Application of MODE to 13km GFS and 27km GFS Precipitation Verification

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MODE stands for "Method for Object-Based Diagnostic Evaluation" and is one of several forecast verification tools in the Model Evaluation Tools (MET) verification package developed by the National Center for Atmospheric Research (NCAR) Developmental Testbed Center (DTC). MODE was developed using precipitation as the forecast variable to be verified, but this object-based tool can also be applied to any forecast variable that can be defined as an object on a gridded map.

Object-oriented verification techniques are beneficial to forecasters and model developers because these techniques provide diagnostic information on the differences between forecast and observations in terms of spatial displacement, coverage areas, orientation, and intensity. Object-based verification methods also better show the benefits of higher resolution models, as they avoid the "double penalty" problem that is so prevalent in traditional verification measures.

MODE works by comparing a gridded forecast file to a gridded observations file. The raw forecast and observation fields are put onto the same grid and are smoothed using a **user-defined convolution smoothing radius** in units of grid squares. After the fields are smoothed, objects are defined wherever the values of the forecast variable of interest equal or exceed a **user-defined intensity threshold** (in variable units; millimeters in this case of precipitation). Once objects are identified based on the convolution radius and the intensity threshold and additional user-defined parameters in a configuration file, the original intensities within the raw forecast field are added back into the newly defined objects.

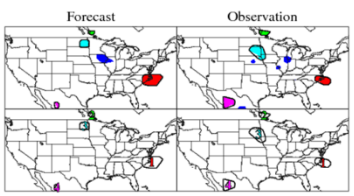

Figure 1: An illustration of the objects that MODE identified in the forecast (*left*) and observation (*right*) fields based on a user-defined convolution radius of 5 grid squares and an intensity threshold of 11 millimeters.

Following the identification of objects, MODE calculates simple object attributes such as centroid latitude/longitude, *n*th percentile intensity, object area, object axis angle, and object count. MODE then computes pairwise attributes such as centroid distance, percentile intensity ratio, area ratio, axis angle difference, union area, intersection area, and boundary distance for all possible pairs of objects.

Specific pairwise attributes are then considered in the computation for the total interest values. The *interest value* is a summary measure that quantifies the overall similarity between two objects across fields and is computed using a fuzzy logic engine. User-defined weights for the pairwise attributes are included in the computation of the total interest values, T(α), as well as interest maps and confidence maps as shown in the equation below:

$$T(\alpha) = \frac{\sum_i w_i C_i(\alpha) I_i(\alpha_i)}{\sum_i w_i C_i(\alpha)}$$

Interest values range between 0 and 1, with values closer to 1 indicating a better match between forecast and observation objects. A forecast and observation object pair is considered to be a "match" if the interest value exceeds a user-defined interest threshold, which in this analysis is 0.7. MODE output includes statistics on simple objects, pairwise objects, and matched objects to evaluate how close the forecast and observations are to each other.

This analysis:

Observations used for validation in this analysis were Climatologically Calibrated Precipitation Analysis (CCPA) files of 1/8 degree resolution.

The GFS (T1534) resolution is 13km, or about 1/8 degree. The previous GFS (T574) resolution is ¼ degree. The T1534 GFS was implemented for operation on January 14, 2015. It replaced the previous operational T574 GFS.

The forecast and observation gridded files were put onto the NCEP common grid 193, which is ¼ degree resolution over the contiguous United States.

Evaluated four seasons from 2013-2014 divided into 3-month periods (DJF, MAM, JJA, SON).

All forecasts were initialized at 00Z for 13km GFS and 27km GFS.

Forecast and observations were grouped into 24-h precipitation accumulation periods. The focus was on forecasts for 24-h precipitation accumulations leading up to the 36, 60, 84, 108, 132, 156, and 180 hour forecasts.

Results:

The *Median of Maximum Interest* (MMI) is found by finding the maximum total interest value associated with each individual forecast and observation object, and then finding the median within that set.

MMIO – MMI with respect to observation objects only (starts with obs)
MMIF – MMI with respect to forecast objects only
MMI – MMI with respect to both forecast and observation objects

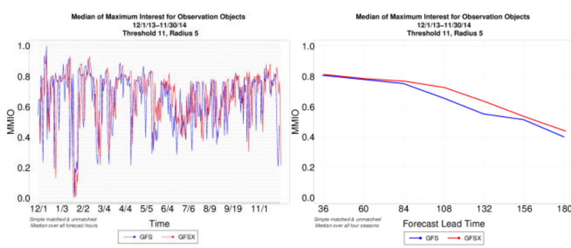

Figure 2: Median of Maximum Interest with respect to observation objects (MMIO) as a function of time (*left*) and as a function of forecast lead time (*right*). MMIO daily values on the left plot are the median over all forecast lead times. MMIO values on the right plot are the median over the four seasons as a function of forecast lead time. The GFS (T574) is in blue and the GFSX (T1534) is in red.

There are many "dropouts" for both the 13km GFS and the 27km GFS throughout the four seasons, especially in the winter seasons. The largest drops in MMIO are during the winter season in mid to late January 2014.

The MMIO decreases with forecast lead time for both global models. The 13km GFS features higher MMIO than the 27km GFS for the later forecast lead times.

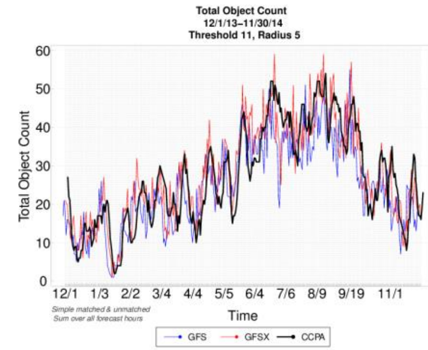

Figure 3: Total object count as a function of time. Daily object count is the sum over all forecast lead times. GFS (T574) is in blue, GFS (T1534) is in red, and CCPA observations are in black.

The 13km GFS and 27km GFS are generally close to observations, but the 27km GFS produces fewer number of objects than observations in summer.

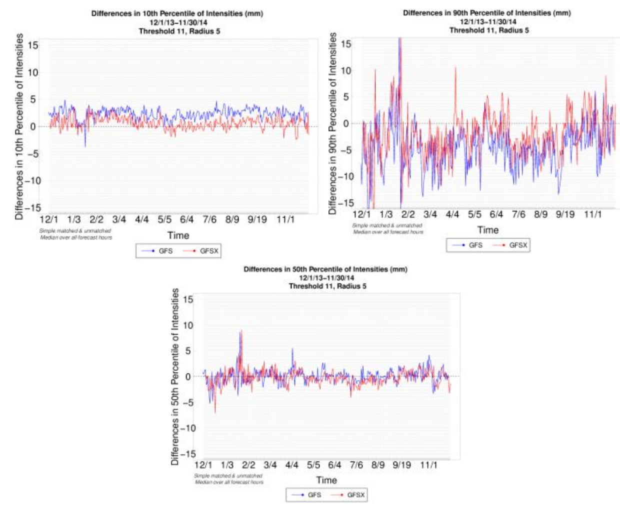

Figure 4: The differences in intensity between forecast and observations for the extreme intensities (*top*) and median intensities (*bottom*) as a function of time. The differences in the 10th percentile intensities (*left*), 90th percentile intensities (*right*), and 50th percentile intensities *(bottom)* are shown for all four seasons.

Both the 13km GFS and the 27km GFS forecast light rain intensities that are larger than observations, while both models forecast near-peak intensities that are smaller than observations. For both light and heavy rain forecasts, the 13km GFS reduces the biases. Both the model versions are close to observations for the median intensities, but in the summer the 13km GFS forecasts intensities that are weaker than observations and farther from observations than the 27km GFS. MET/MODE is currently in the process of being added to the EMC verification package.

For more information on MODE and results, please visit my webpage at: http://www.emc.ncep.noaa.gov/gc_wmb/tdorian/

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