J12.5 An Object Oriented Approach to the Verification of Quantitative Precipitation Forecasts: Part II - Examples

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1. Introduction

In the past, the verification of Quantitative Precipitation Forecasts (QPFs) has had many problems. Traditional approaches for the verification of convective forecasts are inadequate (Brown et al. 2002). One of the obvious deficiencies of standard grid-based approaches is that the results are often not consistent with subjective perceptions of the quality of a forecast. Even though a subjective verification of QPFs is not the final goal, a technique that mimics what a human might produce could prove valuable in assessing the quality of the forecast.

In Part I of this study, a new verification technique for QPFs was described (Bullock et al. 2004). This “object-oriented” method is used to decipher the parts of the forecasts and observations that would be relevant to a human observer. These “regions of interest” are initially identified by the use of convolution with a shape, such as a cylinder. After the convolving takes place the field is then thresholded. Thresholding helps to “smooth” out the boundaries around the area making the shapes appearance look more human-rendered. After the smoothing, some objects may be “merged” if it is determined that the regions are related to one another. As objects are identified, attributes of the forecasted and observed regions, such as location, shape, orientation, and size are compared.

In this part of the study, a critical look at the performance of the technique is undertaken. Initially, the 22 kilometer Weather Research and Forecasting (WRF) model was used as the forecast data set and was restricted to areas within the borders of the Continental United Sates (CONUS). Stage IV data were utilized as the observation data set. The higher resolution Stage IV data were smoothed to allow for a more valid comparison with the lower resolution WRF model forecast output. The convolution radius and threshold are varied to assess the sensitivity of the technique to these parameters.

The initial examination of this technique uses the 22km WRF and the Stage IV data to provide a “baseline” for the utilization of this approach on other types of forecasts and observations. Data from the 4km WRF and Stage IV data were obtained from the Bow Echo and Mesoscale Convective Vortex Experiment (BAMEX). The forecasts and observations are similar to the preliminary data, but the observations do

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not require smoothing and the domain was reduced to a smaller overall area.

This paper critiques several different cases from both types of forecast data sets and observations. Also, shown in the paper is the versatility of the technique with regard to examining the QPFs on different scales that might be useful for different observers.

2. 22km WRF/Stage IV Cases

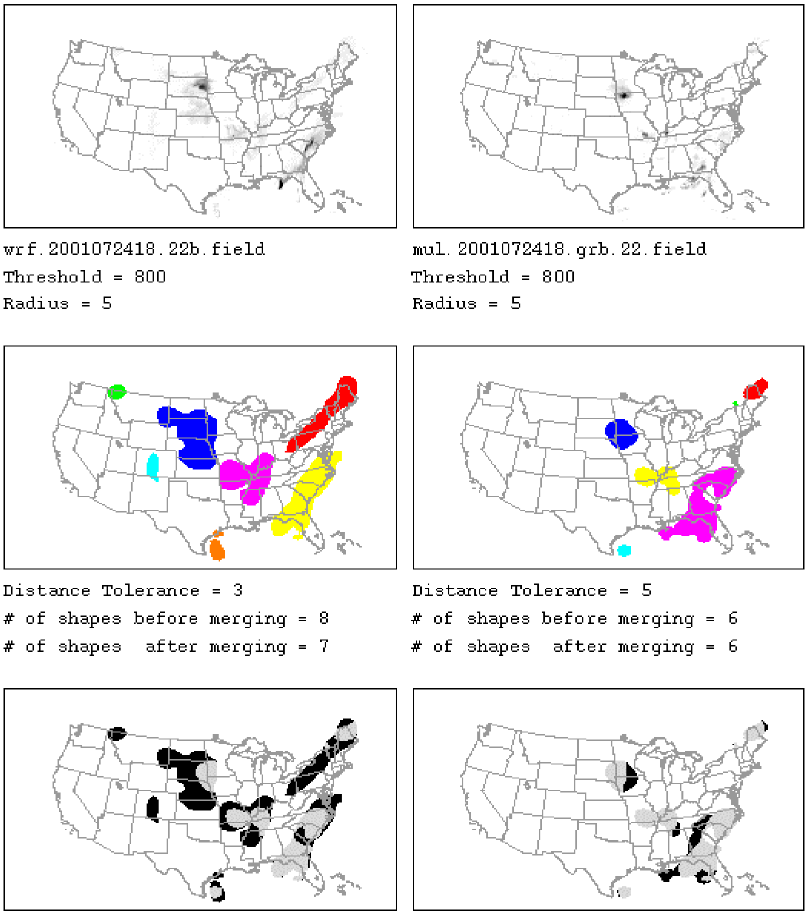


Figure 1 *Plots of 22km WRF and Stage IV data from 24 July 2001*

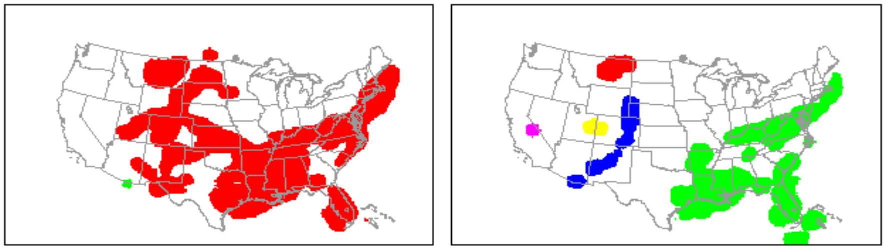
In each of Figures 1, 2, and 3 a set of six images is presented showing the products of the convolution, thresholding, and merging processes. The left column shows the precipitation output from the 22km WRF model masked to only cover areas within the CONUS. The right column of the figures shows the output from the Stage 4 data smoothed to the lower resolution WRF grid. The first row of plots shows the original WRF precipitation forecast and Stage IV observations. The text below the first row identifies the threshold and radius applied for these images. The threshold of 800 is approximately equivalent to 0.03 inches of precipitation. The convolution radius of 5 is equal to five grid points or approximately 100km.

The second row of plots shows the forecast and observations after the convolution, thresholding, and object merging processes have been applied. A simple distance rule was applied to the objects to decipher which objects should be considered merged. The distance tolerance is listed below the second row of images. Objects that are identified as merged are the same color; note, however, that the specific coloring of the objects in the WRF and Stage IV plots are independent of one another. For example, in Figure 1 the only objects that the program merged were the two from the WRF forecast located off the coast of Southeast Texas. These regions were within three grid points of one another and so were colored the same. All other objects were more than three grid points away from any other object and were colored differently. The final row of plots represents the overlap of the WRF forecast with the Stage IV observation. This depiction helps to show how objects might match one another by only using strict location criteria.

Figure 1 depicts a case from 24 July 2001 at 18Z. It shows a fairly reasonable separation of the regions of interest. It is possible to make the case that each region is separated into reasonable objects and thus are colored correctly. A “merging” distance tolerance of three grid points was used in order to separate the two objects over the Midwest and Mississippi Valley. Generally, a distance tolerance of five grid points would be sufficient, but this decrease to three grid points was necessary to keep the two regions independent of one another. The WRF precipitation regions that exist in the Western United States do not exist in the Stage IV data. This could be attributed to the lack of radar coverage and precipitation observations in these areas. Overall, Figure 1 presents a case that shows the technique’s ability to seek out and separate meaningful regions of precipitation. From a human perspective, matching of the objects in Figure 1 would be relatively easy. It also appears that automated matching would be successful.

Figure 2 depicts a case from 26 July 2001 at 15Z. This case appears to be more complex than the case represented in Figure 1. The objects created for the WRF model output seem to be much too extensive, with a merged region stretching from Maine to Texas. It is not possible to make the case that these two regions are related. A more reasonable approach would be to keep the two objects from the WRF model separate. In that case, the object in the Southeast could possibly be matched with the object on the Gulf Coast in the Stage IV data. The object to the north could possibly be matched to the three objects over the Northeast U.S. in the Stage IV data. Complex cases like this one make evident the need for more sophisticated matching and merging rules.

```
wrf.2001072621.22b.field          mul.2001072621.grb.22.field
Threshold = 800                   Threshold = 800
Radius = 5                        Radius = 5
```



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Distance Tolerance = 5                 Distance Tolerance = 5
# of shapes before merging = 4         # of shapes before merging = 10
# of shapes  after merging = 2         # of shapes  after merging = 5
```

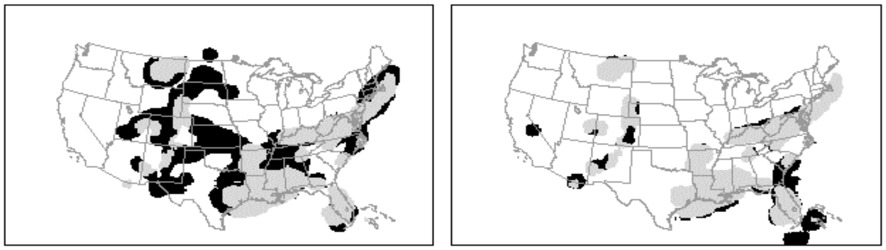

Figure 2 *22km WRF and Stage IV plots from 26July 2001*

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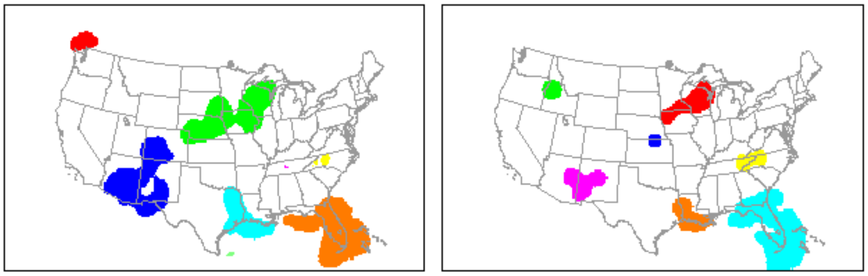
Figure 3 also shows favorable results for the initial run of this technique. The same threshold of 0.03 inches of precipitation was used as well as a convolution radius of five grid spaces. The only discrepancies in Fig. 3 are the rain areas over the Northern Great Plains in both the WRF and the Stage IV plots. The WRF has a large area that is merged over Nebraska stretching through to Wisconsin while the Stage IV has divided the area into two objects. While the Stage IV solution seems to be the most reasonable, it is still uncertain which is correct. Increasing the threshold for the WRF data might divide the area into two separate objects, but the success of the technique in the other areas of the CONUS might in turn be compromised.

Overall, the first pass of the object-oriented verification approach on the 22km WRF and Stage IV data sets for 2001 were successful. Being able to separate precipitation areas from one another in a forecast and confidently match those objects to observed precipitation areas seems to be possible for the initial radius (3-5 grid points) and threshold (0.03 in.).

wrf.2001080121.22b.field
Threshold = 800
Radius = 5

mul.2001080121.grb.22.field
Threshold = 800
Radius = 5



Distance Tolerance = 5
# of shapes before merging = 10
# of shapes after merging = 8

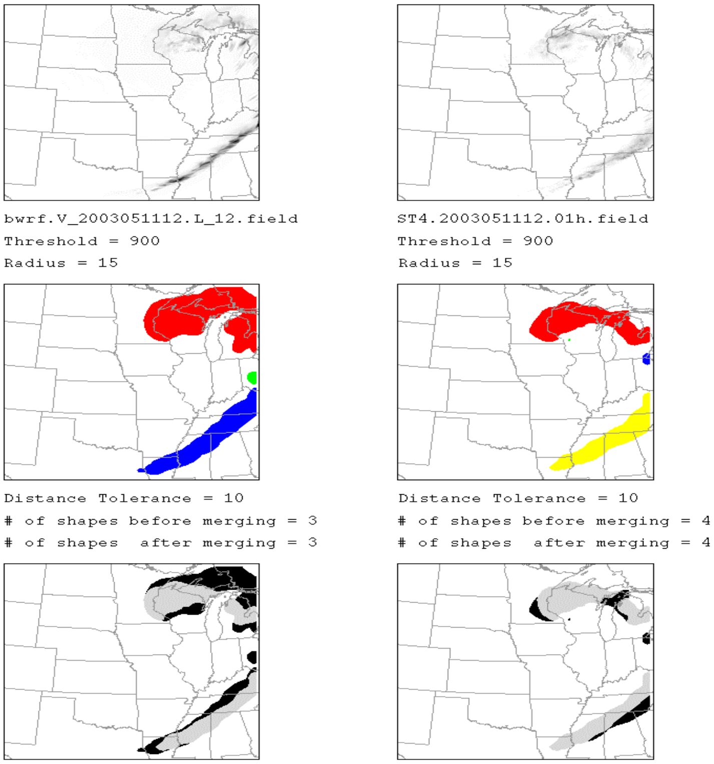
Distance Tolerance = 5
# of shapes before merging = 7
# of shapes after merging = 7

Figure 3 22km WRF and Stage IV plots from 01 August 2001

3. BAMEX cases

Figure 4 SHOWS a case taken from 11 May 2003 from the BAMEX field project data set. It accurately portrays the different areas of interest for both the WRF and the Stage IV data for a threshold of 900 (~0.03in.) and a convolution radius of 15 grid points. The 15 grid points equates to a radius of around 60 km because of the smaller scale of the WRF model (4km) for this particular project. The scale of the objects is close to that applied in the 22km WRF study. In this particular case, the forecasted and observed objects that were identified by the technique could easily be matched.

The analysis of the BAMEX data using the 15 grid point radius and threshold of 900 led to many of the same results as the study applied to the 22km WRF model. There were many cases where the precipitation areas could be confidently matched up after the object-oriented technique was applied. However, several cases like the one in Figure 2 were also found, where the matching of the objects would be impossible to accomplish. To combat this problem, the object identification technique was applied to BAMEX data using a different convolution radius and threshold, in order to attempt to resolve smaller scale structure of the objects. The goal of this redundant object identification was to use the objects' internal structures to help match the forecast and observed objects.



. ***Figure 4*** *4km WRF and Stage IV plots for BAMEX field project*

Figure 5 shows the large-scale object evaluation (threshold ~ 0.03, radius = 15) overlaid with a small-scale evaluation (threshold ~ 0.25, radius = 4). The original large-scale evaluation identified a large irregularly shaped object in the WRF over the Great lakes region while the Stage IV analysis identified two smaller objects over the same area but with different orientations. By adding the small-scale features to the larger objects it is possible to consider these two areas related. The WRF forecast apparently have overforecasted the size of the region of light rain or possibly overforecasted the intensity of the light rain areas. In this situation, a sophisticated matching method would be required to make these assumptions.

Figure 6 presents a case when it is possible to match the WRF forecast and Stage IV observations at both the larger and smaller scales, including area of higher intensity.

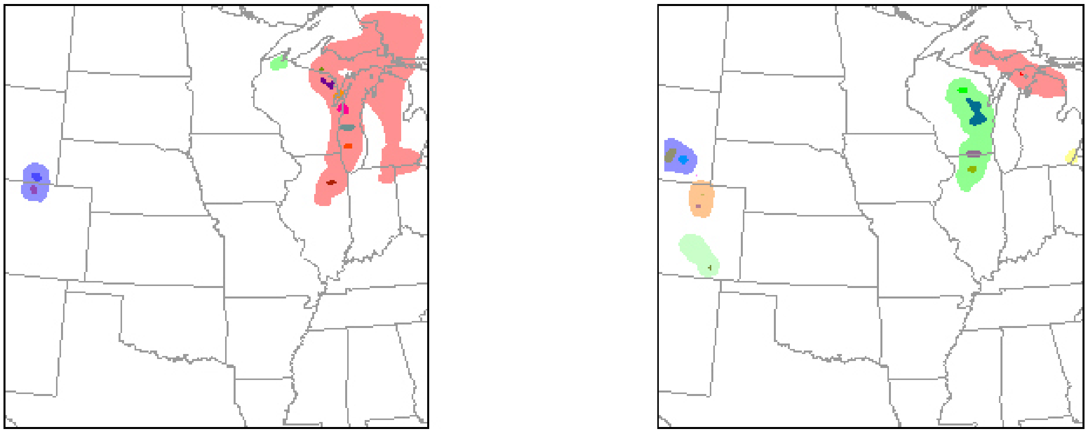


Figure 5 *4km WRF (left) and Stage IV (right) with large-scale and small-scale objects overlaid from 31 May 2003*

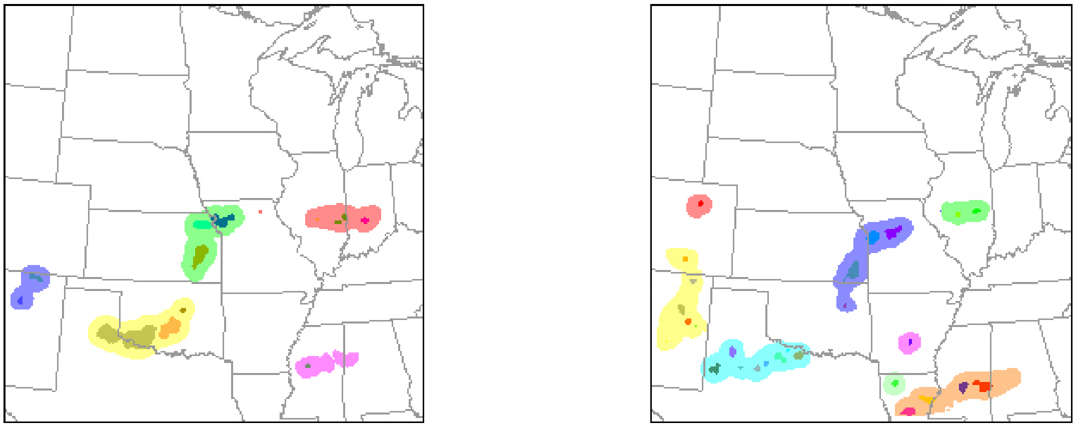


Figure 6 *4km WRF (left) and Stage IV data (right) for the BAMEX field with large and small-scale objects overlaid for 30 June 2003*

Conclusions

The BAMEX study was successful in affirming our belief that it is possible to separate out different areas of interest at a synoptic scale and in many cases confidently match the forecast objects to the observation objects. The need for a more complex matching rule set was also made evident in cases where the complexity of the precipitation areas was such that no objects could be matched with any confidence. Identification of the small-scale structure of the objects may help with some of these issues. Overall, the results of the BAMEX study yielded results that were similar to the results of the initial study. In addition, the use of the small-scale analysis has added a necessary piece to the puzzle of how to appropriately match forecast and observed objects.

The purpose of Part I of this paper was to describe the methodology an object-oriented method for verification of QPFs. Part II has provided examples of this approach and insight into the various strengths and weaknesses of the technique. Scale seems to be the most difficult issue for matching forecasted and observed objects. The comparison of objects on the synoptic scale is fairly successful with the exception of some highly complex cases. It is impossible to compare objects on the mesoscale without first making comparisons on the larger synoptic scale.

The object-oriented technique is highly versatile. With different users desiring different types of information from the same forecast. This technique can accomplish more than one type of verification analysis simultaneously. For example, if a hydrologist is the user, he might only require verification of the forecast on a synoptic scale over certain areas. Yet, if the user is an aviation meteorologist, he might only be interested in areas of high intensity on a smaller scale for the purpose of diverting air traffic. The flexibility of verifying forecasts on many different scales should increase the number of users that might be interested in the object-oriented technique.

Future Work

A more complete examination of these two data sets will be performed. In addition, the technique will be applied to the National Convective Weather Forecast (NCWF) as well as data from the NCAR Autonowcaster. Experiments with different scales should improve the technique’s ability to classify a variety of different types of objects and in turn provide more confidence in the matching process.

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References

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