Interpolation of model forecasts and analyses to the WMO/CBS verification grid for the purpose of verifying Canadian NWP models against analysis: identification of the problem and solutions.

1. Identification of the problem:

CMC participates in a monthly exchange of NWP model verification data with the other major NWP centres of the world. The exchange is standardized in the WMO Manual on the Global Data Processing System (http://www.wmo.int/pages/prog/www/DPS/Manual/WMO485.pdf, pp120-122).

Data from this exchange was presented in a report from the European Centre for Medium-Range Weather Forecasting (ECMWF), which noted the following regarding the verification of 850 hPa wind forecasts over the Tropics:

> *"The most noticeable changes over the past year are the improvement in 850 hPa wind errors for the NCEP forecasts at short-range* ***and the contrasting increase in errors for the Canadian forecasts****."* (bold added).

Technical Report No. 547

Author/s Richardson, D. J. Bidlot, L. Ferranti, A. Ghelli, G. van der Grijn, M. Leutbecher, F. Vitart and E. Zsoter:

Title Verification statistics and evaluations of ECMWF forecasts in 2006-2007.

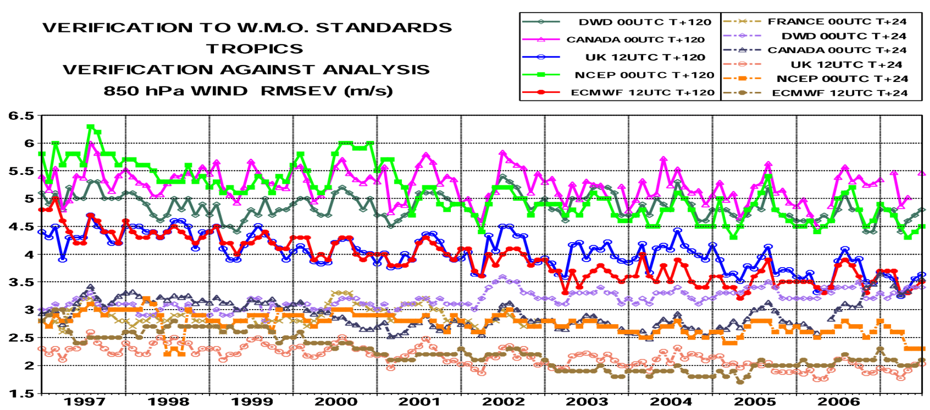

Figure 1: 850 hPa wind root mean square error vector (RMSEV) over the Tropics (20N-20S, from ECMWF Technical Report No. 547, Richardson et al.)

The problem was confirmed at the Canadian Meteorological Centre to have become particularly obvious with the implementation of the 33km meso-global model at the end of October 2006 (fig. 2).

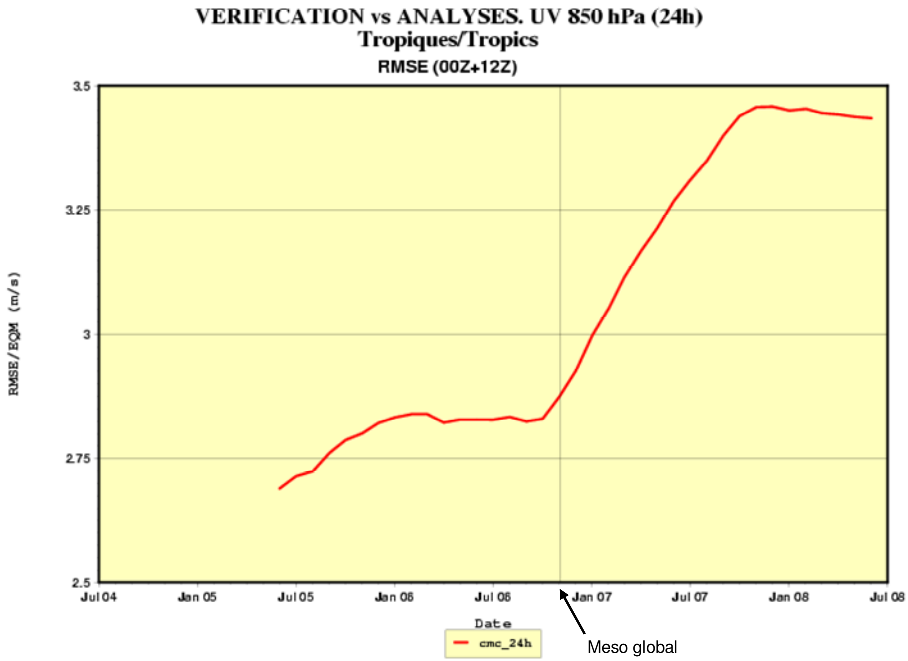

Figure 2: 12-month running mean of 24-hour GEM global model 850 hPa wind RMSEV, scored against analysis over the Tropics (20N-20S).

Further analysis indicated mainly Global model scores of temperature and wind forecasts verified against analysis were affected. Similar pattern of RMS errors to that of figure 2 was noted for winds up to 500 hPa over both Northern and Southern Extra-tropics (20-90N and 20-90S, respectively) and temperatures up to 850 hPa over the Tropics (20N-20S) and Southern Extra-tropics. Scores of geopotential height were not affected and, in fact, a reduction in errors was noted following implementation of the meso-global model. Verification against observations of geopotential height and temperatures were similarly improved with the meso-global model, while the effect on wind forecast scores was more or less neutral.

Investigation of the issue determined that the problem lay not with the new model itself, which overall had a highly positive impact on forecasts, but rather with the bi-cubic interpolation scheme employed at CMC to interpolate model forecast and analysis fields to the WMO verification grid.

The WMO/CBS verification grid is 2.5^0 by 2.5^0, or approximately 278 km north-south, whereas the meso-global grid is a 33km grid model (fig. 3). Bi-cubic interpolation from the higher resolution source-field (meso-global) grid to the much coarser verification grid considers only a small sample of source-field grid-point values around the target verification grid points. As a result, unrepresentative values of the source fields can be interpolated to the verification grid points, particularly with “noisy”, or non-continuous, fields such as temperature, wind and humidity. It is more apparent in the lower levels of the atmosphere owing to higher variability due to terrain effects. As well, it is doubled for scores against analysis because the interpolation must be done on both the forecast and analysis fields.

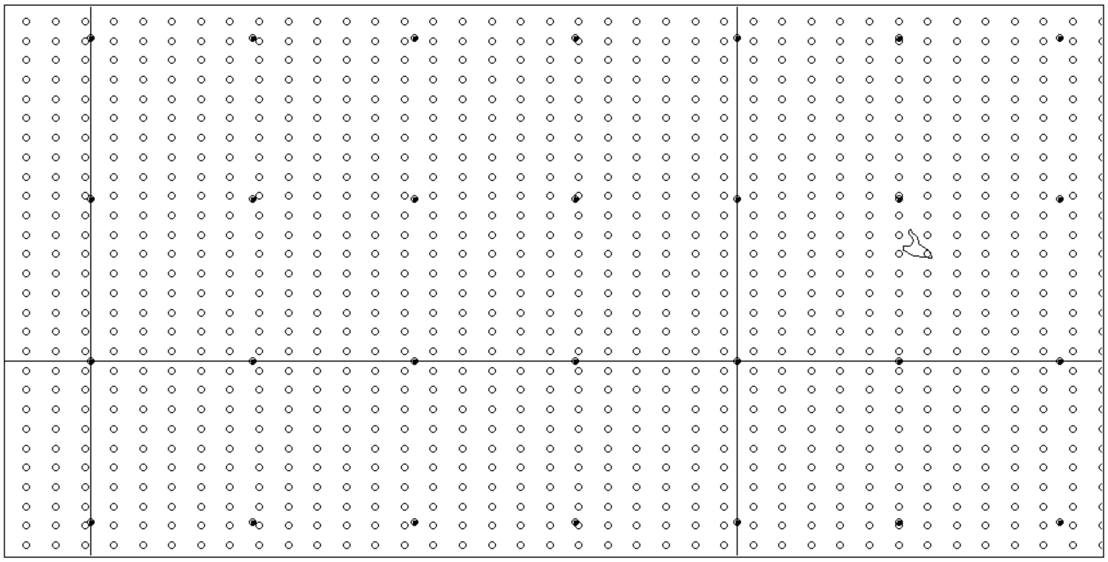

Figure 3: Meso-global grid (open circles) with WMO/CBS verification grid (black circles)

In general, where there are large differences between forecast and verification grids, phenomena occurring in the model at scales below that of the verifying grid will corrupt the verification scores unless steps are taken to ensure that those scales are properly handled in the verification scheme. This can be done via a spectral method, for example, by truncating model and analysis fields in spectral space to eliminate scales below that of the verification grid or by averaging source-field values within target grid-box to create a more representative source-field value at the target grid points.

2. Identification of solutions:

Tests prior to the parallel run phase using a spectral method indicated much less difference in scores between the then operational Global model and the meso-global (fig. 4) than was the case following implementation of the new model using the bi-cubic interpolation.

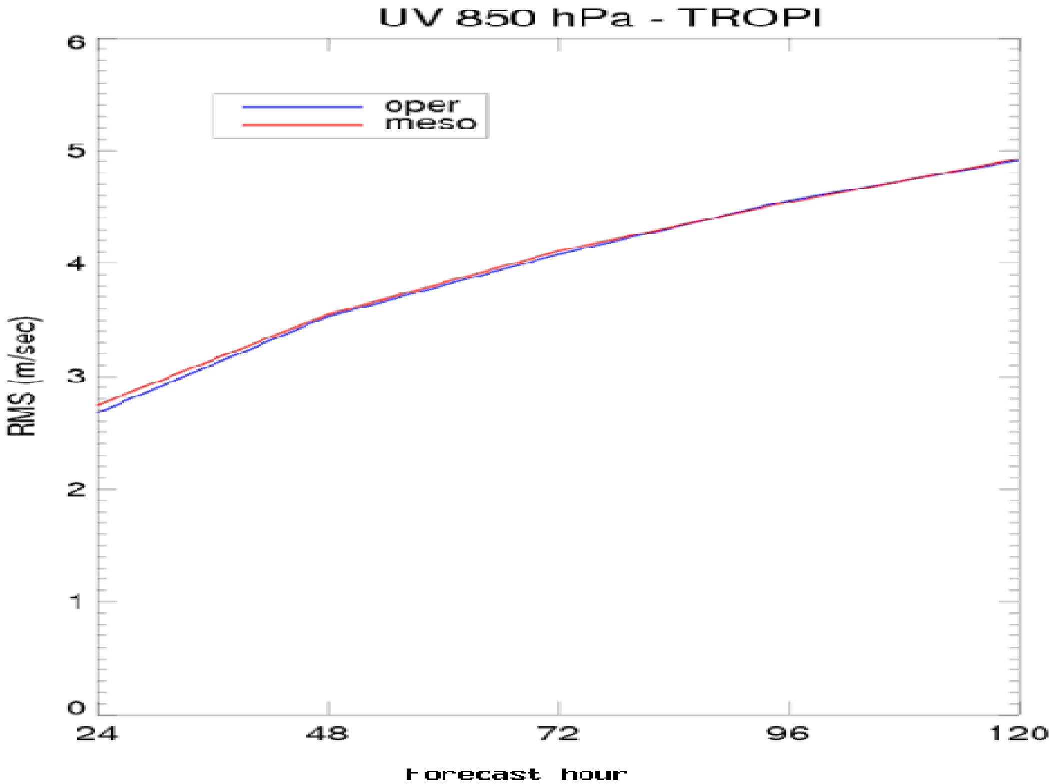

Figure 4: 850 hPa RMSEV against analysis of winds over the Tropics, summer case.

The WMO/CBS verification system places the following constraint on an interpolation scheme:

To the extent possible, horizontal and vertical interpolations from model to verifying grids should not involve multiple steps or explicit smoothing.

To this end, spectral methods, while properly removing unwanted scales, were deemed to be too complex and requiring too many steps for a grid-point model such as the GEM model. It was decided that an areal-averaging method would satisfy the need for a more scientifically valid verification system while not unduly violating WMO/CBS rules. Similar methods are already in use at other NWP Centres (e.g. UKMet Office).

In the areal-averaging method, values at the target (verification) grid points are assigned according to the weighted average of the source (model and/or analysis) grid-point values within the grid-box surrounding each verification grid point (fig. 5).

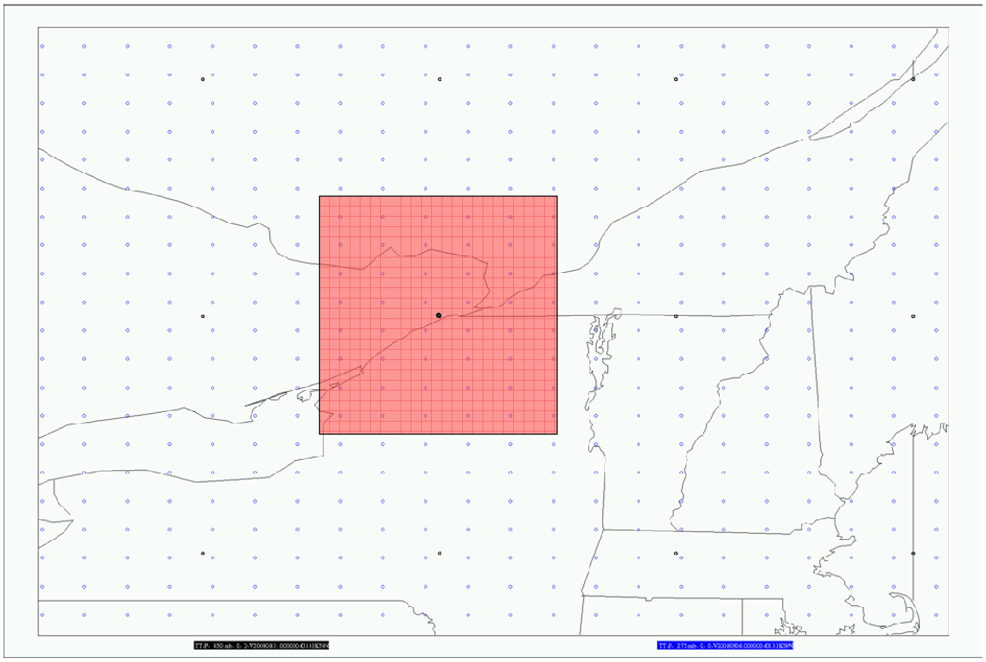

Figure 5: Target (verification) grid box with source (model/analysis) grid points used to calculate source-field value at target grid-point.

Weighting is applied to the source grid-points based on the proportion of the source grid-box which falls within the target grid-box (fig. 6).

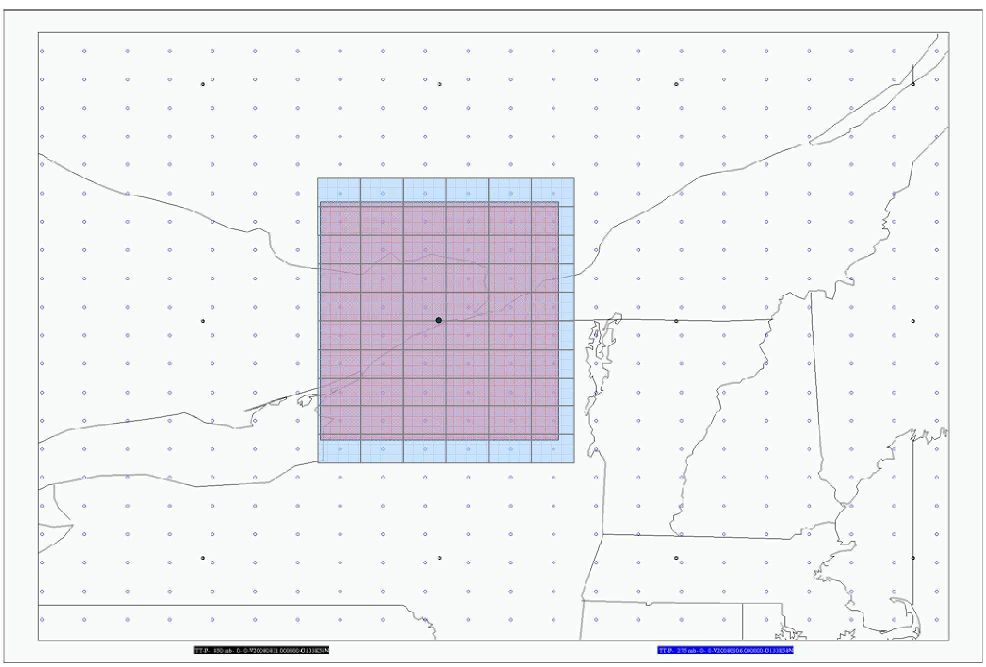

Figure 6: Same a fig 5, with source (model/analysis) field grid boxes added

3. Results of tests using different interpolation schemes:

To test the areal-averaging method, scores on the 850 hPa wind forecasts were compared against both the operational bi-cubic interpolation and a bilinear interpolation. The results (fig. 7) indicate a similar pattern of errors for the bilinear interpolation as for the operational scheme, but at a slightly reduced level. Meanwhile with the areal-averaging method, errors still increased following implementation of the meso-global, but at a much reduced level. Errors with this method were significantly lower prior to the meso-global, but the difference with the operational system was not as great, commensurate with lower difference between the scale of the old model (0.9^0) and the verification grid.

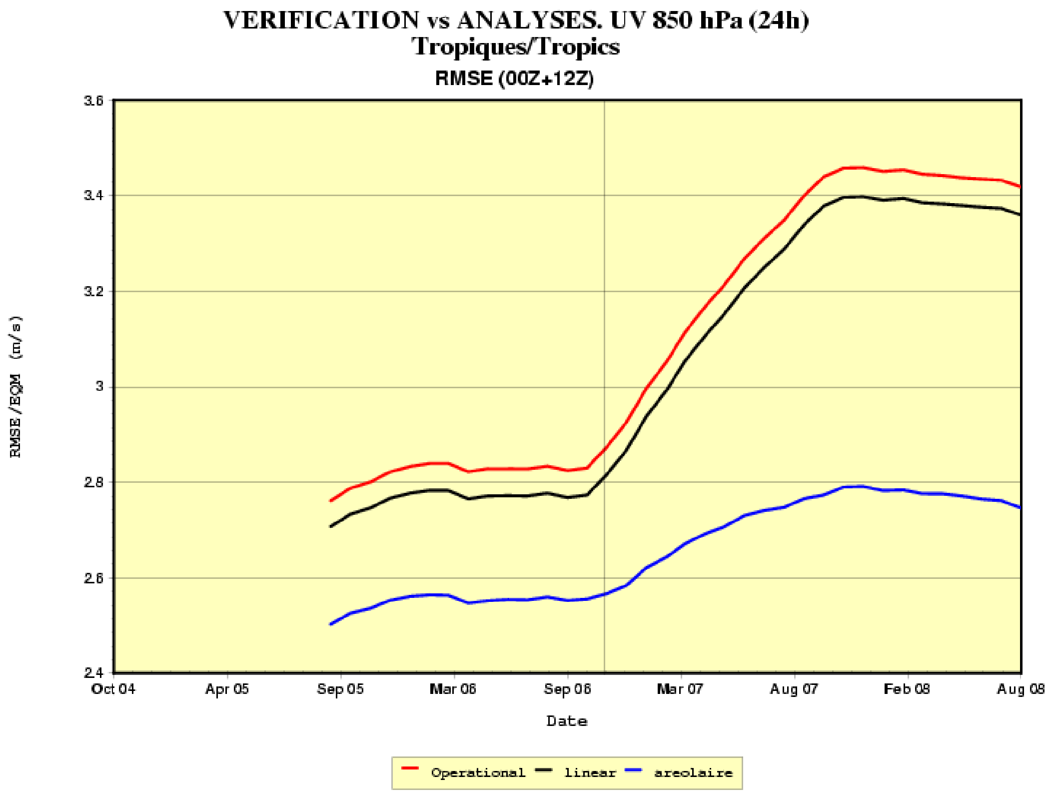

Figure 7: 12-month running mean of GEM Global model 24-hour 850 hPa RMSEV over the Tropics using three different methods of interpolating model and analysis fields to the WMO/CBS verification grid.

The effect of the new interpolation scheme on verification scores for the full set of WMO/CBS variables (PN, GZ, TT, UV) and levels (850, 500, 250) was tested using a one-month period, October 2008 (fig. 8). Comparison against the operational system showed little significant change in RMSE values of geopotential height (GZ) (fig. 8a), while temperature (TT) (fig. 8b) and wind (UV) (fig. 8c, d) errors are reduced at all levels and over all regions (Northern and Southern extra-tropics and the Tropics). S1 values for surface pressure (PN) (fig. 8e) show a similar improvement over the Northern and Southern extra-tropics. Percentage improvement generally decreases with forecast period but remain positive out to ten days. Also percent improvements are largest at 850 hPa, as opposed to higher in the atmosphere, and larger for winds than for temperatures.

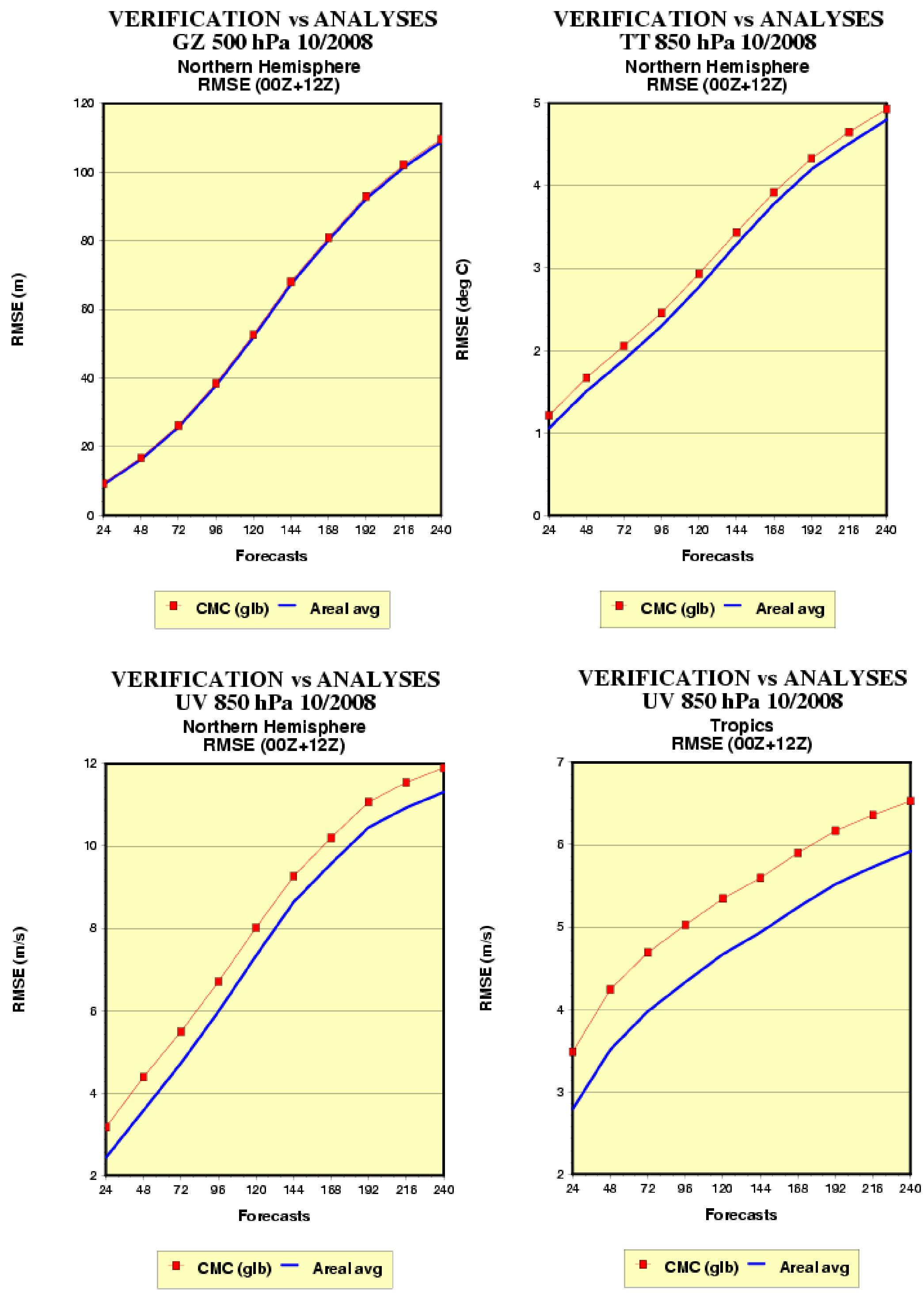

Figure 8: Root mean square error growth for

a. GZ 500, Northern Hemisphere (20-90N)
b. TT 850, Northern Hemisphere (20-90N)
c. UV 850, Northern Hemisphere (20-90N)
d. UV 850, Tropics (20N-20S)

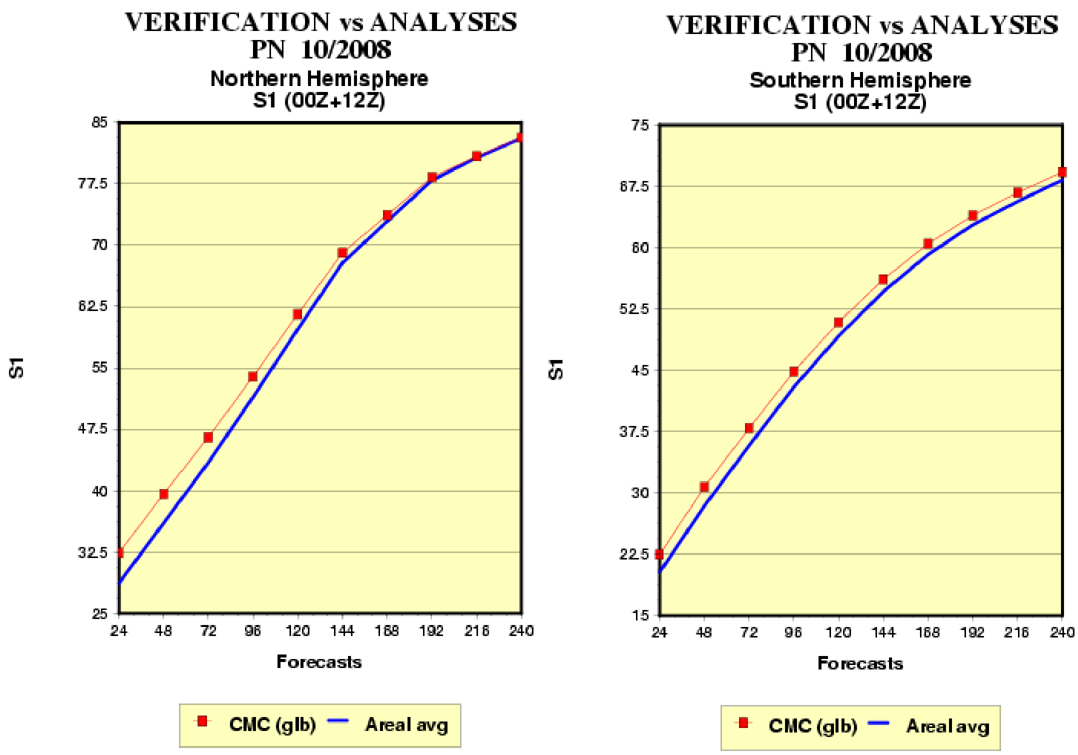

Figure 9: S1 score for forecasts of mean sea-level pressure (PN), Northern Hemisphere (20-90N)

The effect of the using the new interpolation scheme on verification of the GEM model in comparison to the other major NWP Centres is illustrated in the time-series in fig. 10.

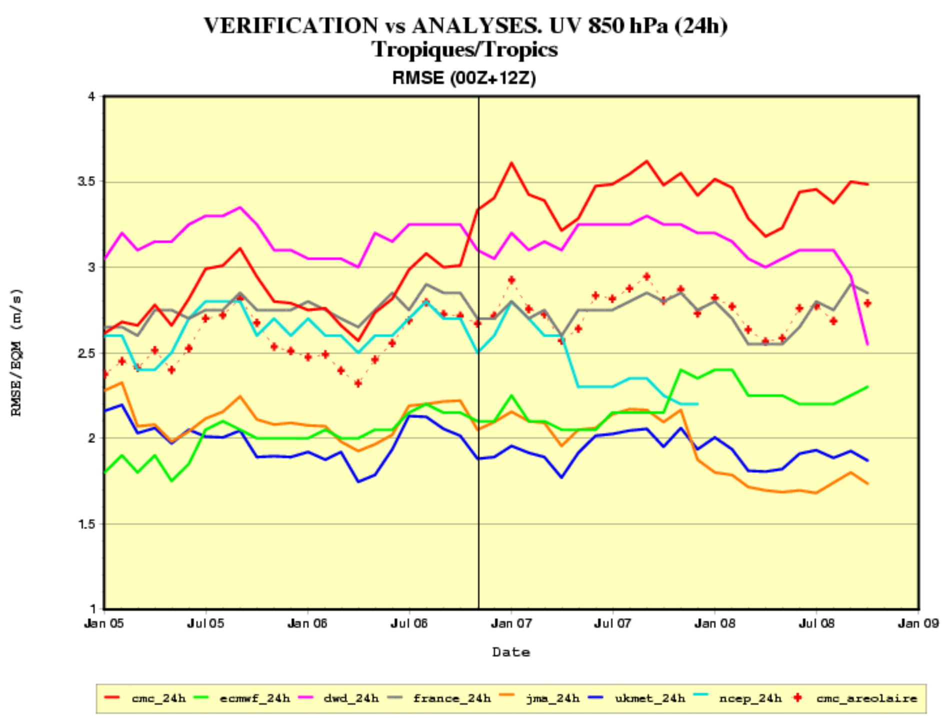

Figure 10: RMSEV of 24 hour 850 hPa winds against analysis over the Tropics (20N-20S)

4. Conclusions and actions:

The areal-averaging method described above is a scientifically valid method of interpolating higher resolution model and analysis fields to a coarser resolution verification grid, without unduly violating WMO/CBS rules regarding the number of steps required. It is also consistent with methods used elsewhere in the world.

It was agreed at a meeting held at CMC on February 10th that this method would be implemented in the operational verification system at CMC. The method will be implemented at the beginning of March 2008.

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February 2008