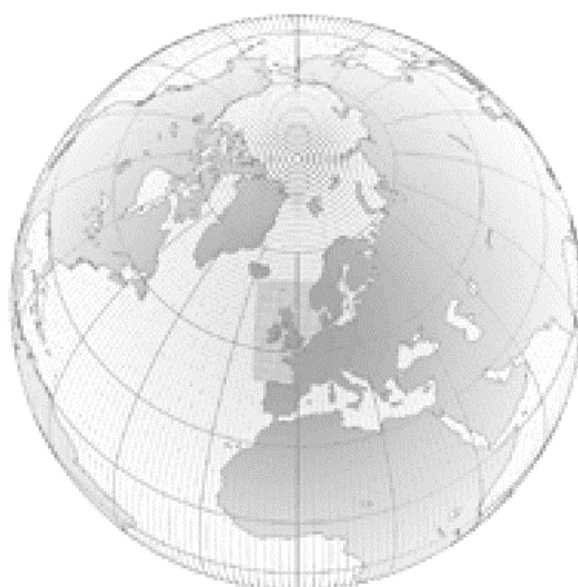


Numerical Weather Prediction

Assimilation of MOPS cloud data in the Limited Area Model



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Bruce Macpherson, Byron Chalcraft and Clive Wilson

email: nwp_publications@metoffice.com

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A decorative wavy line that starts on the left, dips down, rises up to a peak, and then dips down again towards the right.

Assimilation of MOPS cloud data in the Limited Area Model

by

B. Macpherson, B.V. Chalcraft and C. Wilson

Abstract

A trial is reported of the assimilation of cloud data into the LAM from a 'large area' version of the **M**oisture **O**bservation **P**re-processing **S**ystem (MOPS). This development arose from a joint CFO/NWP Workshop on 'Spanish Plume' cases, of which several were poorly handled by the LAM during summer 1994.

A subjective assessment of impact on precipitation forecasts found that for slow-moving, summertime, thundery systems the impact of MOPS can be markedly for the better as far as T+36. For the majority of situations the impact is either neutral or of just slight benefit. There is a worsening of rainfall forecasts in only a small minority of cases and mainly at short range. Objective verification of precipitation against 6-hourly Nimrod accumulations is consistent with these subjective conclusions. Objective verification of cloud cover shows a benefit, while overall impact on screen temperature is marginally detrimental beyond about T+12.

Operational assimilation of MOPS data in the LAM began on July 23rd 1996.

1. Introduction

The rain from Spain

One weather regime which can cause problems for forecasters in the UK in the summertime is known as the "Spanish Plume" (Morris, 1986). This situation often involves a weak cold front moving across England, a heat low over France and an upper trough moving east towards the UK. The heat low is associated with a plume of very warm moist air extending from Spain over France. Thunderstorms develop in this warm air ahead of the front and move north-east over the UK.

Forecasting thunderstorms in "Spanish Plumes" was the subject of a workshop with participants from the Central Forecasting Office (CFO) and the Numerical Weather Prediction (NWP) Development Division (Grant, Bader and Waters, 1995). In summer 1994, there were 13 such episodes. Forecasts for these events at one day ahead from the Limited Area Model (LAM) were assessed by forecasters as 'poor guidance' on 35% of occasions.

A pointer from the MES

The Mesoscale Model (MES) guidance for forecasts out to 18 hours was judged better than the LAM in roughly one third of all forecasts for the 1994 "Spanish Plumes." This led the workshop to recommend a southward extension of the MES domain. Further work revealed that the MES forecast for one event had benefited significantly from assimilation of cloud data from MOPS, the Moisture Observation Pre-processing System (Macpherson et al., 1996a). It was recognized that data differences were potentially at least as important as model resolution differences in explaining the relative performance of MES and LAM. At this point a 'large-area' MOPS cloud analysis was proposed for the LAM, with coverage of the data sparse Bay of Biscay, a key area for thunderstorm development in Plume events.

Adaption of the existing MES version of MOPS, run on the IBM, was completed by Maycock (1995). Initial data impact studies in a Plume situation were encouraging. Further cases were run where impact from cloud data was not especially anticipated. Finally, a four week trial in parallel with the operational LAM took place in June and July 1996. The MOPS cloud data for this phase of the trial were produced by the Nimrod system, which since 4th June 1996 has produced corresponding data operationally for the MES (Macpherson et al., 1996b).

2. MOPS cloud data

Cloud data for the LAM are processed within Nimrod by the same algorithms used in the Mesoscale (MES) version of MOPS. The 'large-area' coverage is shown in Figure 1. There are a couple of *minor* differences from the MES version. The background field for the LAM version is a pure model field (valid at t+6 or t+9), while in the MES version, the model field is combined with persistence and an extrapolation from a previous Nimrod analysis. There is no precipitation

analysis in the LAM version, and so no impact of observed precipitation on analysed 3-dimensional cloud structure.

3. Conduct of the trial

As already outlined, the trial was run in two phases. The case study phase first examined a few summer cases where beneficial impact *was* anticipated, followed by several more from winter covering a range of synoptic situations where impact was *not* particularly expected. Trial cases were run generally with 18-24 hours of data assimilation and two forecasts from data times 6 hours apart.

Phase two ran in parallel with the operational suite from 6th June 1996. There were occasional interruptions to the trial arising from computer problems. After these, the trial assimilation with MOPS data was run for 12 hours before a forecast was considered for assessment.

For the parallel trial, objective verification of 6-hourly forecast rainfall accumulations was performed against Nimrod accumulations within the UK radar area. This system, run in delayed real-time, was implemented approximately one week into the trial. Previously, parallel suite trials have verified rainfall accumulations against station data. In this trial, we have the benefit of the much better coverage afforded by radar data. The Nimrod accumulations were averaged to LAM resolution.

The winter and spring cases from phase one of the trial complement phase two run in the summer, though the two phases were run with different versions of MOPS. As the 'large-area' version of Nimrod MOPS was a new development, it was not possible to rerun old cases with it. In combining the conclusions of phase 1 and phase 2 of the trial, we are recognising that the Nimrod version of MOPS for the Mesoscale model was judged to be slightly better than the "IBM" version (Macpherson et al., 1996b).

4. Trial Results for Case Study Phase

4.1 Subjective assessment of precipitation

Six cases were examined, using a total of 13 different model run times, with 3 of the cases in summer and 3 in winter. The full list of cases is as follows:

13th July 1994:	Spanish Plume ahead of cold front
9th July 1995:	Thundery trough moving north.
25th July 1995:	Thundery trough
13th January 1996:	Slow-moving Atlantic frontal trough
7th March 1996:	Polar continental easterly
21st March 1996:	Depression across southern England, active warm front following

Of these 6 cases :

- 1 had substantially improved precipitation forecasts with MOPS,
- 3 had at least a slight improvement and
- 2 showed no significant differences from the operational output.

The Spanish Plume case of 13th July 1994 showed the largest benefit, in which the operational run failed to initialise any rain and the test run handled the rain area well, from northern France across southeast England to the North Sea and Holland (Figures 2 & 3). The benefit from MOPS is still clear at T+24. Two other summer thundery trough cases were slightly improved as was a cold, continental easterly. Out of the 13 model runs, in only one was there a preference for the operational output, and then only at short range over a small area (Figure 4). For the runs where the MOPS version was preferred the positive impact was present as far as T+36.

4.2 Objective assessment of screen temperature and cloud cover

Objective verification against UK stations was carried out for the 6 cases. The case-composite verification of screen temperature (Figure 5) showed a slight fall in RMS error with MOPS of around 2% overall, with a 6% fall at T+15 but a 3% increase at T+24. Mean temperature errors showed a slight reduction in negative bias at short range and a small increase from T+30 to T+36, but overall no significant difference.

The RMS total cloud cover error (Figure 6) increased with MOPS by nearly 0.4 okta at T+0 but from T+6 to T+30 there was a slight decrease in error of 0.1 or 0.2 oktas (3-5%). Mean cloud cover errors showed a negative bias increase of nearly 0.8 okta at T+0 but thereafter any differences were very small and overall about neutral.

4.3 Case study conclusions

The greatest impact on precipitation was seen in the three summer thundery rain cases, with little or no impact in the winter ones. The impact was generally positive, particularly for the Spanish Plume case. In general a very slight improvement in errors is evident in the case-composite objective verification statistics for screen temperature and cloud cover.

5. Trial Results for Parallel Run Phase

5.1 Precipitation

5.1.1 Wet Spell 1: 7th-11th June "Thundery trough followed by broad southwesterly"

- *Subjective assessment*

13 model runs were assessed and the outcome was:

MOPS run preferred in	5
operational preferred in	3
no preference in	5

Where there was a preference it was in general only slight, including the runs where the operational output was preferred. In one run the MOPS version had more spurious rain at short range (T+0 & 3 only) than the operational, with another having overdone convective precipitation on the Continent (see Figure 7). The positive impacts were for the most part in the first 15 hours of the forecasts but in some runs to T+30. In a third run, the operational's frontal rain-band was better (Figure 8). A typical frame where the MOPS version output was preferred is shown at Figure 9. Objective assessment of precipitation was not available for this period of the trial.

5.1.2 Wet Spell 2: 20th June - "Thundery trough"

- *Subjective assessment*

8 model runs were assessed, starting with the 06Z run on the 18th and ending with the 00Z run on the 20th of June. In **all** of these the MOPS version was preferred and in two (06Z and 12Z runs on the 19th) the improvement over the operational output was quite dramatic. There was consistently better advice from the MOPS version as to the development and subsequent intensity of an area of heavy rain that affected southern England on the morning of the 20th, (Figure 10). Most of the positive impact was seen in the first 24 hours of the forecasts but in the earliest runs of the series, i.e. those with longer lead times, the positive impact was still seen at T+36.

Additionally, the 18/6/96 06Z *Mesoscale* model run suffered from some spurious rain over parts of Ireland (associated with medium level instability and probably mis-assignment of cloud top height from MOPS) but the LAM run with MOPS did not. It should be noted, however, that this kind of problem could affect LAM forecasts occasionally. There is a scheme under development in the Satellite Image Applications Group to correct IR cloud top temperatures with water vapour imagery, which it is hoped will cure the problem.

- *Objective assessment*

The verification against Nimrod accumulations was performed for thresholds of >0.1mm/6 hours and >2mm/6 hours. Scores computed were Hit Rate (HR), False Alarm Rate (FAR) and Equitable Threat Score (ETS), the latter being a skill score which corrects for the contribution

expected from a random forecast. The results for this event (Figure 11) support the subjective assessment above. For the 2mm threshold, the MOPS scores show a consistently higher ETS, especially in the range T+24 to T+36. This is a consequence of a higher HR and a FAR which is no worse on average. For the 0.1mm threshold (not shown), the MOPS ETS was similar to T+24, and better beyond T+24.

5.1.3 Wet Spell 3: 25th-26th June - "Weak front"

- *Subjective assessment*

7 model runs were assessed, from 12Z on the 24th to 00Z on 26th. There were no significant differences between the operational and MOPS versions of the LAM in 6 of these, therefore no preference. However, the 06Z run from the 25th did have slightly better guidance from the MOPS version in that it correctly had a narrower rain belt on a weak cold front as it crossed southern Britain, with the positive impact evident out to T+27.

- *Objective assessment*

Figure 12 gives scores for the 0.1mm threshold. There is little difference as far as T+24, though the MOPS version has an edge by T+36 with a higher HR and lower FAR.

5.1.4 Wet Spell 4: 1st-7th July - "Showery week at Wimbledon"

An objective assessment was compiled for the full week of forecasts, in what was a very showery period. Figure 13 gives results for both 0.1mm and 2mm thresholds. At the lower threshold, runs with MOPS score marginally worse up to T+12, with little difference thereafter. At the higher threshold, there is little MOPS impact until T+27 and beyond, when a benefit becomes apparent. There was no subjective assessment for this period.

5.2 Objective verification of cloud cover and screen temperature

A set of forecasts drawn from both the 'mainly wet' and 'mainly dry' periods of the trial was verified against UK stations. For screen temperature (Figure 14), the trial verifies a little worse than the operational from T+9 onwards (This was true of both the wet and dry periods, but was more noticeable in the wet period). Rms errors are 2% higher overall, though 7% higher at T+15.

Since the parallel phase is in summer only, it is worth combining results with the case study phase which includes winter cases (Although this neglects any differences between the performance of IBM and Nimrod versions of MOPS, the impact of these on temperature verification was negligible in the trial of the Nimrod version). In the combined results, the impact of MOPS data on screen temperature (Figure 15) is marginally beneficial in the first 12 hours and slightly detrimental beyond T+12. For example, there is a 2% improvement in rms at T+9, and a 4% worsening at T+24.

For cloud cover, verification is available for the 'mainly wet' spell and shows benefit (Figure 16), as in the case study phase. The improvement is around 5% overall. Despite this improvement in cloud cover, a slightly detrimental temperature impact is present.

6. Conclusions

The results of assimilating MOPS data in the LAM can be summarised as follows. The impact on precipitation forecasts in slow-moving, summertime, thundery systems can be markedly for the better (out to 36 hours ahead) in capturing rain bands that would otherwise be largely missed. For the majority of precipitation situations, and for the winter cases tested, the impact is either neutral or of just slight benefit. There is a worsening of rainfall forecasts in only a small minority of cases and mainly at short range (12 -15 hours ahead), showing itself in occasional weakening of coherent frontal rain bands. The parallel trial also showed evidence of an earlier onset (by about 3 hours) of diurnal convection on the continent, though no examples of the same behaviour over the UK were seen. Objective verification of cloud cover shows a small benefit, with a reduction in negative bias and a lowering of rms error over much of the forecast period. Overall impact on screen temperature is marginally detrimental beyond about 12 hours into the forecast.

MOPS data in the MES sometimes give rise to spurious mid-level instability, a fault which could happen occasionally in the LAM. There is a project underway in NWP division to rectify this problem by using water vapour imagery to help with height assignment of thin cirrus.

Improved LAM forecasts should have a beneficial effect on the UK MES forecasts through improved boundary values, although no evidence has been obtained to support this.

Based on the findings of the trial as described above, operational assimilation of MOPS data in the LAM began on July 23rd 1996. It should be noted that the 'large-area' MOPS analysis can easily be tailored for the proposed high resolution global model. Similar benefits to those found in the LAM can be expected.

7. Acknowledgements

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8. References

Grant J.R., Bader M.J. & Waters A.J. 1995. Forecasting thunderstorms in "Spanish Plumes". Forecasting Research Division Technical Report No. 170.

Macpherson B., Wright B.J., Hand W.H. & Maycock A.J. 1996a. The Impact of MOPS Moisture Data in the U.K. Meteorological Office Mesoscale Data Assimilation Scheme, Mon. Weath. Rev., **124**: 1746-1766.

Macpherson B., Chalcraft B.V., Maycock A.J. & Golding B.W. 1996b. Assimilation of MOPS moisture data from the Nimrod nowcasting system into the UK mesoscale model. Forecasting Research Division Technical Report No. 198.

Maycock A.J. 1995. Conversion of the MOPS system for use in the Limited Area Model Forecasting Research Division Working Paper No. 172.

Morris R.M. 1986. The Spanish Plume - testing the forecaster's nerve. Meteorol. Mag. **115**: 349-357.