A STUDY OF DIFFERENT METHODS OF INTERPOLATING NUMERICAL FORECAST DATA FOR THE PURPOSE OF VALIDATING CLOUD MOTION WINDS

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ABSTRACT

This paper suggests ways of improving the current method used to interpolate the fine-mesh winds with the SCMW (Satellite Cloud Motion Winds) to provide the wind data required by the Operational (fine-mesh) Model. The SCMWs are provided by Meteosat. Statistics are calculated for different ways of performing horizontal, vertical and time interpolation.

1 Introduction

At present the method used to interpolate fine mesh winds (Bell and Dickinson, 1987) for the assimilation of wind data for the numerical model is as follows using :
a) pressure as the vertical coordinate.
b) simple horizontal interpolation to nominal position of the SCMW.
c) interpolation to the nominal time of the SCMW.
The purpose of this research is to investigate how this method could be improved by using temperature as the vertical coordinate, using weighted means for the horizontal interpolation and using the true time of the SCMW.

ESA convert the temperature of SCMWs to pressure using ECMWF forecasts (in general these are 24 or 36 hour forecasts). It seems likely that the use of shorter range, higher resolution forecasts will give rise to improved statistics.

Meteosat CMWs are calculated for segments which comprise 32 x 32 infra red pixels. At the SSP this is an area of 160 x 160 km. Over the U.K. this is an area of approximately 160 x 320 km . Given that CMWs represent the wind on this scale, and given that the grid length of the fine mesh is approximately 75 km, it seems likely that it would be better to compare CMWs with some weighted mean wind than to compare them with a value interpolated to the point of the CMW. One commonly heard criticism of SCMWs is that they have a low speed bias when compared with interpolated model data. Given that vectorial averaging of a number of winds will in general reduce the mean speed, it seems plausible that averaging (as opposed to interpolation) might ameliorate this shortcoming.

Most users of METEOSAT CMWs will be unaware that the true time of the CMW is different from the nominal time. This arises because the nominal time of all CMWs produced from one triplet of images is constant, whereas all the component images take 25 minutes each to be compiled. So although the nominal time of all segments is 11:00, in actual fact, the true time varies from about 10:32 (for winds at 50^0 south) to around 10:52 (for winds at 50^0 north).

2 Method

METEOSAT CMWs produced operationally by ESOC are collected together with model data in the neighbourhood of each CMW in real time. Normally the analyses verify 2 hours before the SCMWs and the forecasts verify 1 hour after the SCMWs but these time intervals are reversed during eclipses, when the SCMWs have a nominal time of 22z instead of 23z. Because these forecasts are made by the fine mesh model which only extends to 30^0 north CMWs south of that latitude are not assessed.

A combination of two ways of performing time interpolation, two ways of performing vertical interpolation and two ways of performing horizontal interpolation provide the 8 model winds to be compared with the satellite wind. The accuracy of each method is assessed by comparing the mean speed difference, the mean direction difference and the root mean square vector difference calculated between the CMW and the interpolated wind for each of the eight cases.

As the satellite scans the earth's disk the lines of data are read in from the southern edge to the northern edge of the disk and hence the time of the satellite wind is a linear function of the y co-ordinate of the segment within the full disk. The y coordinate can be calculated from the latitude and longitude of the CMW.

Vertical interpolation is carried out using either pressure or temperature as the vertical coordinate. (Note that the winds at model levels (sigma levels) have already been interpolated to the standard pressure levels). In order to calculate a wind from the model data, using pressure as the vertical coordinate, it is interpolated linearly from winds at standard pressure levels which span the pressure of the CMW. When temperature is the vertical coordinate the process is analagous, but of course the temperature at a number of levels have to be examined to find the pair of levels whose temperatures span the temperature of the CMW. In addition a preliminary step is performed in which the temperatures at all levels are interpolated horizontally and with respect to time.

Horizontal interpolation is performed by either interpolating the model forecast data to the nominal position of the CMW (in the horizontal these are the four model grid points which span the nominal location of the CMW) or by the calculation of a weighted mean of model data. The process for calculating the weights for a particular segment is as follows : There are 32 x 32 infra-red pixels in the segment. The position of each pixel in the segment is calculated and for each of these pixels the nearest fine-mesh grid point is also calculated. A value of 1 is then added to the weight for that grid point. After processing all pixels in the segment, the weights for all grid points for that segment are divided by 1024.

3 Results

The wind data used in this investigation ran from 7th February 1990 until the 5th August 1990. The number of low level winds produced in this investigation was 8168 and the number of high level winds used was 9684. The method used to produce the winds ran automatically and the data was generated every 12 hours. Statistics were produced separately for low level and high level winds. For the low level winds, Table 1.1 shows the statistics for interpolations carried out using time promulgated with the observations and Table 1.2 displays the results for interpolations carried out using time corrected for satellite disk scanning. Tables 2.1 and 2.2 show comparable statistics for high level winds. All the wind statistics are in knots.

We expected the smallest rms vector difference values and hence the smallest errors to occur in Tables 1.2 and 2.2 in the box where temperature is used as the vertical coordinate and weighted means are used in the horizontal interpolation method. However, the algorithm used for calculating the temperature weights did not take into consideration the case of a very hot or a very cold satellite temperature which would lie outside the range of the model temperatures. This bug was not discovered until the project was nearing completion and hence some of the values produced using temperature as a vertical coordinate are inaccurate. However, the other values produced are encouraging. By using time corrected for satellite disk scanning the statistics are slightly improved. The sharpest improvement occurs when weighted means are used instead of simple horizontal interpolation.

Since a small number of values with very large errors can dominate statistics a set of contours were computed to overcome this problem. By drawing diagrams the effect of outliers, which can give an anomolous mean, is reduced. If we were considering scalar quantities we would generate graphs but since wind is a vector quantity we generated contour plots to show up speed and direction biases.

These contours depict the relationship between the errors in the wind speeds and wind directions for both high level and low level winds. Figure 1 indicates the x axis and y axis used, alpha = satellite dir-model wind dir, x = sat speed-model speed x cos(alpha), y = model speed x sin(alpha). Hence, the speed bias is given by the contour of maximum probability displaced in x axis and the direction bias is given by the contour of maximum probability displaced in y direction. Thus if, for example, the only source of error in the satellite winds was a speed bias, all winds would lie along the x axis, with distance from the origin being a function of that bias. Similarily, if the only source of error was a direction bias, all winds would lie along the y axis, with distance from the origin being a function of that bias.

Figures 2.1 and 2.2 show the contours generated for high level winds. Algorithm 1 represents the errors occuring in the present method used for interpolating model winds and Algorithm 8 is the case where temperature is used as the vertical coordinate, weighted means are used in the horizontal and the time is corrected for satellite disk scanning. The contours produced for the low level winds were not quite as encouraging.

4 Concluding Remarks

From the results produced it appears plausible that there is room for significant improvement in the current method used to interpolate these winds operationally - by using temperature as the vertical coordinate, corrected time values and weighted means in the horizontal. However we require more knowledge about the way SCMWs are actually produced, especially from the Japanese and American satellites, to enable us to interpolate the model winds more accurately.

5 References

Bell, R.S. and Dickinson, A.(1987)
The Meteorological Office operational numerical weather prediction system *Met Office Scientific Paper No. 41 HMSO*

Statistics for low level winds (pressure above 500 mb)

Table 1.1 interpolation using time promulgated with the observations

vertical interpolation	pressure	temperature	horizontal interpolation
mean speed difference (knots)	-0.08558	-0.19381	simple
mean direction difference (deg)	-3.31832	-5.03146	
rms vector difference (knots)	8.55190	8.65477	
mean speed difference (knots)	-0.02143	-0.13492	weighted mean
mean direction difference (deg)	-4.01237	-4.47147	
rms vector difference (knots)	8.30118	8.40836	

Table 1.2 interpolation using time corrected for disk scanning

vertical interpolation	pressure	temperature	horizontal interpolation
mean speed difference (knots)	-0.07811	-0.17801	simple
mean direction difference (deg)	-3.18915	-4.38467	
rms vector difference (knots)	8.53915	8.62311	
mean speed difference (knots)	-0.00967	-0.12169	weighted mean
mean direction difference (deg)	-3.55485	-4.31660	
rms vector difference (knots)	8.28888	8.39170	

Statistics for high level winds (pressure below or equal to 500 mb)

Table 2.1 interpolation using time promulgated with the observations

vertical interpolation	pressure	temperature	horizontal interpolation
mean speed difference (knots)	-0.41574	-0.11565	simple
mean direction difference (deg)	-3.81578	-3.19217	
rms vector difference (knots)	15.49298	15.49210	
mean speed difference (knots)	-0.29513	-0.01022	weighted mean
mean direction difference (deg)	-3.87949	-3.44093	
rms vector difference (knots)	15.19537	15.18594	

Table 2.2 interpolation using time corrected for disk scanning

vertical interpolation	pressure	temperature	horizontal interpolation
mean speed difference (knots)	-0.41863	-0.11968	simple
mean direction difference (deg)	-3.82621	-3.11431	
rms vector difference (knots)	15.46426	15.46773	
mean speed difference (knots)	-0.29729	-0.01817	weighted mean
mean direction difference (deg)	-3.73234	-3.22697	
rms vector difference (knots)	15.18309	15.17302	

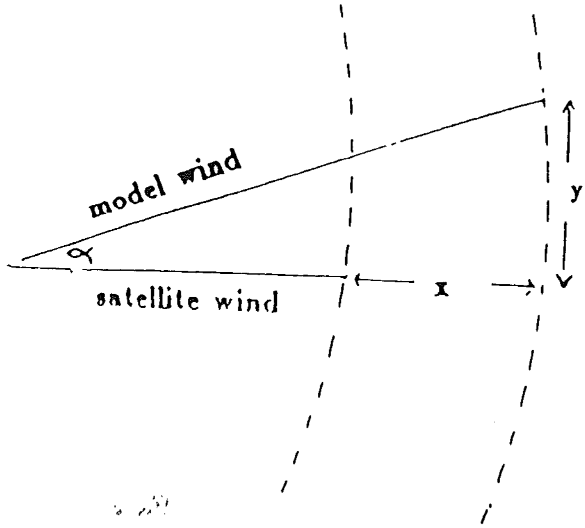

FIGURE 1

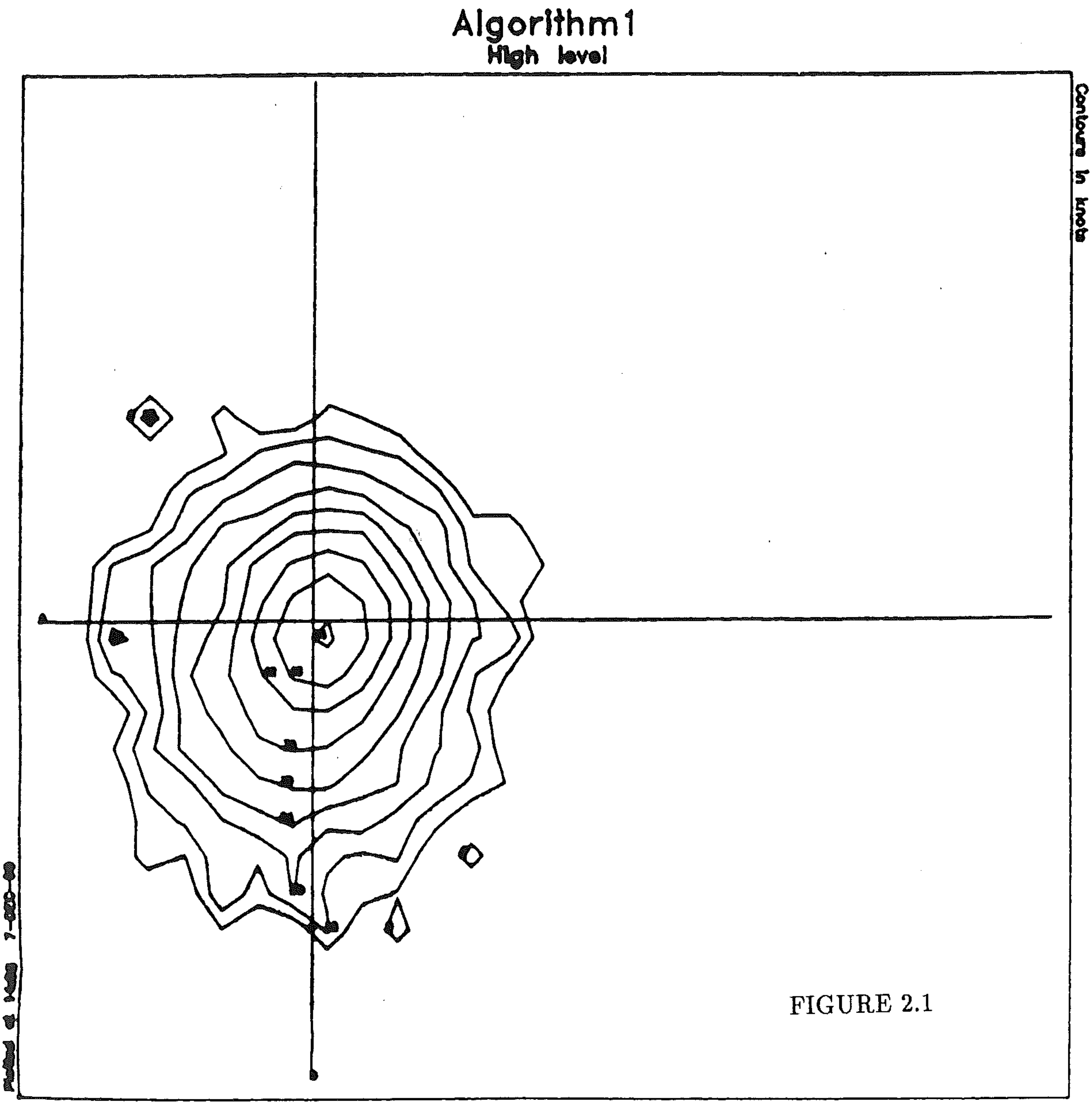

FIGURE 2.1

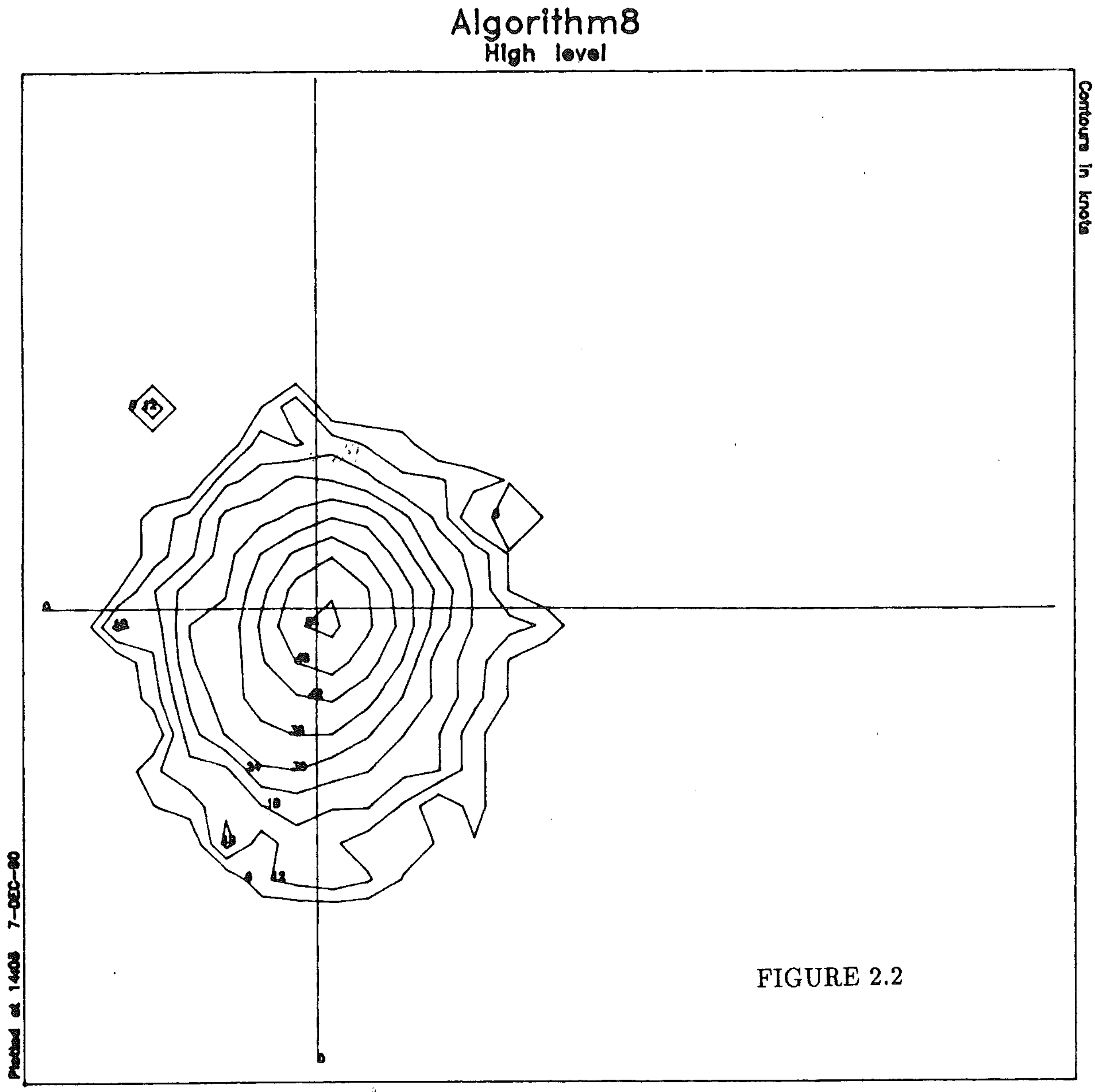

FIGURE 2.2