Forecasting Research

Met O 11 Technical Note No. 40

The Impact of the Interactive Mesoscale Initialisation

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1 INTRODUCTION

The UK Met Office Mesoscale Model is used routinely to predict the weather over the British Isles on a 15 km grid. Synoptic scale development is largely controlled by the time-dependent boundary conditions. However, the mesoscale evolution is sensitive to the initial conditions within the domain, and especially to the humidity distribution. One of the main problems in attempting to specify these initial conditions is the lack of data. The surface observing network has at best a resolution of 50 km, with upper air observing stations being spaced more than 300 km apart. Over the sea areas the problem becomes an order of magnitude greater with only a few ships and oil rigs providing regular observations.

In an attempt to solve this problem, the Interactive Mesoscale Initialisation (IMI) has been developed. This provides an environment within which to make the best possible use of all the available data. A broad range of surface observations is incorporated, including cloud reports, visibility and snow depth, with satellite and radar imagery acting as additional data, providing much needed information over sea areas. These data, together with the most recent forecast fields, are used to produce a set of key analyses of surface variables and cloud distribution. The whole system is under the control of a human analyst, who, in addition to having control over the use of the data, is able to modify the analyses in order to incorporate his own knowledge of the situation. Conceptual models are used to relate the other model variables to the analysed quantities.

An assessment programme has been carried out, with subjective comparisons being made between the forecasts run from the current objective initialisation (OI) and those run from the IMI. Particular attention has been given to cases where the routine forecast (initialised using the OI) was deficient in some way.

After describing the initialisation procedures in some detail (section 3), a summary of the results of this assessment is presented in section 4, with a more detailed look at two of the cases of particular interest.

2 MODEL FORMULATION

The UK Met Office Mesoscale Model (Golding 1987) uses a non-hydrostatic, compressible formulation of the primitive equations with a semi-implicit finite difference scheme, allowing a forecast timestep of one minute. An Arakawa C grid of 63×79 points covers the British Isles, with a resolution of 15 km, giving good representation of orography (figure 1). An enlarged model domain of 120×133 points was used for one of the cases. The vertical coordinate is height above orography, with 16 levels in the vertical, the lowest at 10m, the highest at 12010 m, with the level spacing increasing linearly with height from 100 m to 1500 m.

The model has a detailed boundary layer mixing formulation with turbulent kinetic energy carried as a variable. Cloud water and humidity are predicted separately to give a good representation of cloud, and both grid scale and convective precipitation processes are modelled. The radiation scheme is also particularly detailed with respect to cloud.

A continuous three hour assimilation cycle is run. The observations are analysed using a combination of a three hour Mesoscale Model forecast and fields interpolated from the most recent forecast from the Finemesh Model (the UK Met Office regional model) as a first guess. This "Hybrid" first guess takes the synoptic scale component of the upper air fields from the Finemesh Model, with the short wave component derived from the Mesoscale Model forecast. The cloud and surface fields are also taken from the Mesoscale Model forecast. The analyses are used to modify the other model variables to obtain a consistent set of model fields. The IMI can be used in the place of this objective initialisation.

Two 18 hour forecasts are run each day, from midnight and midday. Hourly predictions are obtained of pressure, wind, grid scale and convective precipitation, cloud cover and base, visibility, temperature and humidity.

Three hourly boundary conditions are taken from the Finemesh Model; a 15 level sigma coordinate model, with a resolution of about 75 km in the area of interest. Cloud water mixing ratio is not carried as a variable in the Finemesh Model, and so has to be diagnosed from the relative humidity. This and the interpolation required, can cause undesireable effects close to the boundaries. Because the edges of the model domain are so close to the forecast area the forecast is generally driven by the boundary conditions in the latter stages, although it can develop topographically driven mesoscale features well. But in the first 6 to 9 hours, and longer in static situations, the initial conditions are very important.

3 DESCRIPTION OF INITIALISATION SCHEMES

3.1 Interactive Mesoscale Initialisation (IMI)

The Interactive Mesoscale Initialisation is a menu driven system, controlled by mouse input (and keyboard where required), which is operated by a human analyst on an interactive graphics workstation (figure 2). It allows the analyst to monitor the use of surface observations, and satellite and radar imagery in the production of a set of key analyses of surface variables and the cloud distribution. The analyst is able to modify the data which are used in the analyses and modify the analyses themselves, thus incorporating his own knowledge of the situation into the final result. Conceptual models are used to make remaining model fields consistent with these analyses.

The analyst has a choice of using the Hybrid (see section 2) or a set of fields interpolated from the most recent Finemesh Model forecast as a first guess. The latter is normally selected only if a serious timing error is present in the forecast from the Mesoscale Model. The first guess is then used as a background field to carry out all the analyses, which are displayed with the observations, for the analyst to check. If he is not happy with an analysis, then he has the option of either modifying the observations and reanalysing or modifying the analysis.

The analyst is able to delete, correct or add observations which are then reanalysed using either the first guess or the original analysis as the background field. The use of the original analysis allows the observations to be repeatedly analysed, if necessary, to fit them better.

Corrections to the analysis itself can be applied in a broad variety of ways. Areas, lines and points, to be altered, can be selected on the screen or from a range of values in any of the fields available. In the area selected it is possible to set a value, apply a correction, multiply by a factor, copy values from another field, or smooth the current values with a user-selected smoothing radius.

Finally, if the analyst is not happy with the result, he has the option of restarting the analysis.

The mean sea level (MSL) pressure is analysed first, followed by the 10 m wind components. Prior to the wind analysis, corrections are made to the first guess to reflect the changes to the geostrophic wind in the pressure analysis. Corrections to the upper level pressure, potential temperature and wind fields are computed from the pressure and wind analyses. The pressure corrections are calculated from the the change in MSL pressure, assuming a one in a hundred slope normal to the mean MSL pressure gradient, with a linear decrease in magnitude to zero at 8 km. Potential temperature increments are computed hydrostatically from the pressure corrections at each level. Above 1 km, adjustments to the wind fields are obtained geostrophically from the pressure corrections. Below 1 km, a height dependent, linear combination of the geostrophic correction and the surface correction is used.

A surface precipitation rate analysis is carried out using a FRONTIERS (Brown 1987) radar image as the first guess within the the radar coverage area, if an image is available for the correct time. Present weather reports and hourly accumulations (SREWs) are used to estimate the precipitation rate at the observing stations. These rates are then analysed assuming a small area of influence within the radar domain, but a broader influence outside it. The Meteosat cloud top temperature image and sferics reports are usually available to aid the forecaster in verifying the analysis. The distinction between water and ice precipitation is made within the analysis, but is not as yet made use of in the initialisation procedure.

The Meteosat cloud top temperature image is used to derive an improved first guess total cloud cover, by assuming that cloud is present where the satellite temperature is 10°C or more colder than the first guess surface temperature. Because the satellite image is retrieved with a resolution of 7 km, counting the "cloudy" pixels gives a good estimate of the total cloud cover. The surface reports are then analysed using this improved first guess.

The satellite image is adjusted for surface radiation effects in partially cloudy areas, using the cloud cover analysis. A cloud top height field is then derived by using first guess temperature profiles to assign heights to the satellite cloud top temperatures. If a satellite image is not available, then the first guess cloud distribution is used to define the cloud top.

The first guess cloud base is adjusted to ensure that it is at least 200 m below the cloud top, before it is used as the background field to analyse the surface observations. If cloud top and cloud base conflict after the cloud base analysis, then one or the other is modified. Below 8000 ft the cloud base is assumed to be more accurate, so adjustments are made to the cloud top. But, above 8000 ft more faith is placed in the satellite derived cloud top, so the base is adjusted.

The 8-group cloud reports are analysed using the first guess cloud distribution, with the cloud top, base and total cover analyses acting as constraints. This is carried out by interpolating the first guess cloud cover values to the observation points and using them to interpret the 8-groups, to give a profile of cloud cover values at model levels. The values are then analysed level by level.

The cloud and temperature structures may be examined in more detail by selecting up to twenty locations within the model area, for which profiles of cloud cover and potential temperature are displayed. Either or both of these profiles may be adjusted if desired, with the temperature corrections and the adjusted cloud cover values being imposed over an area selected on the screen. To assist the analyst, if a radiosonde ascent is available at the selected location it will also be displayed, in the form of a potential temperature profile and a dewpoint potential temperature profile.

The final four analyses are visibility, lying water (snow depth), screen temperature and dewpoint. For the lying water analysis, state of ground reports of dry, damp, flooded and frost are interpreted quantitatively, and snow depth reports are used directly.

The screen temperature analysis is used to modify the soil, surface and first level temperatures assuming either a logarithmic or a linear profile depending on the first guess temperature profile.

The low level relative humidity, cloud water and the boundary layer cloud condensation nucleus (CCN) concentration are initialised using the temperature, dewpoint and visibility analyses. The humidity mixing ratio is calculated at screen level, and the relative humidity at the lowest level is computed from this, by assuming that the humidity mixing ratio remains constant up to 20 m. Where the relative humidity is greater than 99% or the visibility is less than 1.5 km, then cloud water is assumed to be present in the atmosphere and is initialised using an empirical relationship relating it to visibility and CCN concentration (derived from Kunkel 1983):

$$M = \frac{0.03058}{\left[\text{visibility} \times \{\log_{10}(C_0) + 0.25\}\right]^{3/2}}$$

M is the cloud water mixing ratio and C_0 is the first guess CCN concentration. The relative humidity is also increased to 100% and eight oktas cloud is set. Elsewhere, the visibility is assumed to depend only on the humidity and the aerosol content. The analysed visibility and relative humidity are used to diagnose the boundary layer CCN concentration, using an empirical relationship derived from Hänel 1987 and Kunkel 1983:

$$C = \frac{-109732 \times \log_e(0.01 \times RH)}{\left[\text{visibility} \times \{\log_{10}(C_0) + 0.25\}\right]^{3/2}}$$

C is the diagnosed CCN concentration, C_0 is the first guess CCN concentration, and RH is the relative humidity. The cloud water mixing ratio and the cloud cover are set to zero. The resulting field is inherently rough, so it is constrained to be between 20 and 500 cm^{-3} and smoothed.

The upper level humidity distribution is adjusted to be consistent with the analysed cloud cover, using a simplified form of the equations which are used in the forecast model.

Empirical relationships are used to initialise the cloud water/ice profiles consistent with the analysed cloud and precipitation. A single column version of the model precipitation scheme is used to iteratively adjust the cloud water/ice profile to produce the analysed precipitation rate at the surface for each grid point.

After the surface temperature has been initialised, it is possible for the analyst to modify the field either by hand or by copying in a sea surface temperature field which has been generated using successive infrared Meteosat images over the period of a week.

Temperature profiles are adjusted from the lowest level upwards to spread the influence of the surface observations and to enforce stability where no cloud is present. The temperatures is adjusted to be stable, using the modified temperature from the level below, and assuming a cloud fraction dependent, linear combination of the saturated adiabatic lapse rate and the dry adiabatic lapse rate. Immediately above the cloud top, the temperature is adjusted to be stable to air parcels following a saturated adiabat from anywhere within the cloud deck. This allows convective instability within the cloud itself, in a way that is consistent with the forecast model turbulence scheme, but does not allow instability in the clear air. If necessary, where excess stability is present, it may be eroded in order to minimise deviations from the mean temperature in the first guess.

The temperature stability adjustment has been added in an attempt to limit excessive convection which often occurs in the early stages of the forecast.

The divergence profile is adjusted to give zero vertical velocity at the upper boundary. A single column version of the model precipitation scheme is used to to calculate the height dependent precipitation rate using the initialised cloud water profile. Where precipitation is being produced, the vertical velocity is reset so as to lift enough saturated air to replace the precipitation falling out of the layer. The cloud top is reinforced by a small negative vertical velocity. Within the lowest kilometre, the vertical velocity is set equal to a height dependent, exponentially weighted combination of the vertical velocity recalculated from the horizontal winds and the initialised vertical velocity. A heavy smoothing is applied and values are limited, in order to eliminate sudden changes and unreasonably high values. The divergence stucture is adjusted again to be in balance with this final vertical velocity.

Finally, the analyst has to make a 'Y' or 'N' response, to either use the initial fields which have been created by the IMI, or fall back on the initial fields generated by the OI.

3.2 Objective initialisation (OI)

The main differences between the OI and the IMI are the use of radar and satellite imagery and interactive control given to the analyst. In the OI a similar set of key analyses is carried out and a more limited set of conceptual models is used to make the other model variables consistent. Overall a less thorough knowledge of the situation is incorporated into the initial fields.

The Hybrid (see section 2) is taken as a first guess, and thus is used as a background for the analyses of mean sea level pressure, wind, precipitation rate, cloud cover, visibility, snow depth, screen temperature and dewpoint.

The soil, surface and first level temperatures are adjusted to be consistent with the analysed screen temperature, preserving the the initial model lapse rate. The temperature, relative humidity and winds within the boundary layer (whose depth is diagnosed from the first guess temperature profile) are adjusted to be consistent with the analysis values. Super adiabatic lapse rates are removed at all levels.

No geostrophic adjustment is made to the winds, but the upper level pressures are recalculated hydrostatically, starting from the analysed mean sea level pressure.

The first level relative humidity and cloud water mixing ratio are diagnosed from the analysed visibility. The surface observations of cloud are used in conjunction with the cloud cover analysis to generate a three dimensional cloud analysis, which in turn is used to initialise relative humidity and to obtain a first guess cloud water mixing ratio distribution. A single column version of the model precipitation scheme is used iteratively to adjust the cloud water mixing ratio until it produces the analysed precipitation rate.

The divergence profile is recalculated to give zero vertical velocity at the upper boundary, but no account is taken of precipitation within the vertical velocity initialisation.

4 CASE STUDIES

4.1 Summary of results

Forecasts were run for eight cases using initial conditions generated by both the OI and the IMI. Each case was chosen because the routine forecast (initialised using the OI) was deficient in some way. The comparison between the two forecast runs was, in each case, a subjective one, with the type of comparison being dictated by the particular details of the weather which were of interest to the forecaster on that day.

A summary of the cases is given below, with the impact to the forecast of using the IMI referred to as either none (no major differences from the OI forecast), some (some significant improvements to the forecast) and good (some very marked improvements to the forecast). It is worth noting that in none of the cases investigated did the use of the IMI have a negative impact on the forecast.

No	Type	Analysis time	Impact	Description
1	Sc cloud and fog	12z 5/11/88	Good	See section 4.2
2	Rain/snow	12z 26/2/89	None	A complex low system covered the British Isles. Within the northwesterly flow a small low centre formed and swung south-eastwards across Ireland, Wales and southern England, bringing rain across the south of the country, with snow on the northern edge and triggering some thunderstorms along the south coast. Both of the forecasts failed to maintain the area of precipitation for more than a few hours into the forecast, leaving most of southern England with a dry afternoon.
3	Frontal rain	6z 15/2/89	Some	See section 4.3
4	Sc cloud	0z 12/12/88	Good	An anticyclone was centred over Ireland, with a weak cold front moving southwest-wards across England. There was a lot of low cloud associated with the front and the general area of warm moist air circulating around the high centre. The OI forecast maintained too much cloud over southern England, whereas the IMI forecast developed the observed breaks, giving much better guidance.

5	Winds	Oz 5/5/89	Some	A generally slack, anticyclonic pressure gradient covered the British Isles. The OI forecast developed unrealistically strong southerly winds in the North Sea, resulting in a spurious trough which propogated slowly eastwards. The winds were much lighter in the IMI forecast, leading to a more realistic evolution.
6	Convection	Oz 23/5/89	None	Under the influence of anticyclonic conditions, with very warm, moist air feeding northward across the country, a mesoscale convective system (MCS) moved north from France and redeveloped over Hampshire. Both the forecasts totally failed to develop this feature.
7	Convection	Oz 24/5/89	Some	The situation was the same as case 6 except that the MCS developed slightly later in the night. Despite initially having quite a good representation of the feature the OI forecast failed to maintain it beyond 6z. The IMI forecast did not have the feature particularly well represented at the beginning of the forecast, but did manage to develop and maintain the feature, correctly moving it northwestward, albeit rather slower than reality.
8*	Depression	Oz 11/4/89	Some	A deep depression was centred to the northwest of Scotland, with a strong southwesterly flow covering the British Isles. A small low ran to the south of the main centre, developing as it moved into Ireland. The OI forecast did not develop the small low properly, instead concentrating on another centre further north, which meant the frontal rainbands were not well predicted. The IMI forecast developed the small low more successfully, resulting in a more realistic rainband structure. It also correctly had stonger winds in the following westerly flow.

* carried out on the large model area.

The following two sections take a more detailed look at cases 1 and 3.

4.2 Anticyclonic stratocumulus (5/11/88)

The use of satellite imagery and manual intervention within the IMI should lead to a better cloud analysis, and thus a better cloud forecast. This is especially true for static situations involving persistent layer cloud, such as anticyclonic stratocumulus, where the boundary conditions become less crucial. The case investigated here, is such a cloud forecast.

On the evening of November 5th 1988, under the influence of anticyclonic conditions (figure 3), fog formed over much of southern England and remained for several days in parts. The thickness of the fog experienced in many places may have been a consequence of the large amount of smoke ejected into the air by bonfires on that evening, but the actual distribution of the fog was very much dependent on the low cloud distribution, as figure 5 shows. A good forecast of the movement and development of the stratocumulus cloud present in the high cell circulation was crucial for the prediction of the onset and the distribution of the fog that night. The midday run of the Mesoscale Model did not produce a very good 18 hour cloud forecast and failed to develop the observed fog, instead keeping visibilities in excess of 20 km. The forecast run from the IMI had a better cloud distribution which was reflected in the lower visibilities produced.

Within the IMI, the Meteosat image was used in both the cloud cover and the cloud top analyses. After incorporating the observations, the cloud cover appeared slightly deficient to the north of East Anglia, so 7 oktas cloud was set where the satellite image was colder than 0°C. With very little data present to influence the analysed cloud bases over the sea areas, they appeared to be too high over the North sea and to the west of Scotland. So, in these areas, the bases were adjusted to agree with the few observations that were available. The resultant cloud analysis produced by the IMI (figure 4a) has much more low cloud over the sea areas than the objective analysis (figure 4b), which illustrates the importance of the satellite image over data sparse areas. Otherwise the two analyses are generally similar over much of the British Isles, except over Wales and the Irish sea, where the cloud is more broken in the IMI analysis. There is also less high cloud in the IMI analysis and cloud tops over Ireland are higher.

The 18 hour forecast run from the IMI has a cloud sheet covering Wales and just beginning to extend into England, but with the majority of southern England cloud free (figure 6a), which compares favourably with the observed low cloud distribution at 6 GMT (figure 5). By contrast, the forecast run from the OI has much of southern England under a veil of low cloud, with the only significant breaks being on the south coast and in Humberside (figure 6b), this being a very poor reflection of reality. So the incorporation of satellite imagery has had a marked impact on the 18 hour low cloud forecast.

The forecast visibilities were not as impressive, with the IMI forecast failing to develop the observed fog. But its visibilities were of the order 4 km over most of southern England, which is a marked improvement on the OI forecast which kept visibilities at over 20 km. The improvement in the visibility forecast is a result of the improved cloud forecast and the higher aerosol concentrations initialised in the visibility analysis.

Possible reasons for the failure to forecast the fog are the non-representation of the increase in aerosol concentration which occurred during the evening as a result of the bonfires across the country, and the omission of any interaction between the cloud condensation nucleus concentration (which acts only as a tracer in the forecast) and other model variables.

The use of the satellite imagery within the IMI was reflected in the overall improvement in the forecast. The failure to produce the observed fog is disapointing, but the cloud forecast in itself would have been good guidance to the forecaster trying to predict the fog distribution on the morning of the 6th.

4.3 Frontal precipitation (15/2/89)

Radar imagery is currently the only available source of data that captures the mesoscale detail present within frontal rainbands. Thus the incorporation of this data within the IMI should lead to a better precipitation analysis, which when used in conjunction with the satellite derived, three dimensional cloud analysis, in the initialisation of the cloud water and the vertical velocity, should generate and maintain a realistic frontal structure. This case investigates the impact of the IMI in the forecasting of a cold front.

On February 15th 1989 an active cold front passed southeastwards across the British Isles (figure 7). Associated with it was an area of heavy rain and a well marked band of line convection (figure 9). Both the midnight and midday runs of the Mesoscale Model moved the front on too fast, tending to lose the rain to the rear of the front, developing instead a spurious area of rain in the English Channel, well ahead of the front. It was decided to run the Mesoscale Model, using initial fields generated by both the IMI and the OI at 6 GMT, which was the time when the front first entered the radar domain.

Within the IMI the radar data were incorporated into the precipitation analysis, and produced a good representation of the front over Ireland and northern England. Over the North sea, where there was no radar coverage and observations were sparse, the front was badly represented. So, within that area, the precipitation was replaced by 0.4 mm/hr where the Meteosat image showed cloud tops colder than -20°C. The satellite image was also used in generation of the cloud cover and cloud top analyses. The front was badly represented in the pressure pattern, so a trough was inserted before the observations were analysed , and was maintained in the analysis. Some spurious fog over northern France was removed. The resultant precipitation analysis produced by the IMI (figure 8a) had a more continuous band of precipitation than the objective analysis (figure 8b), with the main area of rain further north over Ireland, leaving southern Ireland and Wales dry at 6 GMT.

The radar image for 12 GMT (figure 9) shows a large area of moderate rain over Wales, with a narrow band of line convection stretching from the Wash through to the Bristol channel. There are some smaller areas of rain apparent over Cornwall, and there is an area of light rain over southwest and central southern England which does not show up on the radar, but can be seen on the observations chart for 12 GMT (figure 10).

The 6 hour forecast run from the OI (figure 11b) has a band of rain which is roughly coincidental with the line convection, but far too wide, with too much rain over East Anglia. It has the main area of rain too far south, over southwest England, where there was only light rain in reality, and much of Wales is completely dry. It has also developed a large area of precipitation over the English channel, giving southern England and the north coast of France some rain. This area of rain was not supported by observations or radar and appears to be totally spurious.

The forecast run from the IMI (fig 11a) has a sharper band of quite heavy rain which agrees well with the actual position of the line convection. Like the OI forecast, it has the main area of moderate rain too far south, but does have slightly more rain over Wales. Southeast England has been left completely dry which is in accordance with reality, and although there is evidence of the area of spurious rain in the English channel, it has not been developed to the same extent as in the OI forecast.

Further into the forecast period, both the OI and the IMI forecasts continued to have the rain too far south, and developed the spurious rain area over the English channel. However, the spurious rain was not developed so soon or to the same extent within the IMI forecast as it was within the OI forecast. The IMI forecast also had the convective band slightly further north towards the end of the forecast, giving a better indication of the real distribution of the rain.

Although the use of the satellite and radar data within the framework of the IMI did not totally remove the forecast errors, it did provide some improvements on the OI forecast, especially in the early stages, and would have acted as better guidance to the forecaster attempting to predict the rain areas. The incorrect development of rain in the English channel may have been a result of erroneous boundary conditions.

5 CONCLUSIONS AND FURTHER WORK

The eight cases investigated here illustrate that the use of the Interactive Mesoscale Initialisation scheme, incorporating satellite and radar imagery, can have a positive impact on the Mesoscale Model forecasts.

The most significant improvements occurred in the predicted low cloud distribution, in static situations such as cases 1 and 4. These cases illustrate that the impact of an improved cloud analysis can last throughout the forecast period. The impact was generally not so long lived in more mobile siuations, such as case 3, with significant improvements tending to last only for the first 6 to 9 hours. The prolonged impact experienced in case 8 when using a larger domain supports the idea that this limit is due to the influence of the boundary conditions. In cases 2 and 6 the use of the IMI appeared to have no effect on the forecasts, which in both cases, failed to develop a small scale feature which had a significant effect on the weather. One possible explanation is that the observed feature was not initialised properly, due either to lack of information or shortcomings in the methods used to initialise the upper air fields.

Future improvements which may reduce the problems are likely to come from increasing the model domain, the use of more conceptual models and the utilisation of other sources of data as they become available.

Further comparisons between the OI and the IMI could usefully be carried out in several ways.

In all the cases investigated here, the routine forecast (initialised using the OI) has been deficient in some way, thus leaving plenty of room for improvement. To obtain a more balanced view of the effect that the use of the IMI has on the forecast, it would be beneficial to run some comparisons on cases where the use of the OI has resulted in a good forecast, to see if the IMI provides further improvements to the forecast, has no impact or possibly degrades it.

Another factor in this assessment is that the cases shown here have all been carried out in a research enviroment, away from the pressures and time constraints experienced by a forecaster in the Central Forecasting Office (CFO). The next logical stage in the assessment of the IMI, would be to compare forecasts initialised by forecasters in CFO using the IMI with those initialised using the OI. This would provide a much better insight into the improvements that could be obtained by using the IMI operationally.

Since the Mesoscale Model has a continuous assimilation cycle, it would also be useful to compare forecasts when the OI and the IMI had been used on more than one assimilation cycle.

References

Brown, R 1987 The use of imagery in the Frontiers precipitation nowcasting system. Proceedings of workshop on satellite and radar imagery interpretation, Reading, England. 24 July. 459-472.

Golding, B W 1987 Short-range forecasting over the United Kingdom using a mesoscale forecasting system. In MATSUNA, (Ed) Short and Medium-Range Numerical Weather Prediction, Meteorological Society of Japan, Tokyo.

Hänel, G 1987 The role of the aerosol properties during the condensation stage of the cloud: A reinvestigation of the numerics and the microphysics, Beitr. Phys. Atmosph. Vol. 60, No. 3.

Kunkel, B A 1983 Parameterization of droplet terminal velocity and extinction coefficient in fog models, Journal of Climate and Applied Meteorology, Vol. 23.

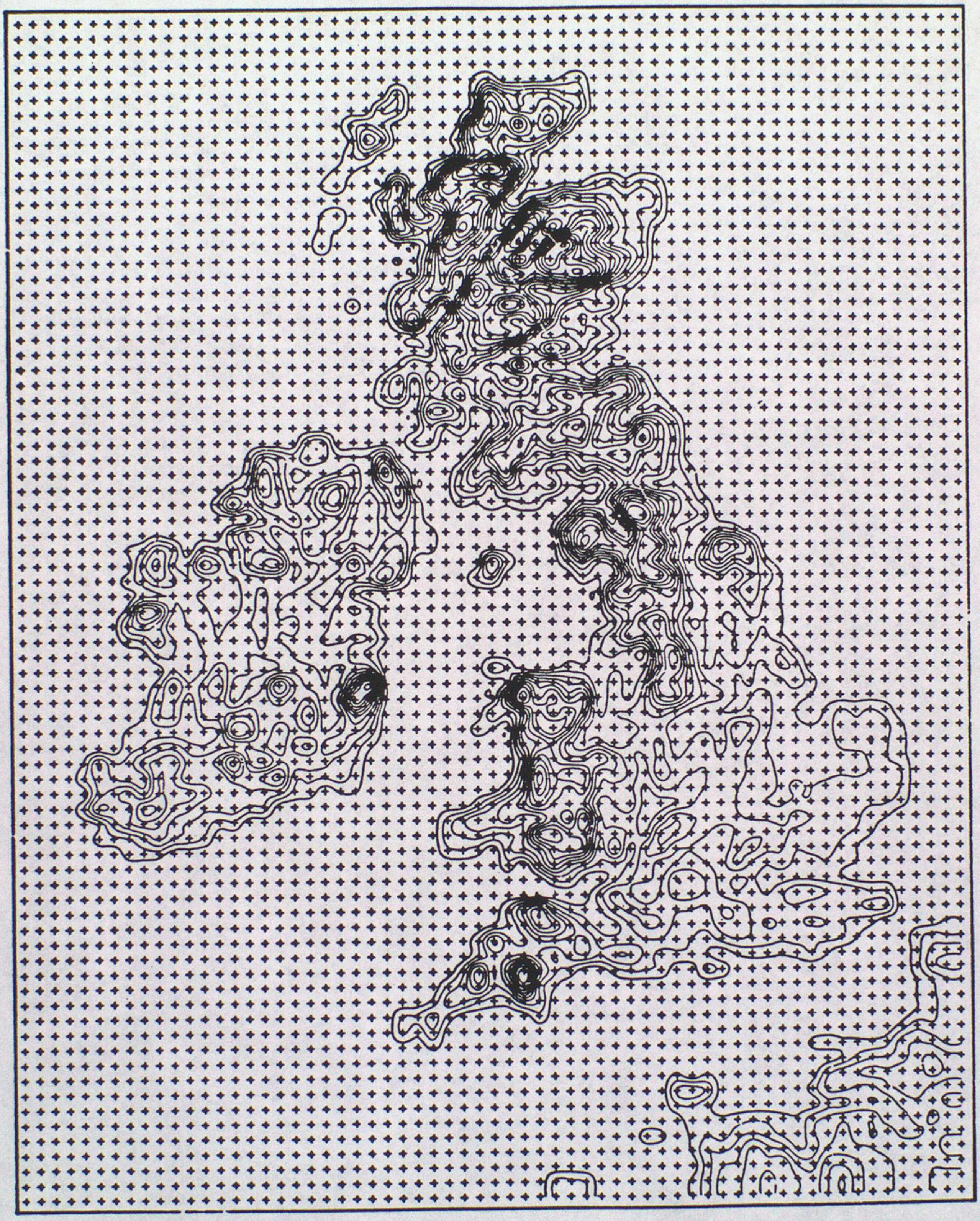

Figure 1 Model domain and orography. The gridpoints have a 15 km spacing and the contour interval is 50 m.

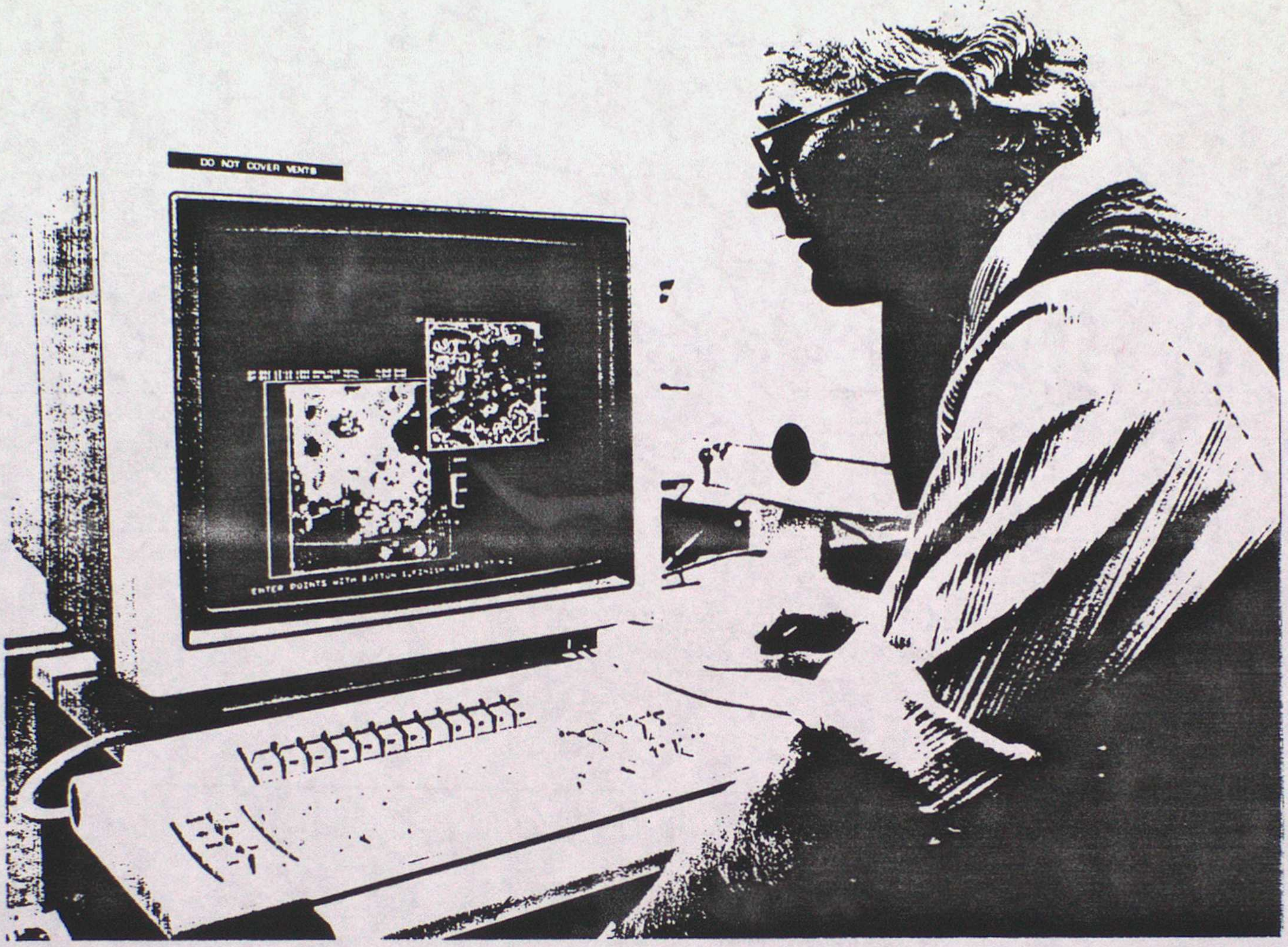

Figure 2 A forecaster in the Central Forecasting Office performing the Interactive Mesoscale Initialisation.

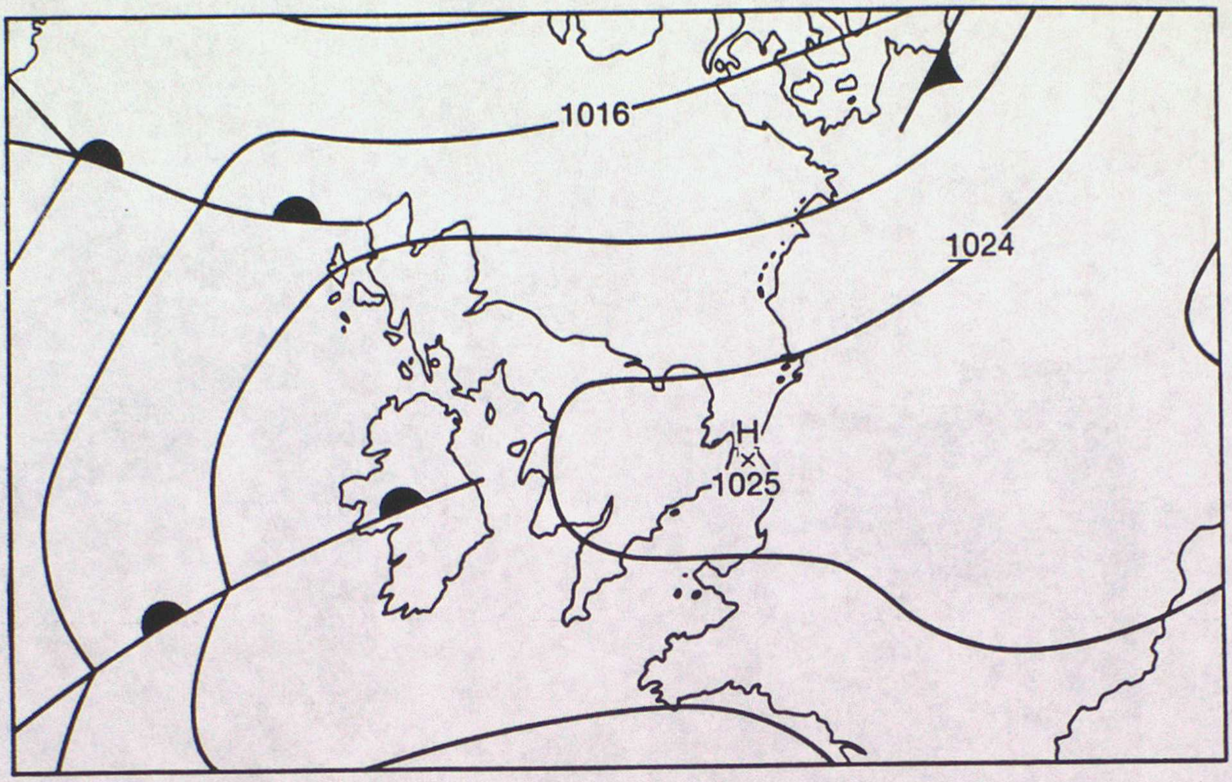

Figure 3 Mean sea level pressure analysis with fronts for 6 GMT on 6th November 1988.

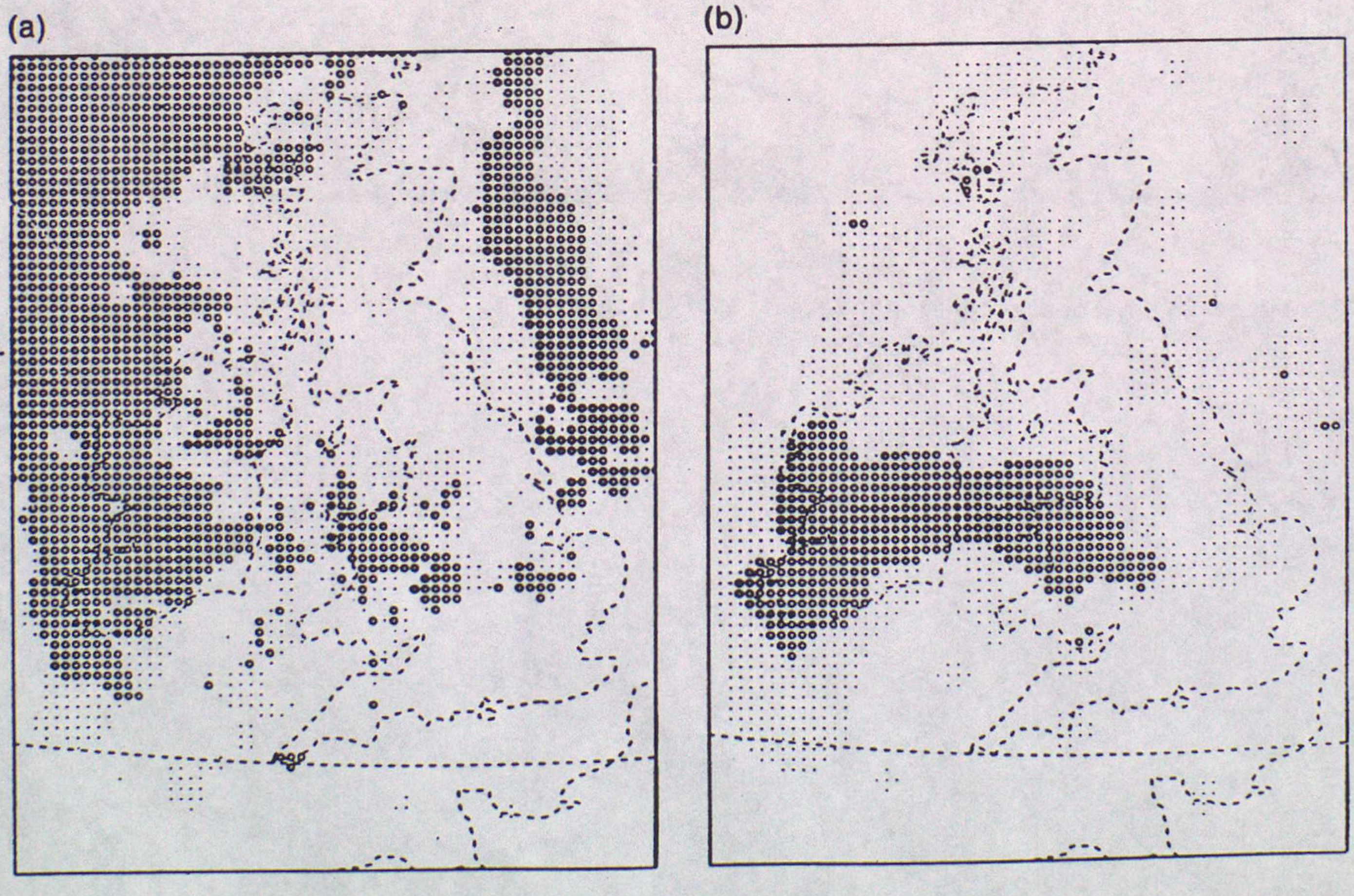

Figure 4 Model analyses of low cloud cover for 12 GMT on 5th November 1988. (· > 4 oktas, o > 7.5 oktas).
(a) IMI analysis. (b) Objective analysis.

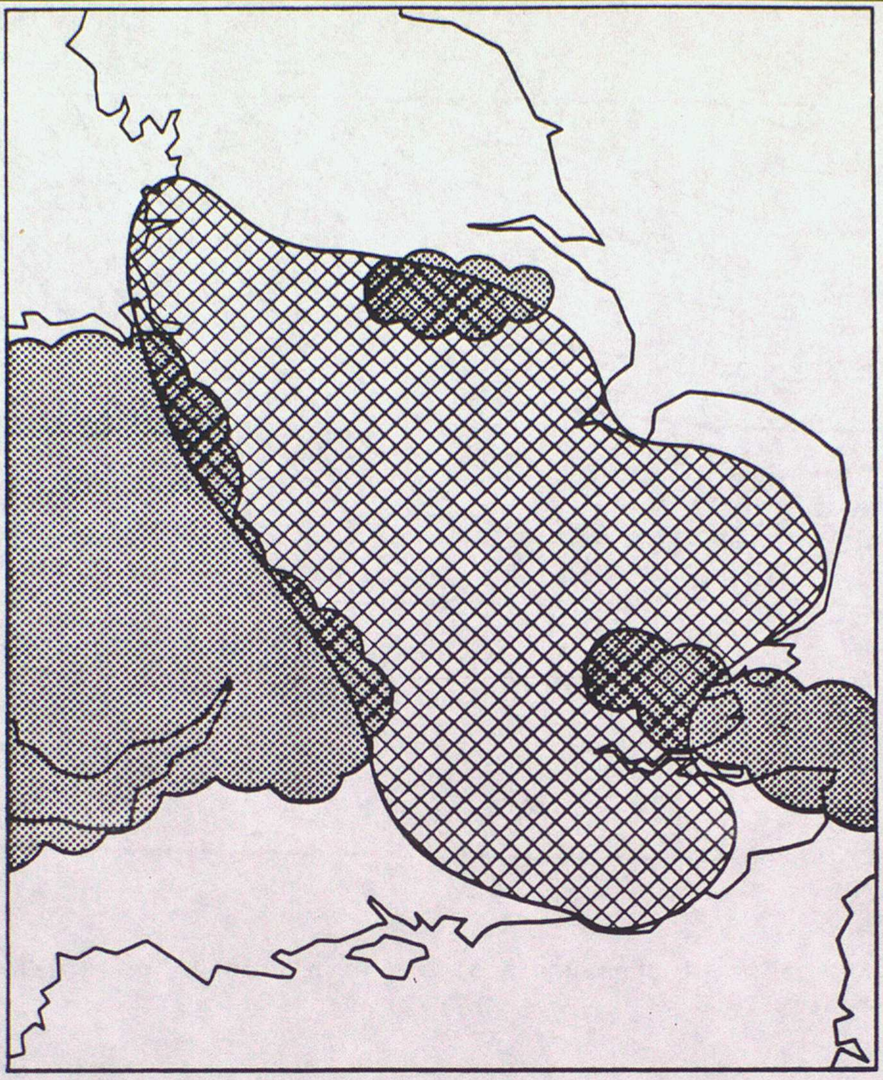

Figure 5 Observed low cloud and fog distributions for 6 GMT on 6th November 1988. (stippled area denotes greater than 5 oktas low cloud cover, cross-hatched area denotes less than 1000 m visibility).

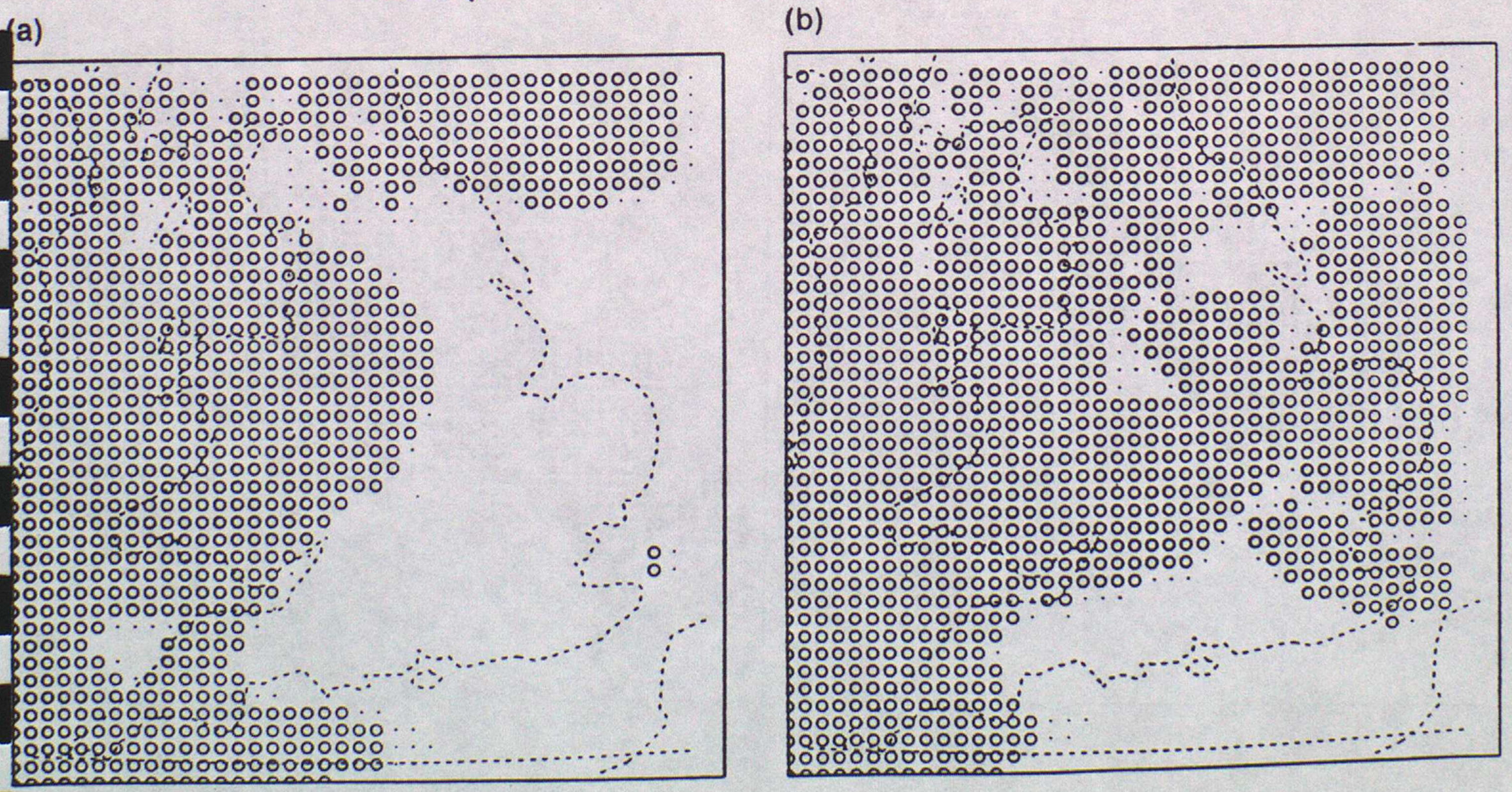

Figure 6 18 hour forecast low cloud cover for 6 GMT on 6th November 1988. (· > 4 oktas , o > 7.5 oktas).
(a) IMI forecast. (b) Objective forecast.

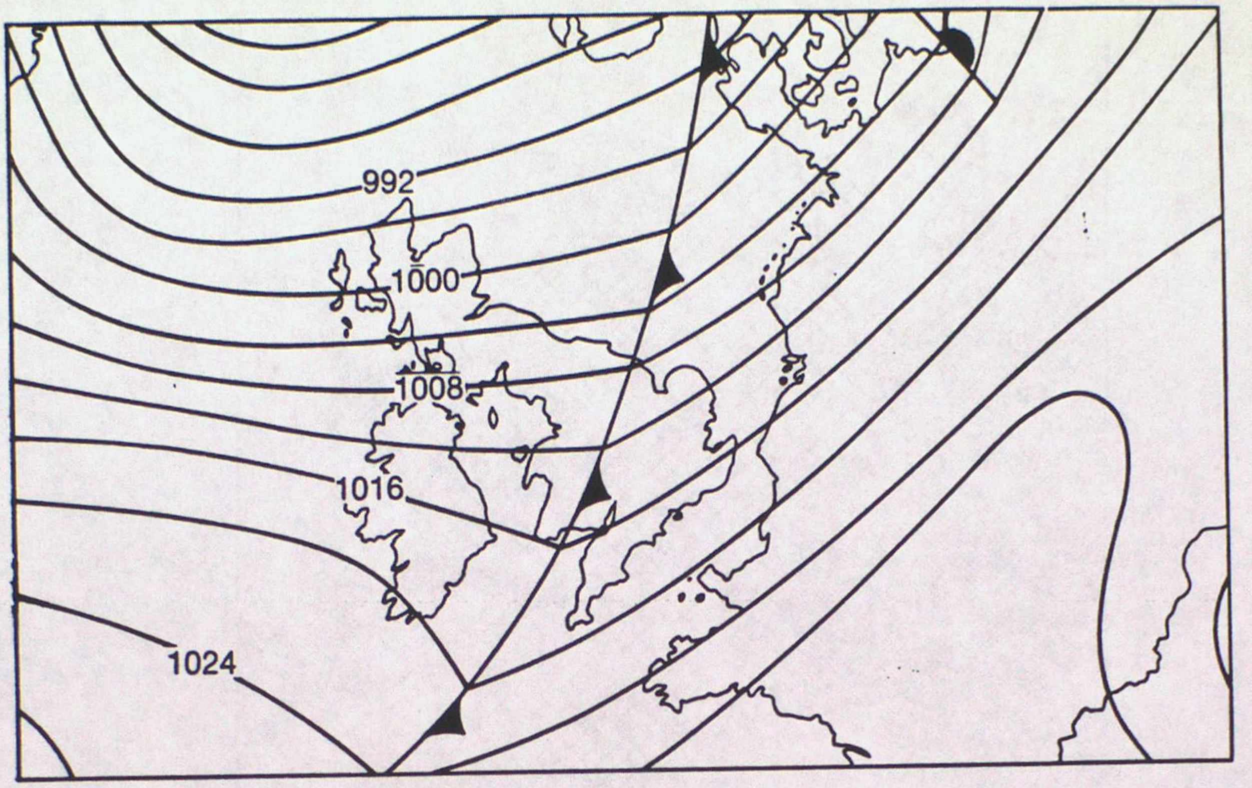

Figure 7   Mean sea level pressure analysis with fronts for 12 GMT on 15th February 1989.

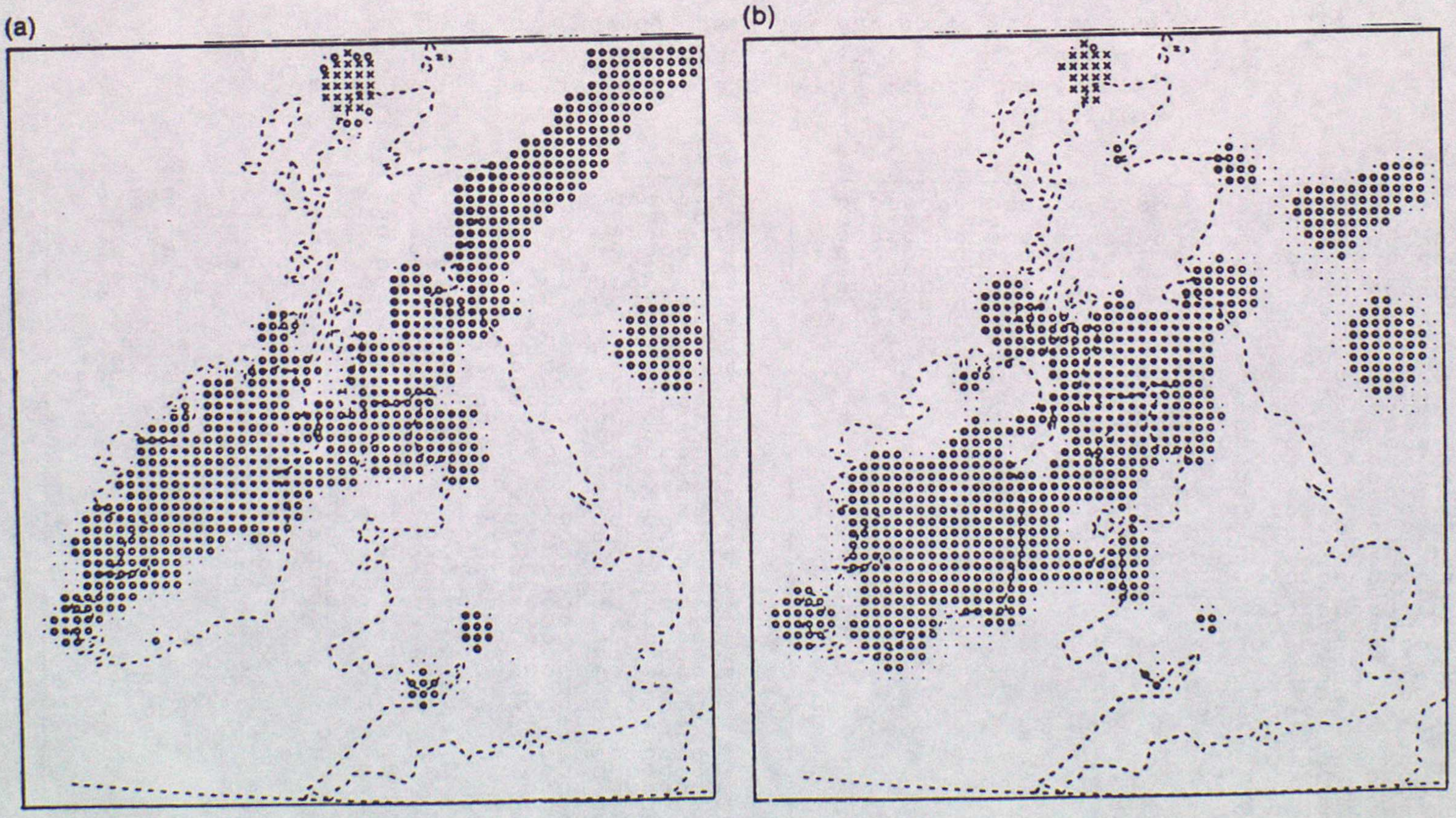

Figure 8   Model analyses of precipitation for 6 GMT on 15th February 1989.
(Rain: - · > 0.05 mm/hr, o > 0.1 mm/hr, ● > 0.5 mm/hr,
Snow (rainfall equivalent): - × > 0.05 mm/hr, ✱ > 0.5 mm/hr).
(a) IMI analysis.   (b) Objective analysis.

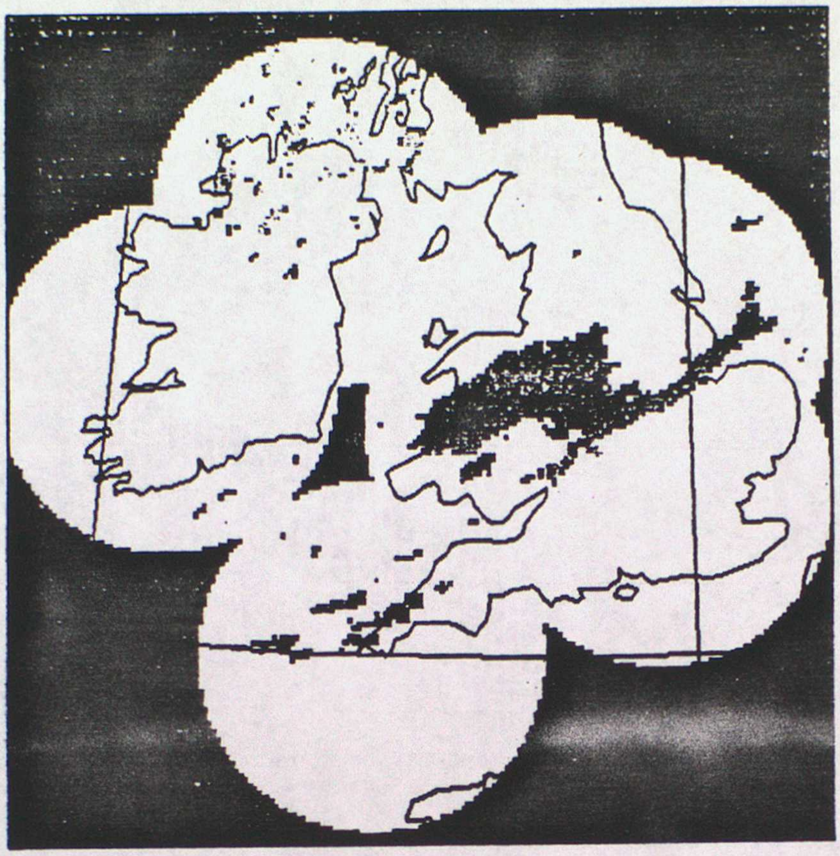

Figure 9 Composite radar image for 12 GMT on 15th February 1989.

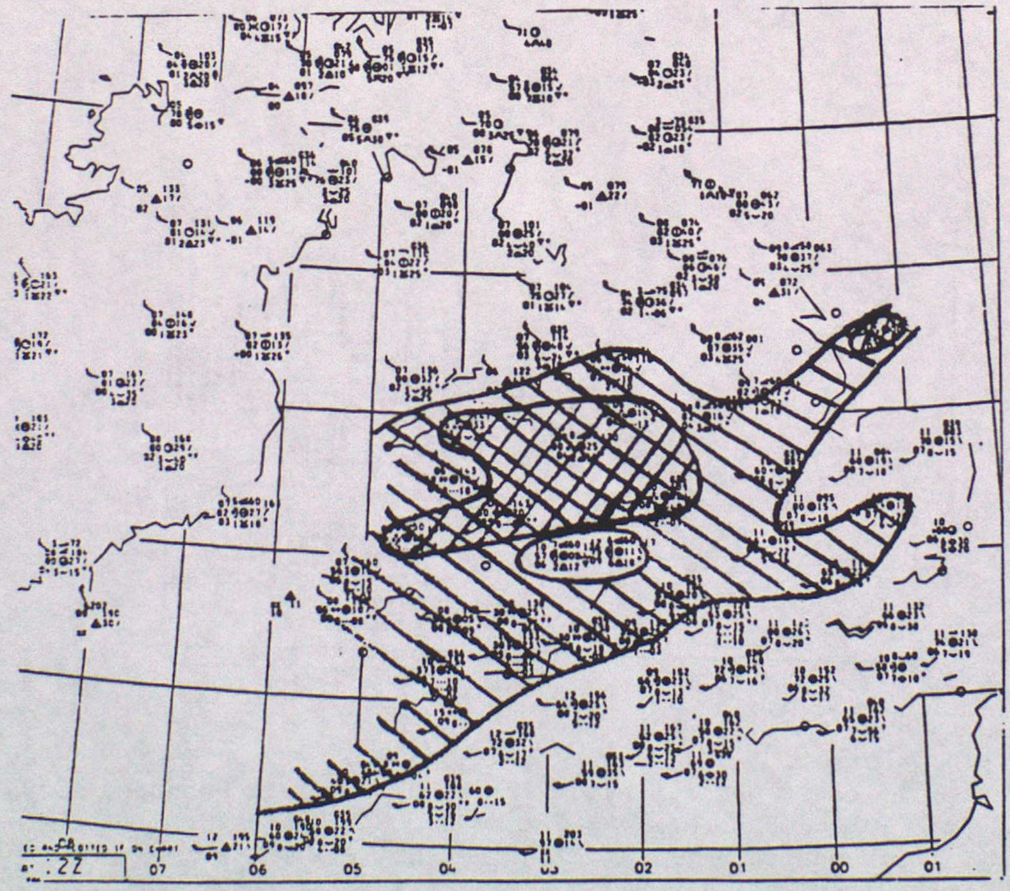

Figure 10 Surface observations for 12 GMT on 15th Febuary 1989, with areas of rain indicated (hatched area denotes light rain, cross-hatched area area denotes moderate or heavy rain).

(a)

(b)

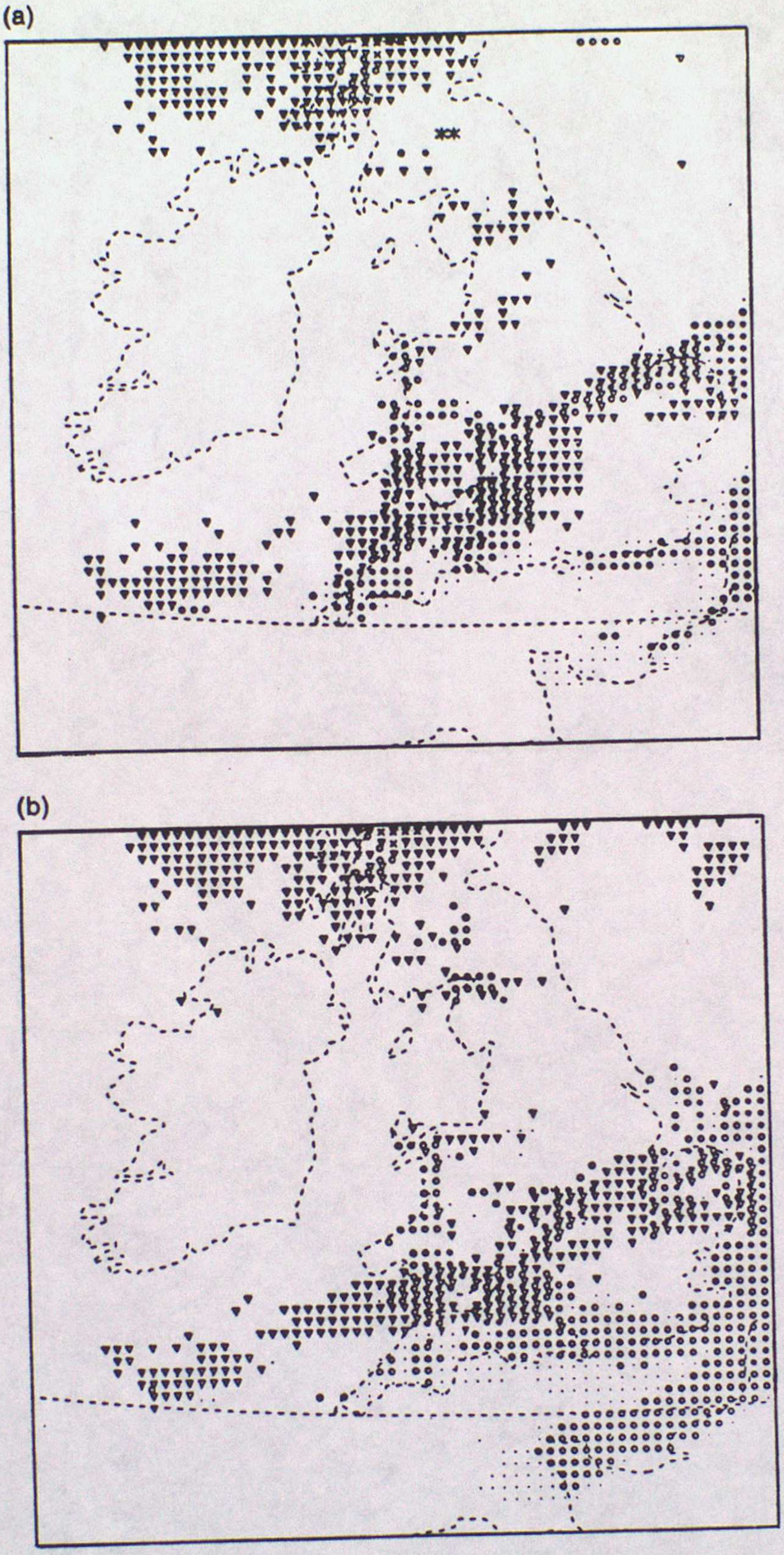

Figure 11 6 hour forecast precipitation for 12 GMT on 15th February 1989.
(Rain:- · > 0.05 mm/hr, o > 0.1 mm/hr, ● > 0.5 mm/hr,
Snow (rain equivalent):- × > 0.05 mm/hr, * > 0.5 mm/hr,
Showers (local rate):- ∇ > 0.4 mm/hr, ▼ > 2 mm/hr)
(a) IMI forecast. (b) Objective forecast.

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The Met O 11 Technical Notes which contain information of current use and *which have not been published* elsewhere, are listed below. The complete set of Technical Notes is available from the National Meteorological Library on loan, if required.

186. The representation of boundary layer turbulence in the mesoscale model. Part 1. The scheme without changes of state.
R.N.B. Smith
April 1984

187. The representation of boundary layer turbulence in the mesoscale model. Part 2. The scheme with changes of state.
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195. Assessment of HERMES data: a case study comparison with the operational analysis for 2nd March 1984.
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December 1985, revised July 1987

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