

## A Weighted Fuzzy Verification of Precipitation Forecasts

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## Abstract

Traditional verification methods require an exact match between the observation and the forecast in the same grid box. They often performed poorly for the high-resolution model forecasts due to the difficulty of the exact match at finer scales. Thus, Fuzzy verification methods are developed and used to give some partial credit to the forecasts in the neighborhood around the point of interest. However, most of them treat the grid points within the neighborhood equally. A generalization to weighted fuzzy verification method is investigated. It provides for the incorporation of weighting schemes to give more credit to the near neighbor forecasts than the far neighbors within a relatively large neighborhood of the point of interest. The weights assigned to the grid points within the neighborhood are defined as a function of distance from the grid point to the point of interest, the spatial scale, and temporal scale. The spatially and temporally varying weights allow the user to determine how the neighbor grid points affect the forecast skill in order to refine the verification results.

This method is applied to daily precipitation totals in Arkansas-Red River Basin. The space-time neighborhood is used for both the observation and forecast.

## Introduction

Precipitation verification is a process of assessing the quality of model forecasts. The study on the precipitation forecasts can benefit the society in making correct decisions (e.g. decision to protect properties from a severe storms, decision to grow crops at the locations with moderate precipitation, etc.). The agreements (disagreements) between observations and forecasts can be assessed in different ways.

Traditional verification of forecast products is based on matched pairs of observation and forecast on the same grid point (Figure 1a). It is simple and useful. However, the strict match between observation and forecast seldom happens in high-resolution models.

Fuzzy verification or neighborhood verification methods relaxes the exact match requirement in traditional verification. It evaluates forecasts and/or observations in a space-time neighborhood around the point of interest. Ebert (2008) reviewed several fuzzy verification methods and proposed a general fuzzy verification framework. Those methods can be classified into two categories according to their matching strategies: single observation neighborhood forecast (Figure 1b) and neighborhood observation - neighborhood forecast (Figure 1c). In fuzzy verification, the forecasts within a neighborhood of a given grid box are assumed to be independent and uniformly distributed over space and time. In other words, all the grid points within the neighborhood are equally important. This assumption is not realistic, especially when the size of neighborhood is quite large.

Weighted fuzzy verification takes into account the spatial and temporal correlations among the forecasts within the neighborhood. Intuitively, near observations/forecasts in space and time are more related than far observations/forecasts. The degrees of agreement (or disagreement) to each of the grid boxes within the neighborhood are weighted inversely to the distances from the grid boxes to the point of interest in both space and time (Figure 1d). The spatially and temporally varying weights allow the user to determine when the forecasts are useful at the finer scales.









Figure 1: Verification methods

## Methods

For any given grid point within a circular neighborhood around the point of interest, the weight is defined as a function of distance r from the given point to the central point, spatial scale s, and temporal scale t:

$$\omega_{s,t}(r) = \frac{a_{s,t}(r)}{N(S_r)}$$

where  $s_{j}$  denotes the set of grid points whose

distance to the center of the neighborhood is between r-1 and r, and  $N(S_r)$  is the number of grid points in  $S_r$ .  $a_{i,r}(r)$  represents the tuning parameter that controls the degrees of agreement. The larger the  $a_{i,r}(r)$  value, the more weight is given to the grid point within the neighborhood. Figure 2 shows an example of grid points within a space-time

neighborhood and their weights. Note that both traditional verification and fuzzy verification are the special cases of weighted fuzzy method when

 $a_{s,t}(r) = 0$  and  $a_{st}(r) = N(S_r)$  respectively.

Thus, the fractions of neighborhood with observed and forecast events are weighted accordingly. The observed fraction  $p_o$  and forecast fraction  $p_f$  can be expressed as

$$p_o = \frac{\sum_{s,t,r} \omega_{s,t}(r) I_{s,t}(O)}{\sum_{s,t,r} \omega_{s,r}(r)}, \quad p_f = \frac{\sum_{s,t,r} \omega_{s,t}(r) I_{s,t}(f)}{\sum_{s,t,r} \omega_{s,r}(r)}$$

where I(O) is the indicator function (1 = yes and 0 = no) for observed events and I(f) is the indicator function for forecast events. Here event defined as a value exceeding a give threshold, for example, rain exceeding 0.1 mm/hr.



Figure 2: A spatial and temporal neighborhood of a given grid point

# **Preliminary Results**

ABRFC data are used in the study as verification reference. The hourly precipitation data in Arkansas Red River Basin have been collected for the time period from 1 June, 2007 to present. The total number of grid points in the domain is 8929 and the size of the grid box is regridded to10 km x 10 km. Both NEXRAD Stage IV and CMORPH forecast products are compared with the ABRFC data set. The forecast precipitations are obtained for the region from latitude 32N to 40N and longitude 110W to 90W. Only the data inside the study area are verified here. Figure 3 shows the observed and predicted 6hr rainfall accumulations at 12 UTC on 30 June, 2007.

The categorical scores BIAS, ETS, FAR, and POD are computed for all the three verification methods for 7 thresholds. Figures 4 and 5 summarize the verification results for CMORPH and Stage IV, respectively. Weighted fuzzy methods give the highest values of the ETS (perfect score is 1) and lowest FAR (perfect score is 0) for both forecast models. BIAS scores for weighted fuzzy verification are closer to 1 than fuzzy and traditional methods. When the rain threshold was low, weighted fuzzy verification has the POD values higher than fuzzy and traditional verification methods for CMORPH data, whereas Stage IV has the perfect POD for all the thresholds.



Figure 5: Verification results: reference=ABRFC, forecast=Nexrad Stage IV at 12 UTC on 30 June, 2007

#### Figure 3: Observed ABRFC (top), forecast Stage IV (middle) and CMORPH (bottom) 6hr rainfall accumulations at 12 UTC on 30 June, 2007

### Reference

Ebert, E.E. (2008). Fuzzy verification of high-resolution gridded forecasts: a review and proposed framework, *Meteorological Applications*, 15: 51-64.

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