

Numerical Weather Prediction

The impact of automating and thinning the "visual" part of UK SYNOP reports on Mesoscale Model forecasts



Forecasting Research Technical Report No. 214

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A decorative wavy line that starts on the left, dips down, rises up, and then levels out towards the right.

The impact of automating and thinning the "visual" part of UK SYNOP reports on Mesoscale Model forecasts.

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1. Introduction

1.1 Background and aims

Rationalisation of the UK synoptic network is likely to lead to the continued replacement of manned observing stations with Automatic Weather Stations (AWS). From the point of view of NWP applications, automation of the "non-visual" elements of the SYNOP report (e.g. pressure, temperature and wind) is generally considered to be advantageous, since automatic reports of these elements are as accurate as (or better than) manual reports and automation will facilitate delivery of 24-hr coverage.

The concern is with the parts of the report (referred to here as the "visual" part of the SYNOP) which currently require the judgement of a trained observer e.g. cloud amount, cloud base, cloud type and present weather (also visibility, though the impact of this element is not addressed in this report). For these elements replacement of visual measurement with automatic may result in a loss of information, accuracy or representativeness. For example, automatic stations do not specify the cloud-type and make reports of cloud-cover and base height which are based on localised measurement. Any consequent degradation in the initial data available for assimilation may lead to a loss of skill in model forecasts. Furthermore, present weather indicators are not yet installed on the AWS - so this element would be largely unavailable in a network dominated by current AWS. In addition rationalisation may also lead to the thinning of the SYNOP network, and this could also result in loss of model skill.

The aim of this work is to investigate the impact of automating and thinning the cloud and present weather parts of UK SYNOP reports on the accuracy of forecasts from the UK mesoscale NWP model. The work forms part of a project to guide the rationalisation of the UK SYNOP network.

1.2 Scope and Overview

Emphasis has been placed on assessing the impact on forecasts of 3-hr precipitation accumulation; however the impact on forecasts of other variables - mainly cloud cover, but also 1.5m temperature and 10m wind - is also addressed. The impact of thinning the visual part of the UK SYNOP network is also considered, using network scenarios provided by OPR branch.

A case study approach is used and is described in Section 2. The results of two case studies investigating the impact on rainfall forecasts are presented in Section 3. The

cases were selected because they are good examples of positive impact from the current network of "visual" SYNOP reports on mesoscale model forecasts - and therefore represent useful cases for studying the effects of automating and thinning this observation type. An analysis of the method used to select the cases is given in Section 4, and gives useful guidance on the frequency with which we might expect the visual part of the SYNOP to deliver marked forecast benefits.

In addition to the rainfall cases it was hoped to investigate a number of good examples of positive impact from visual SYNOP reports on forecasts of low-level cloud cover. However, despite processing over 850 forecasts, no good examples of impact were identified. Consequently, further study of the impact of automation on forecasts of cloud cover was not possible. Brief details of the case selection procedure for cloud cases are given in Section 5. An overall summary of results is given in Section 6 and conclusions and recommendations in Section 7.

1.3 Use of cloud and present weather reports in the mesoscale model assimilation.

The visual SYNOP reports enter the mesoscale assimilation through a processing step known as MOPS (the Moisture Observation Processing System). For a detailed description of MOPS the reader is referred to Macpherson et al. (1996). Briefly, the purpose of MOPS is to derive information on atmospheric humidity structure by integrating various observational inputs. Specifically, satellite and radar rainfall imagery, surface observations of cloud and present weather and a short-period forecast are combined to generate a 3-D analysis of cloud fraction. The elements of the SYNOP used are cloud cover, base and type and present weather. The analysis of cloud fraction is then used to derive relative humidity profiles which are assimilated as "pseudo radiosondes" with one profile per grid-square.

2. Method

2.1 Experiment format

To assess the impact of the visual SYNOP reports, a total of six impact experiments are performed for each case. All data impact experiments comprise a 6-hr assimilation step followed by either a 6-hr or 12-hr forecast and use identical boundary conditions (from the UKMO Limited Area Model). The runs are described below and summarised in Table 1. Two control runs are performed. The ALL OBS run which uses all the available data (i.e. as used in the operational mesoscale runs); and the NO OBS run which entails a dummy assimilation using no data.

For the remaining 4 experiments the observational input is the same as the ALL OBS control apart from use of the visual part of the SYNOP reports. Since the visual part of the SYNOP report enters the assimilation via the MOPS processing (see Section 1.5), experiments 2 to 6 all required a remake of the MOPS humidity profiles. In the NSYN run, the MOPS profiles were constructed without the use of

	RUN NAME	DESCRIPTION	PURPOSE
1	NO OBS	No data used	Control
2	ALL OBS	All data used	Control: comparison with 1 gives the impact of all data used.
3	NSYN	All data except SYNOP reports of cloud and present weather used.	Comparison with 1&2 highlights the contribution made by the visual SYNOP reports towards the benefit obtained with the ALL OBS run.
4	NPWX	All data except SYNOP reports of present weather used.	Comparison with 3 highlights the relative importance of SYNOP cloud reports Vs SYNOP present weather reports.
5	MAN60	Visual SYNOP data taken from a network of mainly manned stations thinned to ~60km spacing. No SYNOP present weather used.	Comparison with 4 gives the impact achieved using cloud reports from a thinned network of mainly manned stations relative to that attained with cloud reports from the full network of mixed manned and auto stations.
6	AUT60	As 5, but thinned network comprising mainly automatic stations.	Comparison with 5 gives the impact of replacing most of the cloud reports from manned stations with cloud reports from automatic stations.

Table. 1: The forecast experiments conducted on the case studies

the visual part of the SYNOP (i.e. using only information from satellite and radar imagery). In the NPWX run the SYNOP cloud reports were used but the present weather reports were withheld.

The MAN60 and AUT60 runs use network scenarios specified by OPR branch. The MAN60 network comprises mainly manned stations; the AUT60 mainly automatic stations. The station distributions in MAN60 and AUT60 are shown in Figs.2a&b respectively. Each network is thinned relative to the operational network; the MAN60

network has an average spacing of about 60km with spacing minima (of about 40km) in the south-east and Northern Ireland and maxima (about 80km) evident in Scotland and the Midlands. The AUT60 network has a similar average spacing but differs locally from the MAN60 network. For example, the spacing over Wales and Cumbria is closer (~40km), while over the Midlands the spacing is wider than in MAN60. The use of networks with a predominance of either manned or automatic stations types was preferred to networks comprising exclusively one type, since the later option would lead to unrealistic gaps in the overall coverage. In Table 2 the numbers of manned and automatic stations in the MAN60 and AUT60 networks are contrasted with approximate numbers for the full network (only approximate figures are given because the exact numbers vary according to time of day and day of week). Each network has about 70 stations compared with about 230 for the full network, corresponding to a thinning down to about one third of the current number. The MAN60 network is constructed almost exclusively of manned stations. In the AUT60 network the ratio of automatic stations to total stations is about 0.6 - twice the ratio for the full network.

NETWORK	TOTAL NO.	MANNED	AUTO (OR PART-AUTO)	AUTO/TOTAL
FULL	230	152	78 (20)	0.34
MAN60	70	64	6 (5)	0.09
AUT60	68	25	43 (3)	0.63

Table 2: Numbers of stations in the MAN60 and AUT60 network contrasted with approximate figures for the full network. Part-manned part-automatic stations have been included as automatic; their numbers are shown in brackets. At weekends about 20 manned stations become automatic, and some stations are closed down, making a total number of about 222 stations in the full network, and an automatic/total ratio of about 0.4.

No present weather reports were used in either the MAN60 or AUT60 runs. These runs therefore address solely the impact of automating the cloud reports. The present weather reports were omitted to ensure similarity of information from the two networks, since present weather reports are not currently available from the AWS. No SYNOP information from outside the UK network (e.g. Eire, France) were used in the remaking of the MOPS humidities for these runs.

It should be emphasised that the networks shown in Figs.2a&b show the stations from which visual SYNOP data were supplied to the MOPS processing. In all runs the "non-visual" part of the SYNOPs (e.g. pressure and wind reports) were supplied from the full operational network, and assimilated in the normal way.

2.2 Forecast verification

For the precipitation cases, forecast skill was assessed by comparing the accumulation of precipitation over the final 3 hours of the forecast with an analysis of 3-hour accumulation derived from the UK weather radar network by the Nimrod system (see Appendix 1 for detail). Verification was performed only for the area covered by radar network (see Fig. 1). Equitable Threat Scores (Schaefer, 1990) were calculated at two thresholds, 0.5mm/3hrs and 2.0mm/3hrs. Scores for the 0.5mm/3hrs threshold measure the model skill at predicting the occurrence of rain of light intensity and greater; while scores for the 2.0mm/3hrs threshold measure the skill at predicting the occurrence of precipitation of moderate intensity and greater. The ETS have a theoretical range from 1.0 (highest skill) to -0.33.

The skill of each forecast is expressed as a percentage of the difference in skill between the ALL OBS and NO OBS controls, e.g. for the NSYN experiment.

$$\text{BENEFIT} = \frac{[\text{ETS(ALL OBS)} - \text{ETS(NSYN)}]}{[\text{ETS(ALL OBS)} - \text{ETS(NO OBS)}]} \times 100\%. \quad (1)$$

Hit rates and false alarm rates were also used to assess the skill of the rainfall forecasts. In addition to these objective measure of skill, a synoptic evaluation of the forecast is also performed.

In addition to verification of the rainfall forecasts, mean and rms forecast errors for total cloud cover, 1.5m temperature and 10m wind were assessed using verification against station observations.

3. Results from the rainfall cases

In this section we discuss results from the two rainfall cases. We give a detailed synoptic evaluation of the impact on skill for higher levels of accumulation (rainfall threshold = 2mm/3hrs), followed by a summary of the results of objective verification at both thresholds.

One aim of the study is to separate the benefits contributed by the present weather and cloud reports. In doing so, we have assumed that the impacts from these two data types are independent and additive. Although this will often be a reasonable assumption, it should be appreciated that there will sometimes be redundancy or synergy between the two kinds of report.

3.1 Case A: 12GMT 11 March 1996

The surface analysis for 12GMT 11 March 1996 is shown in Fig. 3a. A slow moving frontal system was located over the Western British Isles with a warm front lying north-south over the Irish Sea. The surface observations at 12GMT (Fig.3b) show a southerly airstream over most of the country with widespread precipitation in the north. Precipitation of moderate intensity was reported in places along a line lying southwest-

northeast through the Scottish borders. Fig. 3c shows the location of accumulations greater than 2mm in the 3hrs 9-12GMT as derived from the Nimrod accumulation analysis. The main area of accumulations in excess of 2mm is over the borders region with smaller areas southwest over the Irish Sea and northeast over Grampian and the North Sea. The Nimrod analysis is clearly consistent with the present weather reports (Fig.3b).

The corresponding 12-hr forecasts from the NO OBS and ALL OBS control are shown in Fig.4a&b respectively. Black shading shows the locations for which an accumulation exceeding 2mm/3hrs was correctly forecast, grey shading shows the locations for which an accumulation exceeding 2mm/3hrs was forecast, but did not occur (false alarm). Both forecasts produce a spurious area of rain over northwestern Scotland, and consequently ETS scores for the entire verification area were low. For this reason it is instructive to consider the hit-rate scores in addition to the ETS. The main feature of interest is the band of rain forecast for the borders region by the ALL OBS run (highlighted in Fig.4b) but absent from the NO OBS run. Comparison with the analysis (Fig.3c) shows clearly that the ALL OBS run (Fig. 4b) gives useful guidance while the NO OBS run is very misleading. The superiority of the ALL OBS run is reflected in a higher hit-rate (43% compared to only 3.2% for the NO OBS run) and a higher ETS score (0.06 compared to -0.01). The greater skill of the ALL OBS run establishes the fact that data introduced in the 6-hr assimilation cycle prior to the ALL OBS forecast delivered a marked benefit. We now investigate the role that the visual SYNOP reports played in this impact.

Impact of the visual SYNOP reports from the full network

The results of the NSYN run are shown in Fig.4c. Clearly, withholding the visual part of the SYNOP reports markedly reduces the skill of the forecast in the borders region. The overall hit-rate reduces from 43% to 16%; the ETS from 0.06 to 0.01.

The relative importance of the cloud reports and present weather reports in the observed impact from the visual part of the SYNOP is addressed by the NPWX run (Fig. 4d). Over the borders region, the NPWX forecast is very similar to the ALL OBS run, indicating that, for this case, all the benefit derives from the cloud reports, with little impact from present weather reports.

Impact of the visual SYNOP reports from the thinned manned and automatic networks

The forecasts obtained from MAN60 and AUT60 runs are shown in Figs. 4e&f respectively. The forecasts are very similar, with only minor differences in the area of hits over the borders. Furthermore, both forecasts are only slightly less skilful than the ALL OBS forecast. Hit-rates for MAN60 and AUT60 were 40% and 38%, respectively (compare 43% for ALL OBS). The ETS were .05 in each case (compare .06 for ALL OBS). We conclude that, for this case, the benefit obtained from the full network of mixed manual and automatic visual SYNOP reports can be largely reproduced with a thinned network composed mainly of automatic reports. The loss of impact due to thinning the

cloud/present weather reports is small for this case, and may be over estimated by the MAN60 and AUT60 experiments because of the omission of reports from non-UK stations (for this case reports over Eire may have been important).

There is a small possibility that a large part of the benefit from the AUT60 run was delivered by the 28 manned or part-manned reports included in the AUT60 network (though most of these are located in the south of the UK, and are unlikely to have had major impact on the forecast over the borders). To investigate this possibility a further run (AUT60X) was performed using the same network as AUT60 but withholding the 28 manned or part-manned stations. The forecast obtained is shown in Fig.4g. The similarity of the AUT60X forecast with the MAN60 forecast (Fig.4e) confirms that, in this case, the benefit obtained using exclusively automatic visual SYNOP reports is equivalent to that obtained with a predominantly manned network.

3.2 Case B: 18GMT 28 May 1996

The surface analysis for 18GMT 28 May 1996 is shown in Fig.5a and shows a double-structured frontal system crossing the British Isles in a generally southwesterly flow. Reports of significant weather at 18GMT (Fig.5b) show widespread rain over Scotland and the borders region with scattered reports of rain in last hour reported in the south and over East Anglia. Twelve hour rainfall totals to 21GMT (Fig.5c) show that while significant totals were recorded in northern England and Scotland, no more than a trace was recorded in the south or over East Anglia.

Fig.5d shows the location of accumulations greater than 2mm over the 3hr period 15-18GMT as derived from the Nimrod accumulation analyses. All accumulations exceeding 2mm/3hrs are located north of the Scottish borders, in good agreement with the present weather and accumulation reports in Figs.5b&c.

The corresponding 6-hr forecasts from the NO OBS and ALL OBS controls are shown in Figs.6a&b respectively. The main features of interest, where differences occur in the forecasts, are highlighted and are over Norfolk, Lincolnshire and Wales and over the North Sea east of Scotland (both forecasts reproduce part of the observed rainfall area over western Scotland). The most striking difference is over Norfolk and Lincolnshire (and adjacent sea areas), where the NO OBS run has produced a large area of accumulations exceeding 2mm/3hrs. There is no evidence of accumulations of this magnitude from the Nimrod analysis (Fig.5d) or from the observed 12-hr accumulations (Fig. 5c). The over-predictions of rainfall amounts for Norfolk and Lincolnshire (and for smaller areas over Wales and Cheshire) are not present in the ALL OBS run. These areas of spurious rainfall in the NO OBS run contribute significantly to a much lower ETS (0.07), compared to the ALL OBS run (0.14). The ALL OBS run also succeeds in forecasting some of the accumulations in excess of 2mm/3hrs to the east of Scotland, this area of rain is completely missed by the NO OBS control. The greater skill of the ALL OBS run demonstrates that data introduced in the 6-hr assimilation cycle prior to the ALL OBS forecast was effective in suppressing the spurious rainfall over Norfolk and

Lincolnshire, and also in improving the forecast of the observed rainfall east of Scotland. We next investigate the contribution made by the visual SYNOP reports to this impact.

Impact of the visual SYNOP reports from the full network

The result of the NSYN run is shown in Fig. 6c. The run is similar to the NO OBS run (Fig.6a), with spurious rainfall in the east and over north-western counties. The similarity with the NO OBS run is also reflected in the ETS score of 0.09 (compare NO OBS score of 0.06 and the ALL OBS score of 0.14). This result demonstrates that the visual SYNOP reports used in the ALL OBS run were largely responsible for correcting the over prediction of rainfall noted in the NO OBS run. Fig. 6c also shows that the visual SYNOP reports were essential for achieving the hits to the east of Scotland seen in the ALL OBS run - these hits are not present when the SYNOP data is withheld.

The relative importance of the cloud reports and present weather reports in the observed impact from the visual SYNOP reports is addressed by the NPWX run (Fig. 6d). In eastern areas the general character of the forecast from this run is similar to that of the NSYN run (Fig. 6c) - with spurious rainfall (albeit over a smaller area) near the coast of Lincolnshire. The NPWX run also fails to reproduce accumulations exceeding 2mm/3hrs to the east of Scotland. These results suggest that much of the impact from the visual SYNOP reports was delivered by the present weather part of the reports. In contrast the spurious rainfall over north-western counties seen in the NSYN run, is not seen in the NPWX run. This suggests that the cloud part of the reports (which are retained in the NPWX run) were responsible for the correction of this feature. The ETS score for the NPWX run lies between that of the NO OBS and ALL OBS at 0.11.

Impact of the visual SYNOP reports from the thinned manned and automatic networks

The forecasts obtained from MAN60 and AUT60 runs are shown in Figs. 6e&f respectively. The forecasts are very similar (each has an ETS score of 0.1), suggesting no relative advantage to manned or automatic networks in this case. Since present weather reports are not used in these runs it is expected, and found, that they both reproduce the spurious area of rainfall near the Lincolnshire coast seen in the NPWX run. However, the spurious rainfall over north-western counties which does not appear in the NPWX run is present in both the AUT60 and MAN60 runs, and must be a result of the thinning of the cloud reports (or possibly from the lack of cloud reports over Eire in the AUT60 and MAN60 runs).

3.3 Results of objective verification for cases A and B

In this section the forecast experiments are assessed using equation (1). The benefits are calculated over the entire verification area (Fig.1), and generally confirm the conclusions derived from the synoptic evaluations given in Sections 3.1 and 3.2.

Impacts at the 2.0mm/3hrs threshold

The percentage benefits obtained at the 2mm/3hrs threshold are shown in Fig.7a. In both Case A and Case B, withholding the visual SYNOP reports (NSYN, dark shading) results in a significant drop in benefit (to around 40% that of the ALL OBS run). For Case A the impact is imparted by the cloud reports, as may be appreciated by noting that the present weather reports give a small negative impact in this case (indicated by NPWX being slightly better than the ALL OBS run). Occasional instances of small negative impact are not considered significant - and can occur with any data type. For Case B the present weather reports deliver most of the impact, their removal (NPWX run) resulting in a drop in benefit to 60% that of the ALL OBS run; removal of the cloud reports results in a further drop to ~40% of the ALL OBS benefit.

In both Case A and Case B, forecasts using the MAN60 and AUT60 networks have similar skill. Comparison with the NPWX run (which uses the full network) gives an idea of the impact of thinning the cloud reports. In both cases there is a loss of skill (a reduction in benefit of about 20% relative to the NPWX run). However, not all the loss in skill can be attributed to thinning the visual SYNOP reports, part may be attributable to the fact that no visual SYNOP data outside the UK (e.g. Eire, France) was used in these runs.

Impacts at the 0.5mm/3hrs threshold

The percentage benefits obtained at the 0.5mm/3hrs threshold are shown in Fig.7b. In Case A withholding the visual SYNOP reports (NSYN) results in a drop of benefit to about 40% that of the ALL OBS run. The NPWX run shows about half this drop in benefit - suggesting that cloud and present weather reports make similar contributions to the benefit. As seen for the higher threshold, the MAN60 and AUT60 runs show similar skill, though both show lower skill than the NPWX run - indicating some negative impact from the thinning network.

For Case B removing the present weather reports (NPWX) reduces the benefit to about 60%. However, when cloud reports are also withheld (NSYN) the benefit increases - suggesting a small negative impact from the cloud reports at this threshold. The MAN60 and AUT60 runs show similar skill to the NPWX run - suggesting that for this case (and this threshold) thinning the network has had little impact. The difference between the AUT60 and MAN60 runs is about 15% for this case - with AUT60 giving the better results. The difference is likely to be due as much to the differences in distribution of the networks as to the different information content and quality of the observations.

Assessment of impact on variables other than rainfall

In addition to verification of rainfall accumulation using the Nimrod analyses, other forecast variables were also verified against station observations, using an "in house" station verification package. For both cases A and B the ALL OBS and NO OBS controls and the NSYN forecasts were verified against observations of total cloud cover, 1.5m

temperature and 10m wind. Results indicated that the impact from the visual SYNOP reports on these variables was very small for these two cases. This is not surprising, since the cases were selected for marked impact on rainfall and a marked impact on other variables (with the exception, possibly, of cloud cover) would be fortuitous.

4. Frequency of significant impact on rainfall forecasts

In this section we discuss the procedure which led to the selection of rainfall cases A and B. The results give an indication of the frequency with which visual SYNOP reports might be expected to have significant impacts on rainfall forecasts with the mesoscale model. The procedure comprised the following 3 steps.

Step 1: Identification of cases in which initial data of any type (not necessarily SYNOP data) or new model boundary information had a marked benefit on forecasts of widespread rainfall.

Definitions of "marked benefit" and "widespread" rainfall are given in Appendix 2, along with a more detailed discussion of the selection procedure. Results are summarised in Table 3. A total of 936 operational mesoscale forecasts from the period 8th March 1996 to 12 November 1996 were checked for sensitivity to initial data. Of these, 512 forecasts (~55%) were for cases in which widespread rain was observed within the Nimrod area at the verifying time. Of the 512 cases with widespread rainfall, 137 (~27%) showed useful impacts from recent observations (i.e. observations assimilated in the 6-hr period preceding the forecast) or from model boundary data.

Subjective criteria were used to select 12 cases from the "shortlist" of 137 for further study. In all 12 cases, beneficial impact from observations was found to dominate over benefit from updated model boundaries. Assuming the cases are representative, we may tentatively conclude that when marked improvements occur between consecutive model forecasts data input, rather than updated model boundary information, is usually responsible. Moreover we can estimate that such marked data impacts occur in about 25% of all forecasts of widespread rain (corresponding to about 15% of the time).

Step 2: Identification of cases in which MOPS humidity profiles or radar rainrates played a major role in the observed benefit.

Having identified cases which have a marked sensitivity to initial data, we then isolate the subset of cases in which cloud and present weather information, as represented in the MOPS humidity profiles, or radar rainrates, played a major role in the

observed benefit. A significant role for MOPS humidities and/or radar rainrates was found in 4 of the 12 cases (see Appendix 2). Assuming the 12 cases are representative we can estimate that MOPS humidities and/or radar rainrates may provide significant benefits in ~9% of all forecasts of widespread rainfall.

	Number	%age of A	%age of B
Total model runs sampled	936 (A)	100	-
Runs with widespread rainfall at verifying time	512 (B)	54.7	-
Runs with significant impact from recent observations or updated boundaries	137	14.6	26.8

	Number	Estimated number (out of 137)	Estimated %age of A	Estimated %age of B
Total cases studied out of 137	12	-	-	-
Runs with a significant impact from cloud information (MOPS) and/or radar rainrates	4	46	4.9	9.0
Runs with significant impact from SYNOP reports of cloud and/or present weather	3	34	3.6	6.6

Table 3: Breakdown of the selection procedure for rainfall cases. Upper part shows estimated frequency of significant impact from data and/or model boundaries. Lower part shows estimated

frequency of impact from MOPS and SYNOP cloud and present weather reports, based on the 12 cases investigated.

Step 3: Identification of cases in which the SYNOP input to MOPS humidities played a major role.

Of the 4 cases which showed a significant impact from MOPS humidity profiles and/or radar rainrates (found in Step 2), the contribution played by the visual SYNOP component of the MOPS humidity profiles was found to be important in 3 cases. We may therefore estimate tentatively that the visual SYNOP reports contribute significantly in about 7% of all forecasts of widespread rainfall.

5. Results of the case selection for cloud cases

A procedure similar to that used to select cases of visual SYNOP impact on rainfall forecasts (described in the previous section) was used to select cases of impact on low-level cloud cover (details are given in Appendix 2). Unfortunately, despite scanning all operational forecasts over the 7 month period November 1995 to May 1996 (some 852 cases) no examples of marked impact from visual SYNOP reports on 6-hr or 12-hr forecasts were found. Consequently, experiments to investigate the impact of automation or thinning on forecasts of low-level cloud cover were not possible. Results of the case selection procedure are discussed briefly below.

Of the 852 cases, a total of 13 cases were found in which forecasts of total cloud cover showed marked sensitivity to initial data. Of these, the forecasts of low-level cloud cover showed particular sensitivity in 3 cases. The NSYN experiment described in Section 2 was conducted on these 3 cases to assess the impact from visual SYNOP reports. In each case a synoptic evaluation suggested that the NSYN forecast was, for practical purposes, identical to the ALL OBS forecast - indicating negligible impact from the visual SYNOP reports.

It is difficult to draw conclusions from this null result. However, the difficulty encountered in selecting a suitable case may suggest that marked impact of visual SYNOP reports on forecasts of low-level cloud cover is an infrequent event. It would seem feasible that low-level humidity profiles, for example, might be expected to have more frequent impact than cloud observations - particularly since extensive low-level cloud cover often develops in cases when clear sky conditions may prevail at analysis time. SYNOP observations of cloud may be likely to have most impact when the evolution of cloud cover over the UK is dominated by the advection of cloud already present at analysis time. It would be instructive to perform further experiments to determine which observation types were responsible for the impact detected in the 3

cases mentioned above.

6. Summary of Results

The results of the study are summarised below. All results refer to experiments in which the use of the cloud and/or present weather parts of the SYNOP were varied. The non-visual part of the SYNOP from the full, mixed manual/automatic network, was used in all experiments.

- In the cases studied, a beneficial impact on rainfall forecasts obtained with SYNOP cloud reports from a network comprised mainly of manned stations was reproduced with a similar network comprised mainly of automatic stations.
- The beneficial impact was shown, in one case, to be retained when the use of cloud reports was restricted to a network comprised exclusively of automatic stations. (A similar experiment was not conducted for the other case.)
- In one case the beneficial impact on the rainfall forecast came mainly from the SYNOP cloud reports, in the other case present weather reports gave most of the impact.
- The "mainly-manned" and "mainly-automatic" networks had a resolution of ~80km, for the cases studied over northern Britain, representing a thinning of the full network. This thinning of the "visual" SYNOP reports resulted in precipitation forecasts up to ~20% less skilful than obtained with the full network.
- Withholding all available visual SYNOP reports reduced the skill at forecasting the occurrence of precipitation of moderate intensity to ~40% of that obtained with a control run using all data.
- It is estimated tentatively that SYNOP reports of cloud and/or present weather deliver benefits of similar magnitude to the two cases studied in about 7% of forecasts of widespread rainfall up to T+12hrs.
- For the two cases studied the impact of visual SYNOP reports on forecasts of total cloud cover, 1.5m temperature and 10m wind was very small.
- No suitable examples of marked impact of visual SYNOP reports on forecasts of low-level cloud were found. This may indicate that SYNOP cloud reports are not the most crucial observations for improving the accuracy of low-level cloud forecasts.

7. Conclusions and recommendations

7.1 Conclusions

It should be emphasised that although they provide useful guidance, results from only 2 cases are not sufficient to draw firm conclusions on the impact of automation or thinning of the visual elements of SYNOP reports. However, the following tentative conclusions may be drawn from the above results.

- Automation of cloud reports should not result in significant loss of skill for forecasts of widespread rainfall.
- The loss of present weather reports may result in significant loss of skill for some cases.
- Thinning the network of cloud and present weather SYNOP reports to a resolution of ~80km (representing a reduction in the number of these reports used from ~230 to ~70) could result in a noticeable loss in forecast skill (up to ~20%) for some cases.

7.2 Recommendations for further work

Recommendations for further work are summarised below.

- More cases need to be studied before firm generalisations as to the impact of automation can be made. (N.B. New cases involving MOPS cannot be performed without access to the MOPS processing on Nimrod. Currently there is no general "user interface" for MOPS).
- The cases reported here correspond to widespread rainfall events. The impact on forecasts for convective situations should not be overlooked.
- The cloud cases showing marked sensitivity to initial data (but not to visual SYNOP reports) should be re-examined to determine the observation types that were responsible for the sensitivity.
- Studies of the impact of network thinning must take account of the benefit from the non-visual parts of the SYNOP (e.g. pressure). The non-visual parts of the SYNOP have been shown to have considerable impact on rainfall forecasts (Graham et.al 1996).
- Investigations into the impact of automation may benefit from simulation

studies of the sensitivity of forecasts to the quality of the visual SYNOP data. Such studies would compare the impact from two networks with identical distribution but with the quality of the observations in one network degraded to match any degradation in quality likely to result from automation.

Acknowledgements

The authors would like to thank Eddie Spackman and John Prior of OPR branch for helpful discussions and for providing the network scenarios. Adam Maycock and Bruce Macpherson for help and advice with using MOPS, and Dawn Harrison and Brian Golding for help and advice in use of the Nimrod rainfall analyses.

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Appendix 1: Assessment of forecast skill

Rainfall cases

The skill of precipitation forecasts is assessed by comparing the accumulation of precipitation over the final 3 hours of the forecast with an analysis of 3-hour accumulation derived from the UK weather radar network by the Nimrod system. The Nimrod analyses include corrections for range and bright band effects, and for orographic enhancement of precipitation (Kitchen et al., 1994). Before use for forecast verification the Nimrod analyses, which have a grid resolution of 5km, are smoothed by assigning the average value over a square array of 9x9 grid points to the central point in the array. The forecast accumulations are smoothed in a similar way using a 3x3 grid-point array. The smoothing yields observed and forecast precipitation patterns that have similar scale representation (~50km). Verification of the model forecasts is restricted to the area covered by the UK weather radars (see Fig.1).

The measure of skill used is the Equitable Threat Score (Schaefer, 1990). The Equitable Threat Score (ETS) is calculated for two thresholds 0.5mm/3hrs and 2.0mm/3hrs. Scores for the 0.5mm/3hrs threshold measure the model skill at predicting the occurrence of rain of light intensity and greater; while scores for the 2.0mm/3hrs threshold measure the skill at predicting the occurrence of precipitation of moderate intensity and greater.

Cloud cases

For the selection procedure the skill of consecutive operational forecasts were compared using mean and rms errors in forecast total cloud cover (Max/random overlap), as measured against station observations.

For the data impact experiments, forecast skill at predicting low-level cloud cover was assessed subjectively rather than objectively. This was partly out of necessity (because of problems with the station verification software), but also from choice, since the higher degree of "noise" in the cloud fields (compared to rainfall fields) can lead to misleading results when objective verification is applied to a single case.

Reference

Kitchen, M., Brown, R. and Davies, A.G., 1994: Real-time correction of weather radar data for the effects of bright band, range and orographic growth in widespread precipitation. *Quart.J.Roy.Meteor.Soc.*,120,1231-1254.

Appendix 2: Details of the case selection procedure

As discussed in Section 4 the case selection procedure comprised three steps.

Rainfall cases

Step 1: Identification of cases in which initial data of any type (not necessarily visual SYNOP data) or model boundary information had a marked benefit on forecasts of widespread rainfall.

Step 2: Identification of cases in which MOPS humidity profiles or radar rainrates played a major role in the observed benefit.

Step 3: Identification of cases in which the visual SYNOP input to MOPS humidities played a major role.

Step 1

Step 1 was achieved (following Graham and Anderson, 1996) by looking for notable improvements in forecast skill between consecutive operational forecasts valid at the same time. Improved skill may be attributed to the additional observations available for assimilation in the later run (provided impact from the more recent boundary conditions used in the later run can be discounted). Cases in which objective measures of forecast skill indicate a significant improvement in the T+18 forecast over the T+12 forecast, or the T+12 forecast over the T+6 were short listed for study. Experience showed that significant local improvements in the rainfall forecast were usually associated with improvements in the ETS of a factor of 1.2 or more (measured over the entire radar area for a threshold of 0.5mm/3hrs). This threshold was therefore set as a criteria for defining a significant improvement. Two further criteria were also defined; a) the ETS of the later forecast must be greater than 0.1 for the 0.5mm/3hrs threshold (mean values of the ETS for widespread rainfall events are 0.25 at T+6 and 0.23 at T+12); and b) the hit rate of the later forecast must be greater than 50%.

Only cases in which observed rainfall was widespread were considered for selection. The criteria used for widespread rain used was that the analysed 3hr rainfall accumulations must exceed 0.5mm at more than 200 mesoscale model grid squares (corresponding to about 7% of the area covered by the radar network).

Of a total of 936 operational mesoscale forecasts considered 137 (~27%) showed useful impacts from recent observations or model boundary data. Of the 137 cases, 12 were chosen for more detailed study. For technical reasons involving the re-making of the MOPS humidity profiles, the majority of cases selected are for dates prior to 4th June 1996.

Step 2

The impact of MOPS humidities and radar rainrates was evaluated by re-running each of the 12 selected cases from Step 1, withholding these elements from the assimilation. The forecast benefit, expressed as a percentage of the benefit from the ALL OBS control, is shown for each of the 12 cases in Figs. 8a&b. At the lower threshold (Fig.8a) the MOPS and/or radar rainrates have a positive impact in 7 cases, a neutral impact in one case and a negative impact in 4 cases. At the higher threshold there is a negative impact in 2 cases and a positive impact in 8 cases. Two cases (Cases 7 and 11) had no observed accumulations above 2mm/3hrs. The impact was deemed to be "significant" if the benefit obtained when MOPS humidities and radar rainrates are withheld falls below 50% that obtained with the ALL OBS run at one or both of the rainfall thresholds. Four cases qualify as showing a significant impact, Cases 1,5,8 and 9. In three of these cases 1,8 and 9 the benefit falls below 50% at both thresholds. These four cases were progressed to Step 3.

Step 3

For the four cases selected in Step 2, the impact of the SYNOP cloud and present weather reports was assessed by re-running the forecasts using a "cut-down" version of the MOPS humidity profiles generated without the use of the SYNOP data. Results are shown for the low and higher thresholds respectively in Figs.9a&b. The histograms shown compare the benefit obtained when the "cut-down" MOPS humidities are used (NSYN), with that obtained when MOPS humidities are not used at all (NMOP). In Case 1, removing only the visual SYNOP component of MOPS reduces the benefit, at both thresholds, to about 40% that of the ALL OBS run, and almost as much as complete removal of the MOPS humidities. For this case we may conclude that the observed impact from MOPS humidities was dominated by the SYNOP components rather the satellite and radar components. The case was therefore considered suitable for studying the effects of the automation of SYNOPs and corresponds to Case A discussed in Section 3. For Case 8 the impact of removing SYNOPs is rather smaller (reducing the benefit to about 80%) at the lower threshold, but is significant at the higher threshold where the impact is reduced to around 40%. The removal of the remaining components of MOPS further reduced the benefit to about 5%. Case 8 was also selected for further study, and corresponds to Case B in Section 3. Cases 5 and 9 were not selected for further study. In Case 5 the SYNOP information appeared to have a negative impact at the higher rainfall threshold. In Case 9, SYNOP information was significant at the higher threshold (removal reducing the benefit to below 50%). However the main rainfall in this case was located over northern Scotland, where the surface network is already largely automated, it was therefore not considered a suitable case for further study.

Cloud cases

To select the cloud cases use was made of the mesoscale model station verification archive. Verification statistics for total cloud cover (Max/random overlap) were scanned for all forecasts during the period November 1995 to May 1996. A shortlist was made of cases in which both the mean and rms forecast errors for total cloud cover were reduced by 1 octa or more between successive forecasts valid for the same time (a total of 852 valid times were processed). Of the 852 cases 13 forecasts were found to meet the above criteria. Each of the 13 cases was then examined subjectively, leading to a shortlist of 3 cases in which marked data sensitivity to low-level cloud in particular was evident.

A NSYN run (see Section 2) was performed on each of the 3 cases. Unfortunately, in all 3 cases the NSYN runs were practically identical to the ALL OBS runs - suggesting no impact worth investigating from the visual SYNOP reports.

Reference

Graham, R.J. and Anderson, S. 1995: The relative utility of current observation systems to global-scale NWP forecasts; preliminary results. UK Met. Office FR Division Tech. Report No.173