Methods for Evaluating High Impact Hydrometeorological Features using METplus

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Introduction

Evaluation of high impact hydrometeorological features in numerical weather prediction is challenging, but critical to understand due to the potential hazards they present. Features with strong gradients over a short distance, such as narrow snow bands, are more susceptible to the 'double penalty' when using traditional verification metrics due to displacement and size errors. This paper will demonstrate innovative tools for evaluating snowband features using object-based methods.

Software and Data

The enhanced Model Evaluation Tools (METplus) is a state-of the-art verification and diagnostics framework that hosts a suite of traditional statistics and diagnostic methods for applications over a wide range of temporal and spatial scales (Brown et al. 2021). Of particular use in assessing snowband events, is the Method for Object-based Diagnostic Evaluation (MODE) tool in METplus, which is used to identify and compare coherent spatial features (Davis et al. 2006). Seven cases of heavy-banded snowfall events over the Northeast, often associated with Nor'Easters, were selected and include initializations on 12/16/2020, 12/24/2020, 1/31/2021, 2/1/2021, 1/3/2022, 1/6/2022, and 1/16/2022. HRRR 1-hr forecast data was verified against the Multi Radar Multi Sensor (MRMS) product and the HRRR analysis. A masking region over the eastern quarter of the CONUS was applied in order to eliminate other snow events that may behave differently compared to the events of interest.

METplus Methods

Three novel METplus tools that enable object-based verification were used to evaluate snowband features including i) feature relative to diagnose systematic biases in the environment relative to the feature, ii) forecast consistency to provide a measure of forecast stability across cycles, and iii) multivariate MODE to identify and evaluate complex super objects from two or more input fields.

a. Feature Relative

The feature relative use-case utilized the seven cases initialized at 00 UTC to demonstrate the identification of systematic biases within the environment relative to the snowband features. The HRRR gridded forecast data was compared against the gridded MRMS accumulated precipitation and HRRR analysis for investigating various mechanisms that drive snowband behavior. This use-case was set up to use the following METplus tools, i) GenVxMask to mask the accumulated precipitation field using categorical snow and apply the east quarter mask, ii) MODE time domain (MTD) to identify and track the snowband events in time, iii) ExtractTiles to extract a tile relative to the snowband centroid, and iv) series analysis to accumulate statistics at each grid point separately within the extracted tile. Relevant configuration settings in MTD include a convolution threshold ≥0.05 inches precipitation, a convolution radius of 5 grid points (or 15 km), and a minimum volume of 1000 grid points. For ExtractTiles, a 30° x 30° tile with 0.25° grid spacing centered on the objects was extracted. Spatial mean error plots from series analysis are shown in figure 1. The aggregated biases are 2-3 mm in the 1-hour precipitation accumulations (fig. 1a), with a high

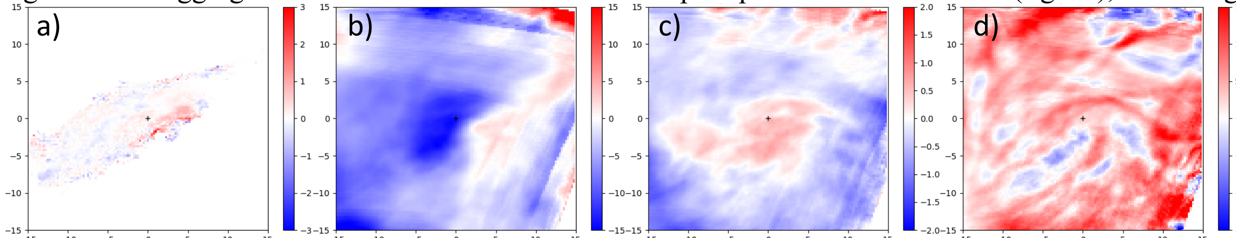

Figure 1. Spatial mean error plots from series analysis of a) 1h accumulated precipitation (mm), and b) geopotential height (m), temperature (K), and relative humidity (%) at 700 mb. The '+' indicates the feature centroid.

snowfall bias near the center and in the southeast quadrant. Geopotential heights in the mid-lower troposphere, such as at 700 mb (fig. 1b) and mean sea level pressure (not shown) show a low bias over the snowband centroid and downstream, which indicates the model low is too strong and too slow for these events. At 700 mb, the environment is too cold to the north and too warm to the south of the centroid (fig. 1c) and generally too moist (fig. 1d).

b. Forecast Consistency

For forecast consistency, the HRRR 1-hr forecasts were used for the 16 December 2020 snowband case. 1-hr cycles from 12/16/2020 12 UTC to 12/17/2020 06 UTC were used for measuring forecast stability as the event neared. This use-case first runs GenVxMask to mask the data using categorical snow and then applies the east quarter mask to focus on snowbands in the northeast. MTD is then run in reverse, starting with the longest lead time to the shortest, while keeping valid hour constant and thresholding accumulated precipitation ≥0.05” and a minimum volume of 1000 grid points. The difference from one time to the next, or the revisions, can then be computed for various object attributes, such as area, intensity, or displacement. The revisions of object area at valid time 12/17/2020 06 UTC are plotted in figure 2, showing small changes, generally less than 600 grid points, throughout the series. Considering the large size of the object (not shown), these revisions are <1% of the object area so the object size is not changing drastically from one time to another, showing consistency in the forecast.

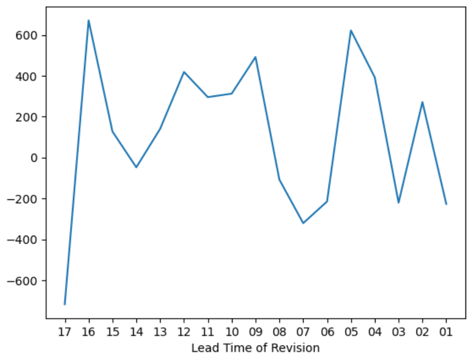

Figure 2. Time series at valid hour 12/17/2020 06 UTC of snowband object area revisions in grid points.

c. Multivariate MODE

The multivariate MODE use-case was applied to the 1 February 2021 snowband case, ingesting categorical snow and accumulated precipitation from the HRRR 1-h forecasts and MRMS. To identify and evaluate super objects in METplus, the use-case first runs multivariate MODE to identify the super objects where accumulated precipitation is identified as snow type. Then GenVxMask is used to apply the super object mask to the raw precipitation field, and finally MODE is run a second time on the masked field to provide attribute statistics. Figure 3 shows time series of object attributes, where it is observed that the forecast super objects are larger (fig. 3a), often more intense with respect to accumulated precipitation (fig. 3b), and have a north-east displacement (fig. 3c) compared to observations.

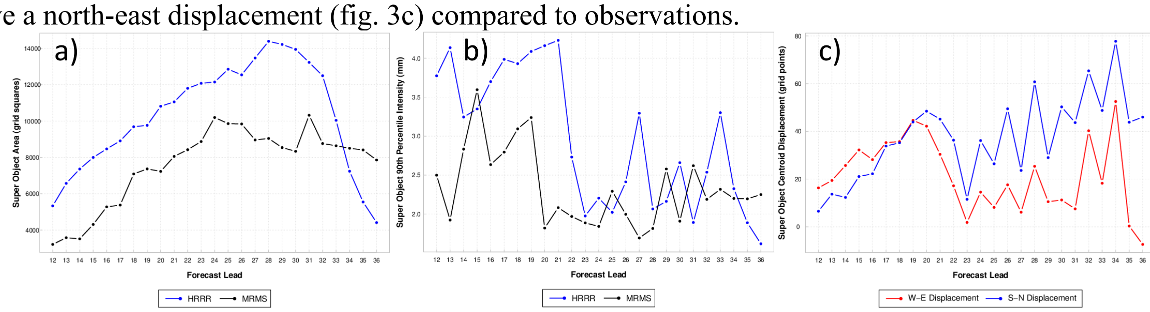

Figure 3. Output from running the multivariate MODE use-case showing time series plots of a) object area and b) 90 percentile accumulated precipitation intensity for the HRRR forecast (blue) and MRMS (black), and centroid displacement in the W-E (red) and S-N (blue) direction, where positive values indicate a E/N displacement and negative values indicate a W/S displacement.

References

Brown, B. G., T. G. Jensen, J. Halley Gotway, R. Bullock, E. Gilleland, T. Fowler, K. Newman, D. Adriaansen, L. Blank, T. Burek, M. Harrold, T. Hertneky, C. Kalb, P. Kucera, L. Nance, and J. Wolff, 2021. The Model Evaluation Tools (MET): More than a decade of community-supported forecast verification. Bull. Amer. Meteorol. Soc., 102 (4), E782 - E807, doi: 10.1175/BAMS-D-19-0093.1.

Davis, C.A., B.G. Brown, and R.G. Bullock, 2006a: Object-based verification of precipitation forecasts, Part I: Methodology and application to mesoscale rain areas. *Monthly Weather Review*, 134, 1772-1784.

Davis, C.A., B.G. Brown, and R.G. Bullock, 2006b: Object-based verification of precipitation forecasts, Part II: Application to convective rain systems. *Monthly Weather Review*, 134, 1785-1795.