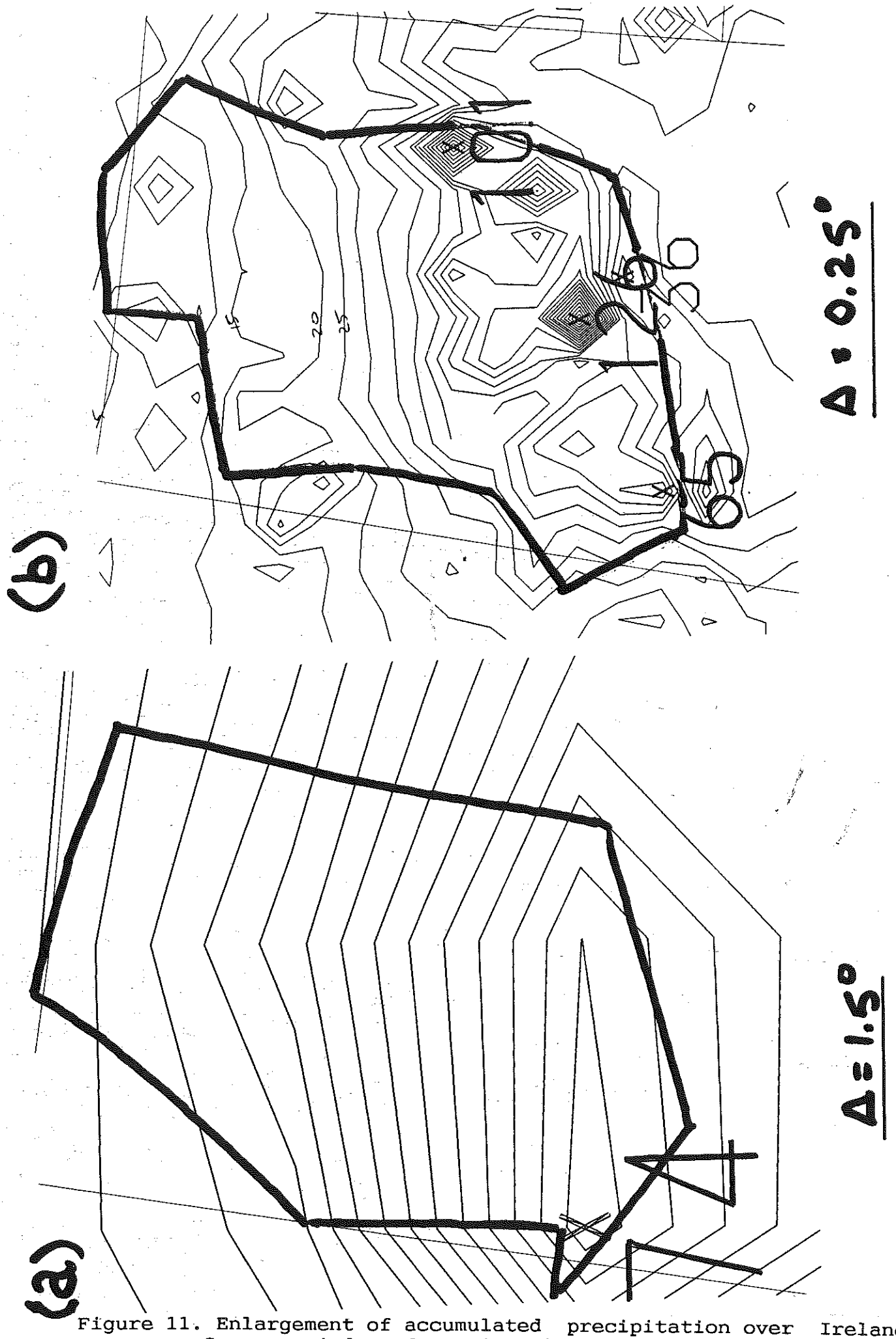


Figure 11. Enlargement of accumulated precipitation over Ireland. Same period as for Fig. 10. (a) Coarse mesh forecast, (b) Fine mesh forecast.

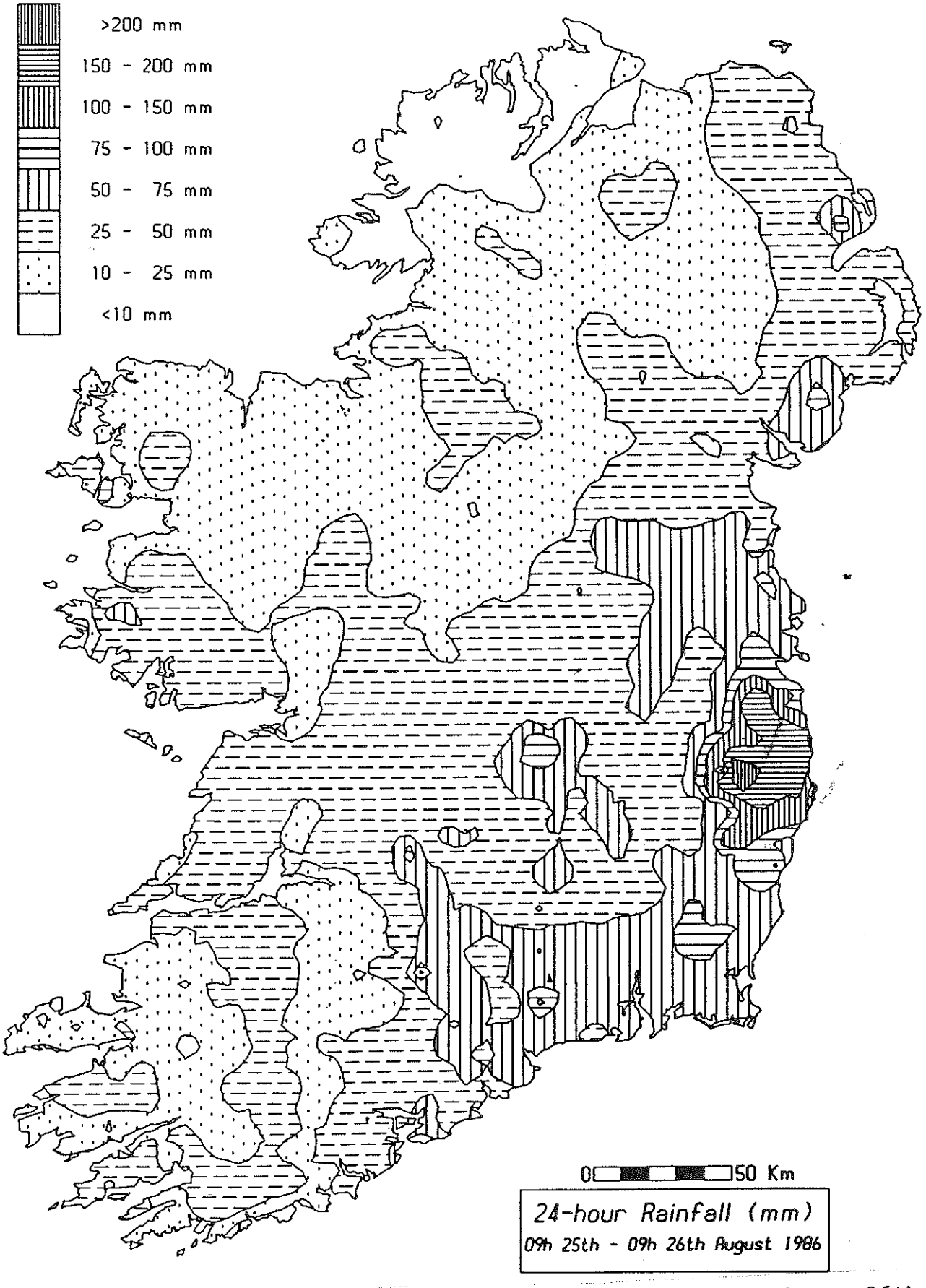


Figure 12. Observed rainfall between 09Z on 25th and 09Z on 26th August, 1986.