J13.1 MVT – An Automated Mesoscale Verification Tool

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1. INTRODUCTION

Traditional verification schemes tend to penalize mesoscale numerical weather prediction (NWP) systems which realistically portray high amplitude, short duration mesoscale phenomena. Small phase, timing or location errors for high amplitude features result in apparent poor performance when traditional verification schemes based on synoptic observations or grid point analyses are employed (Brown, 2002). Yet these same NWP systems provide much more realistic and often more operationally useful depictions of weather events than smoother global NWP or ensemble-mean systems (Mass, et.al., 2003). Unfortunately, taking into consideration small phase or timing errors generally requires labor-intensive case studies which are unable to address the large number of cases required for reliable verification of sophisticated mesoscale NWP systems or mesoscale ensemble systems. NWP centers and forecasters need automated, rapid and more realistic evaluation of mesoscale NWP and ensemble performance.

We are developing a mesoscale verification tool to address these issues. After discussions with developers and forecasters, we have decided such a tool should have the following attributes:

- Automated and flexible requiring only simple setup commands
- Adaptable to today's forecast issues in terms of parameters, timing and intensity
- Capable of evaluating structural distortion (rotation or dilation) and timing errors as well as amplitude (or intensity) errors
- Able to address large numbers of cases and multiple models rapidly to identify systematic errors or to detect small performance differences

While simple and flexible, any evaluation system should also be statistically sound and provide easily interpreted results. Our Mesoscale Verification Tool (MVT) described below is the first iteration of our attempt to develop a verification tool that contains all these attributes.

2. VERIFICATION MECHANICS

MVT currently separates forecast error into an amplitude component and a phase (or timing) component following the method of Van Galen (1970) and Hoffman, et.al., (1995). This technique has been demonstrated for precipitation predictions by Du and Mullen (2000) and Ebert and McBride (2000). Hoffman and colleagues have described improvements to this method in several publications, the most recent being Nehrkorn, et. al., (2003). We have chosen to follow the original method; however, as it is most easily adaptable to computer acceleration techniques required to meet our near-real time objectives.

2.1 *'Full Search' Technique*

The full search technique as developed by Van Galen or Hoffman compares an area (structure) of a specified size or number of grid points on the analysis with the corresponding area on the forecast. The error computation for this comparison represents the total error of the forecast for that area. The analysis 'box' is then moved over adjacent regions on the forecast field, until the error is minimized. This error represents the error in the forecast if the phase would have been correctly predicted, i.e., the amplitude error. The difference of the total error and the amplitude error represents the error due to distortion (Hoffman, 1995). See Figure 1. below. Distortion here is

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timing) error; however, it contains components due to rotation and dilation, which we hope to address in later releases of MVT. The error computation may be any of a number of error metrics such as root mean square error, mean absolute difference, or mean square error (MSE). We use MSE as we have found it performs more consistently in regions of weaker gradients.

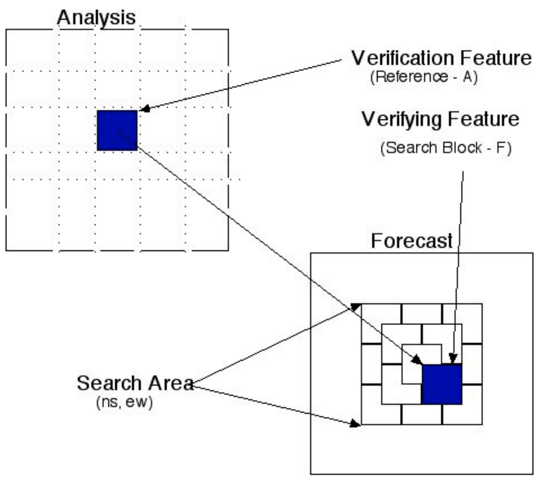

Figure 1. Full Search Method

2.2 *Acceleration Techniques*

The University of Washington Short Range Mesoscale Ensemble or SREF (Mass, et. al., 2002) currently has from eight to twenty five members with a 126 by 150 point outer (36km) grid and a 99 by 102 inner (12km) grid. Verification using the full search method, even with advanced computer processors, is still too slow to be utilized as a near real-time system. Consequently, we have investigated a number of procedures, predominately based on image matching from the motion picture industry, to accelerate the verification. We have implemented two techniques, the Layered Structure Algorithm (LSA) and the Inter-Block Motion Algorithm (IBM) detailed in a review article by Chan (1993). The combination of these two algorithms results in an easy 30 to 50 times acceleration in the verification, with essentially no loss in accuracy (<1% of phase MSE error). This enables a forecaster to quickly verify a series of model predictions, ensuring they will be more willing to consider recent model performance in their forecasts.

LSA assumes the existence of a locally monotonic error field and is simply the technique of searching a large field intermittently, i.e., skipping a fixed number of grid points, to identify local minima, then searching in detail around the local minima to identify the true minimum in the MSE field. See Figure 2. It is a 'layered' search and can be performed in two or more steps depending on the complexity and size of the search area. In MVT, we use a simple two-step procedure that captures three local minima by skipping every other grid point in the search area.

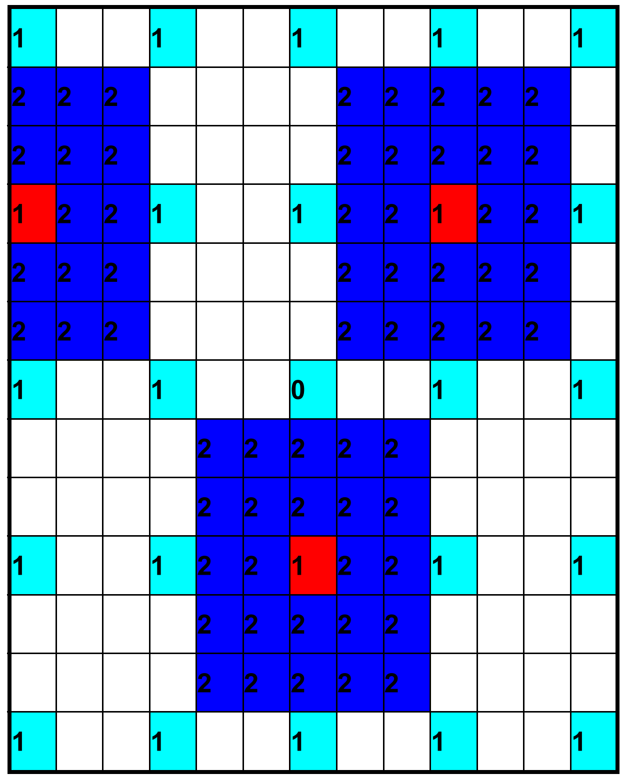

Figure 2. Two-step LSA

IBM assumes groups of adjacent points on the grid are correlated, and consequently, finding the minima for intermittent points allows you to predict the location of the minima for the adjacent points. It can be used either to skip the first step of the LSA (for intermediate grid points), predicting the location of the minima based on the surrounding points, or to skip the LSA entirely, by assuming the minima is given by the average of the surrounding points. In the case of MVT, we simply perform a two-step LSA on every other grid point, then compute the location of the minima for the remaining points from the surrounding four grid points. In addition to being very rapid with little loss in accuracy, it tends to dampen noise in the computed phase shift.

3. VERIFICATION TOOLS

The mesoscale verification tool has two web-based graphical user interfaces; the Mesoscale Verification Tool (MVT) intended for forecaster use, and Mesoscale Data Manipulator (MDP) intended for developer use. Both use the same search and verification engines described in section 2.

3.1 *MESOSCALE VERIFICATION TOOL*

The MVT is a web-based tool that is part of a forecaster tool kit (“MURI Uncertainty Monitor” or MUM) being developed by the University of Washington for the U.S. Navy. The MVT allows a forecaster to quickly select a numerical prediction for any ensemble member, model domain (12 or 36km grid), parameter, level, and forecast hour and verify it against the latest analysis. MVT includes a manual mode that allows the forecaster to quickly select a specific feature or region to be verified. It also allows the forecaster to go back in time and verify historical cases. The MVT outputs both tabular and spatial maps of error fields including MSE and phase error. The spatial maps are overlain with phase error vectors depicting the phase shift between structures on the analysis and on the forecast. The GUI and resultant output are shown in Figures 3 and 4.

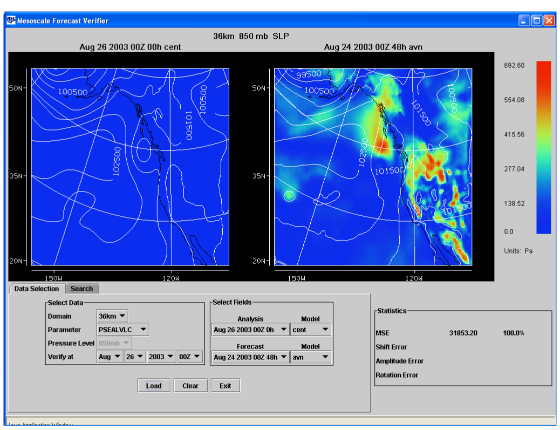

Figure 3. MVT GUI

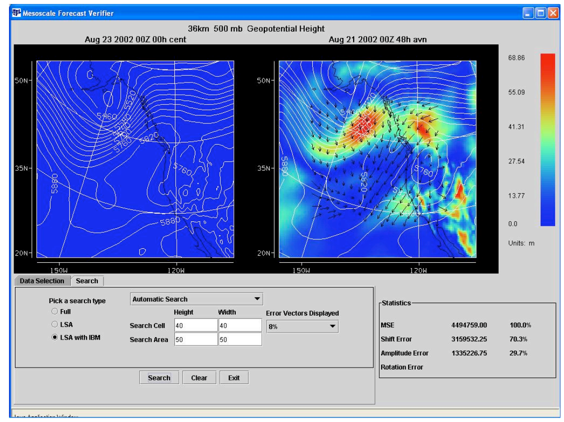

Figure 4. MVT with phase error vectors

3.2 *Mesoscale Data Manipulator*

The MDP is accessed via a powerful web-based GUI that allows the user to set up and execute large verification cases. The user is presented with the screen shown in Figure 5 below.

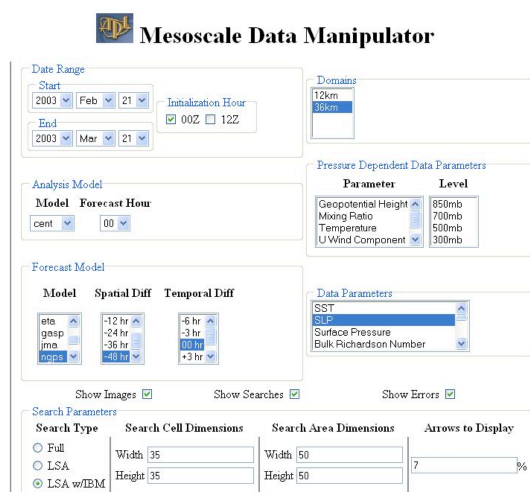

Figure 5. GUI for the MDP

Selectable features of the MDP are (all based on the current University of Washington SREF):

- Range of dates from one day to entire data record.
- Model initialization time - 00Z or 12Z
- Model domain - 36 or 12km
- Verifying field
- Ensemble members to verify**

- Forecast hour to verify**
- Time lagged verification**
- Forecast parameters to verify**
- Output desired - Table, RMSE, Vectors**
- Search mechanics

** Multiple selections allowed for these parameters.

The user can quickly manipulate the GUI to execute complex and large verification sequences. The GUI allows the user to submit the verification sequence for execution on the data server. When the verification is complete, the user is notified automatically by e-mail and given a web address that contains tabulated results and figures.

4. DEMONSTRATION CASES

Several demonstration cases will be presented at the meeting.

5. SUMMARY

MVT and MDP are powerful web-based verification tools developed to improve forecaster and developer evaluation of mesoscale NWP products. At the time of this submission, MVT had been extensively tested; however, many MDP features had not been completely tested. While it is clear that current verification techniques based on synoptic observations or labor intensive case studies are inadequate to rigorously evaluate mesoscale NWP systems, it hasn't been demonstrated that the MVT phase-based verification techniques are the solution to this problem. Tools in hand, we hope to demonstrate their usefulness over the coming months.

6. ACKNOWLEDGEMENTS

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