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1. INTRODUCTION

Weather systems are sometimes difficult to analyse over data-sparse areas, especially if they are small scale. For example, the analysis of small depressions critically influences the future position and intensity of precipitation. Satellite imagery can provide valuable clues about the position and structure of such systems.

A method of exploiting satellite imagery for improving the analysis is described, using an image-based conceptual model of airflow derived from the cloud motion winds (CMWs). This model provides the framework for inserting observations to modify the NWP analysis. The method is illustrated using a case study.

2. NWP MODEL DEFICIENCIES

The forecast at 12 UTC on 31st March 1993 from the Limited Area Model (LAM) of the UK Unified Model (Cullen 1991) was for light rain over the extreme southeast of England, associated with a small shallow depression moving east along the English Channel, clearing the east coast soon after 12 UTC on 1st April (Fig. 1). In the event, the depression was a little deeper and further west (Fig. 2); the rain was more widespread and prolonged and did not clear the east coast of England until 12 hours later than forecast. As the rain area was slow-moving, rainfall totals reached 10 to 20 mm.

The shortcomings of the LAM guidance arose from problems with the LAM analysis:

(a) The depression developed from a significant area of enhanced convective cloud, C, over the North Atlantic west of Biscay (Fig. 3). This cloud, which was present on the satellite images during the morning of the 31st, was developing into a comma shape. The cloud signature is typical of that caused by positive vorticity advection increasing with height ahead of an upper trough. A well-defined surface trough or even a low pressure centre often lies beneath a comma cloud (see e.g. Businger and Reed, 1989). However, the analysis from the LAM at 12 UTC on 31st (Fig. 4a) only had a shallow surface trough (T) in this area which was not sharp enough to produce the surface wind changes reported by drifting buoys in the area.

(b) Fig. 5 shows the differences between the CMWs and the winds from the LAM analysis at 11 UTC on 31st March. The CMWs reveal a stronger southerly component at around 45°N 13°W than in the LAM. The trough and subsequent shallow low were analysed manually using all available observations and the speed of the system determined. When the CMWs at 11 UTC were plotted relative to the movement of the surface trough at this time (255 degrees 35 knots), a definite circulation was revealed (Fig. 6a). These winds had passed quality control checks and been included in the assimilation. However, they had not corrected the LAM background fields sufficiently to include the intensity of this circulation.

(c) The satellite images showed layered cloud feeding northwards into the main convective cloud area by 14 UTC (Fig. 3). This pattern was not consistent with the LAM's analysed relative humidity at 700 hPa (Fig. 4b) which was low near the developing comma C and high in the cloud-free area east of C. The S-shaped edge on the west of the humidity bulge at A is a typical signature of a small circulation in the relative wind field and suggests that the LAM was developing a small circulation too far east.

3. METHOD OF PROVIDING ADDITIONAL DATA TO THE LAM

An attempt was made to improve the LAM's analysis by incorporating additional data for 12 UTC on 31st March into the LAM and re-running the forecast.

The relative winds in Fig. 6a and cloud patterns from animated satellite images were used as the basis for deriving a conceptual model of the airflow (Fig. 6b) based on earlier studies of similar cloud patterns (see e.g., Young, 1995). The important feature is a conveyor belt of warm, moist air ascending from the comma tail and curving into the head, representing the main area of mass ascent which produced the layered cloud and also enhanced the convective cloud.

The additional data were based on the conceptual model (Fig. 6b) and incorporated in two parts:

(a) The CMWs were re-inserted with more weight. (The weighting of CMWs is approximately the same as the radio-sonde winds up to 500 hPa, but is less at higher levels.) At positions where CMWs were available, additional winds, based on the conceptual model, were inserted below cloud-top level to simulate the warm conveyor belt flow. For simplicity, these extra winds were inserted at 800 and 700 hPa in the tail and 700 and 600 hPa in the head of the comma.

(b) An attempt was made to increase the humidity at low levels at B (Fig. 4b) in the comma tail, where the LAM's relative humidity was deficient, and eliminate the bulge of high humidity at A. To insert realistic humidities, values were based on a previous case of a comma cloud which passed over the UK and therefore had a lot of observational data. This resulted in small changes in the humidity field including a slight reduction in the bulge at A.

4. RESULTS

The revised forecast (Fig. 7) agreed better with the observed evolution (Fig. 2) than the original forecast (Fig. 1). The surface depression was a little deeper and its eastward movement was slower. Although the western edge of the rain was still a little too far east, the revised rainfall pattern was essentially correct at 12 UTC on 1st and the rain cleared the east coast of England after 18 UTC. This guidance on the rain area was a significant improvement and turned out to be as good as the operational forecast run 12 hours later.

Two further re-runs of the LAM, one with wind insertion only and one with humidity modification only, showed that nearly all of improvement arose from changing the wind rather than the humidity. This was not surprising as the effect of the humidity modification on the original LAM analysis was only slight.

5. CONCLUSION

The analysis of a warm conveyor belt, derived chiefly from satellite cloud patterns, was matched with a well-established conceptual model. This model enabled the CMWs and humidity data from satellite images to be fitted into a physically and dynamically consistent framework and therefore to be more effectively assimilated into a NWP model. In particular, based on the conceptual model, it was possible to insert reliable winds below the cloud top to take account of the feed of moist low-level air into a developing system which is very important in determining the character of the evolution.

The method, which is particularly useful over data-sparse areas, gave a positive impact in the forecast of precipitation. In the case described, much of the rain fell at the rear of the depression. In this region, a good forecast is particularly important because here, precipitation may be heavy and affect an area for a long time even with small and shallow depressions (see e.g., Grant et al, 1993).

It is possible to extend this method to other weather systems, especially to those for which well established conceptual models have been derived . These include fronts and depressions at different stages in their life cycles (see, for example, Young 1995). The method also has the potential for being applied automatically using pattern recognition techniques (see e.g., Pankiewicz, 1994) which incorporate the CMWs or winds from water vapour imagery to recognise the appropriate conceptual model.

ACKNOWLEDGEMENT

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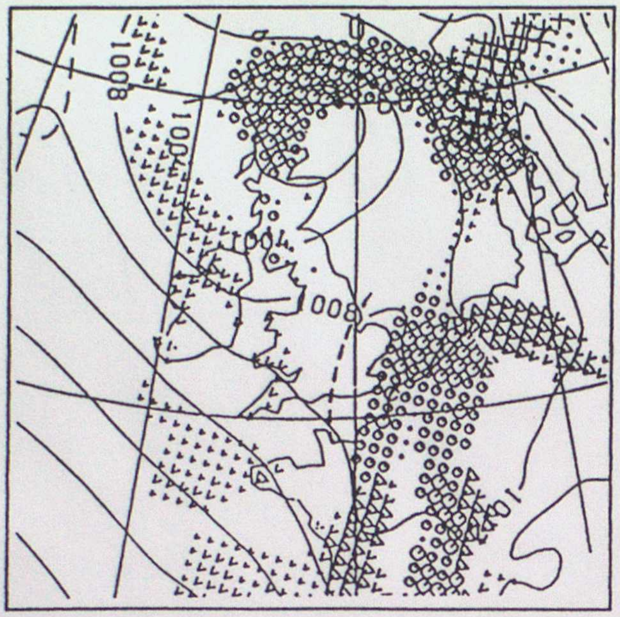

Fig. 1. LAM 24 hour forecast valid at 12 UTC on 1st April 1993. Circles are dynamic and Vs are convective rain; the larger symbols denote heavier precipitation. Dashed line is the rain edge from Fig. 7.

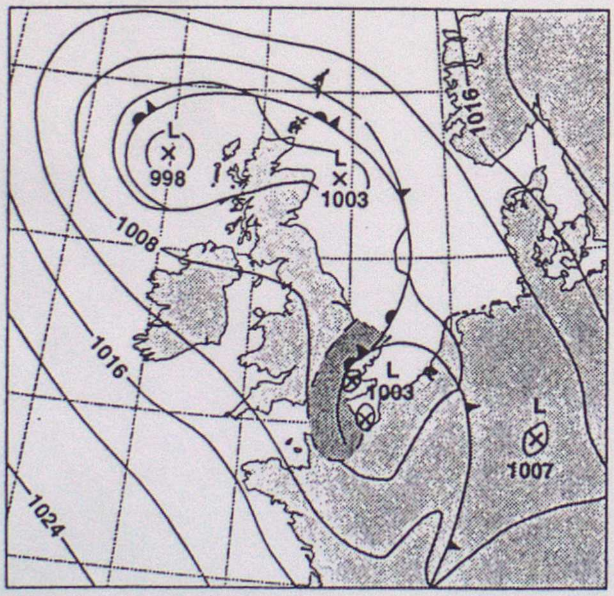

Fig. 2. MSL analysis at 12 UTC on 1st April 1993 showing rain area (shaded), analysed from surface observations and radar.

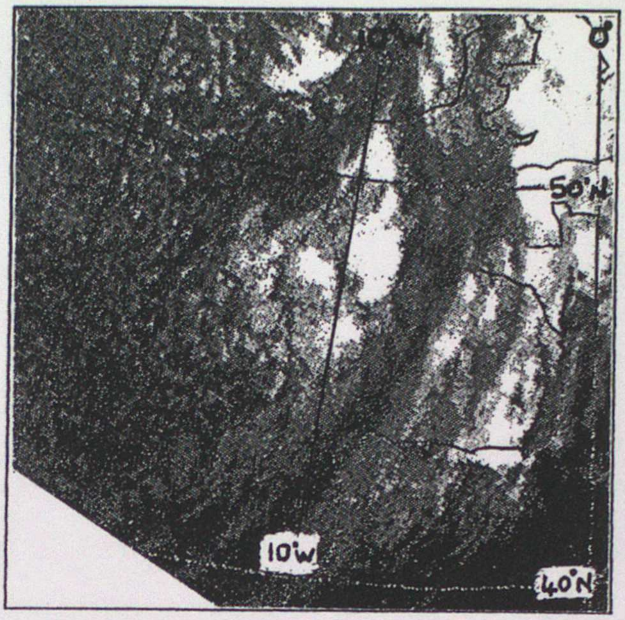

Fig. 3. Meteosat IR image to the SW of the British Isles at 14 UTC on 31st March 1993. C is a developing comma cloud.

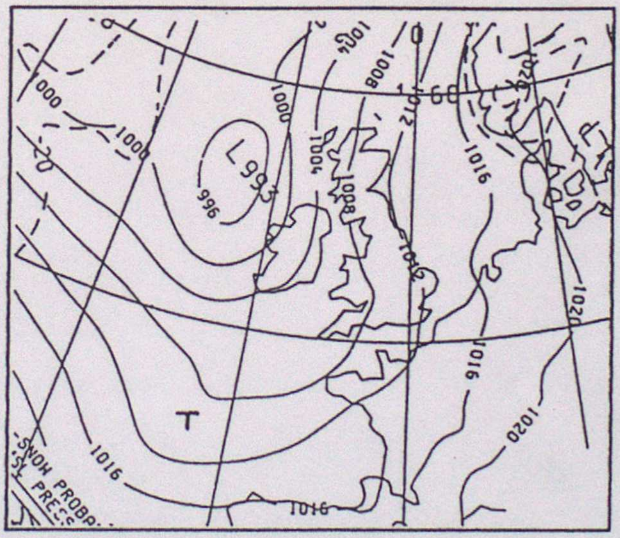

Fig. 4(a) LAM MSL pressure analysis at 12 UTC on 31 March 1993 T is a shallow surface trough.

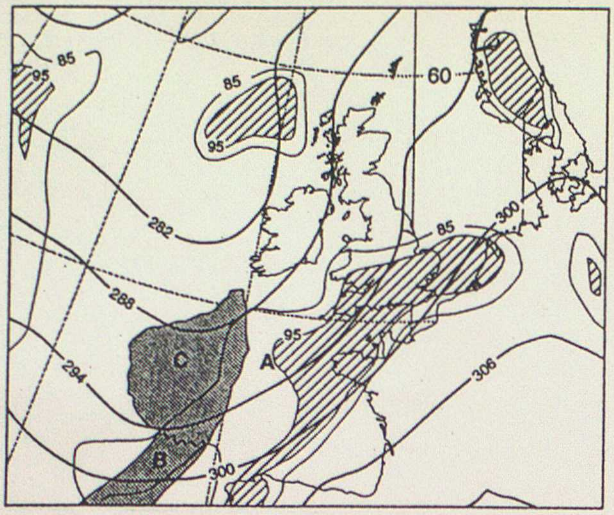

Fig. 4(b) LAM analysis at 12 UTC on 31 March 1993 at 700 hPa showing contours (dam) and relative humidity field (%). Cross-hatching denotes RH>95%. Letters locate features discussed in the text.

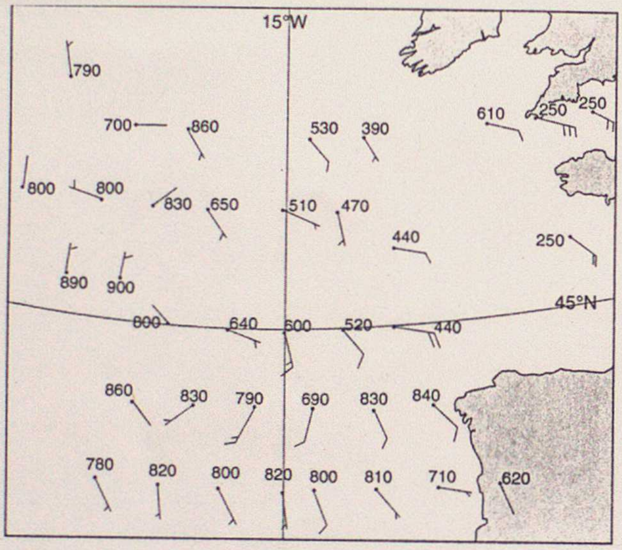

Fig. 5 Vector differences at 12 UTC on 31st March 1993 between cloud motion winds (CMWs) and winds at the same levels in the LAM analysis from which the forecast in Fig. 1 was derived. Numbers indicate pressure (hPa) assigned to the CMWs.

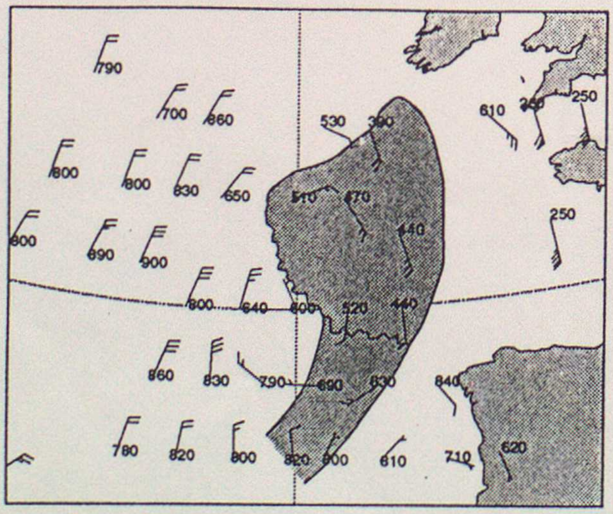

Fig. 6(a) CMWs at 11 UTC on 31st March 1993 converted to winds relative to the developing comma cloud in Fig. 3. Wind levels shown in hPa.

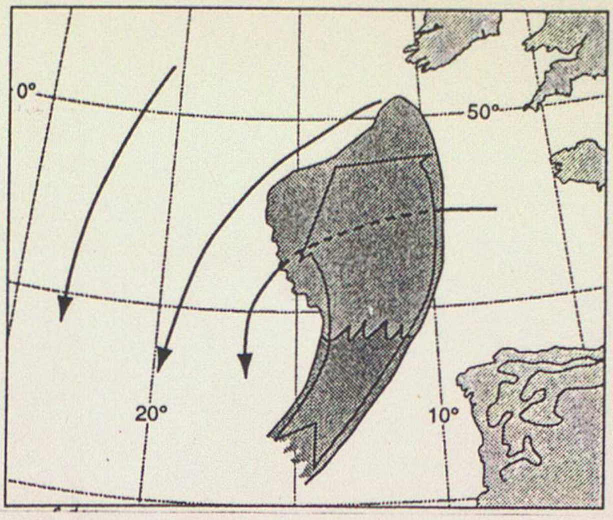

Fig. 6(b) Conceptual model of the airflow relative to the motion of the developing comma; light shading denotes higher- and darker shading low-topped cloud. Broad arrow is the warm conveyor belt. Cold airflow is depicted by line arrows, dashed beneath the warm air..

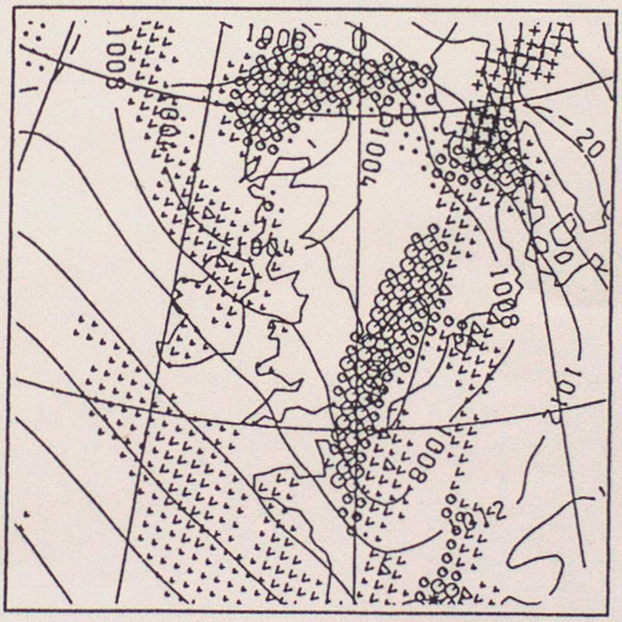

Fig. 7. LAM 24 hour forecast valid at 12 UTC on 1st April 1993 after inserting observations consistent with Fig. 6(b). Symbols as in Fig. 1.