Object Verification of the (CPC) Week-2 US Cold Hazard Outlooks Using the METplus MODE Tool

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Motivation and Goals

The Climate Prediction Center (CPC) forecasts hazardous weather events at a 2-week lead time and issues outlooks (days 8-14) available to the public. Currently, these hazard forecasts are not verified (skill not assessed). Verification is important for understanding strengths and weaknesses in hazards forecasting, in which improvements may help reduce morbidity (Adeyeye 2019, Wellenius 2017)

Model Evaluation Tools (MET) and its suite of Python wrappers (i.e., METplus), developed by NCAR's Developmental Testbed Center (DTC), is used for verification. The METplus Method for Object-Based Diagnostic Evaluation (MODE) tool is used for object verification, allowing users to determine what makes forecasts skillful based on object characteristics (e.g., spatial extent, orientation, shape, etc.).

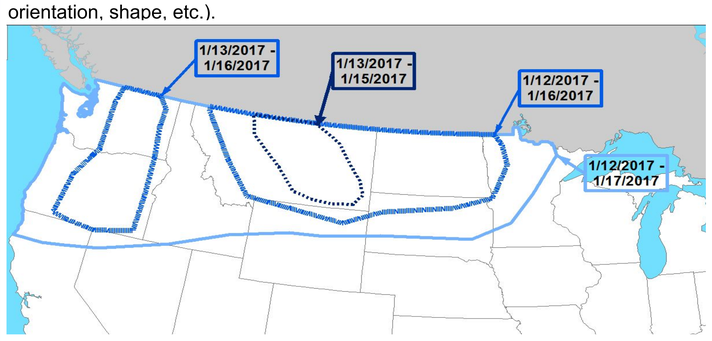


Figure 1 (above) Example of a hazard outlook issued by the CPC, specifically for hazard types that fall within the "much below normal temperatures" category. Contours represent the probabilistic risks areas; the light blue, blue, and dark blue contours are indicative of a slight risk (20%), moderate risk (40%), and high risk (60%), respectively. The valid date ranges are given for each risk contour.

Data

Table 1. Forecast/Outlook (top row) and verification dataset (bottom row) details.

Institution	Dataset/Product	Spatial Resolution	Temporal Resolution	File type
CPC	Week-2 (Days 8-14) cold hazards for three probabilistic risks (20%, 40%, and 60%)	0.5x0.5 degrees, gridded	Daily (except weekends), 2014-present	NetCDF
University of Iowa / National Weather Service	Valid Time Extent Codes (VTEC) archive dataset; observed cold hazards: Warnings, Watches, and Advisories (**WWAs**)	0.5x0.5 degrees, gridded	Daily, 12Z - 12Z valid period	NetCDF

Figure 2 (left) Categorization of week-2 outlook fields. The individual fields outlined in the red box are those that constitute the "much below normal temperatures" category.

Methodology

Hazard forecast shapes are often drawn over broad regions and take up greater area than WWAs (i.e., larger # of grid points + fewer total objects). METplus is first used to combine (or "cluster") WWAs that are alike to have comparable object areas to the hazard outlooks Attribute weights and interest maps need to be fine-tuned.

Maps determine what values for the object attributes should impact each attribute interest score; then attribute interest scores are used to compute the final interest score. Weights determine importance of each object attribute in computing the final interest score. Interest is a unitless score that ranges from 0 to 1. Object attributes like aspect ratio, axis angle, complexity, and curvature are not considered.

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

From Bullock et al. (2016)

T = Total Interest
w = Interest Weights
C = Confidence Maps (C=1 for experiment)
I = Interest Map

Table 2 (below) Description of object attribute weights and interest maps used to match/merge objects and produce interest scores. Different weights are used to cluster the WWAs and compare the forecasts to the merged WWAs.

Object Attribute	WWA Clustering Weight (Forecast Verification Weight)	Interest Map	Characteristic Description
Convex Hull Distance	40% (30%)	1 if x=0; 0 if x=17 grid spaces	Convex hull: the smallest perimeter that can be drawn around or through an object's vertices
Boundary Distance	40% (0%)	1 if x=0; 0 if x=17 grid spaces	Boundary: the smallest perimeter that can be drawn through an object's vertices
Centroid Distance	20% (10%)	1 if x=0; 1 if x=1 grid space; 0 if x=10 grid spaces	Centroid: the geometric center of an object
Area Ratio	0% (20%)	N/A	The ratio between the smaller object area and the larger object area
Intersection Area Ratio	0% (40%)	N/A	The area that two objects share compared to the total area of the smaller object

WWAs issued on February 3, 2018

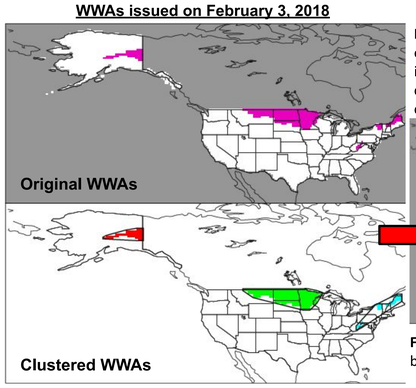


Figure 3 (left) METplus output of WWA clusters issued on February 3, 2018 after the MODE application of interest maps/weights. The black contours are the convex hulls used to define the area of the object cluster.

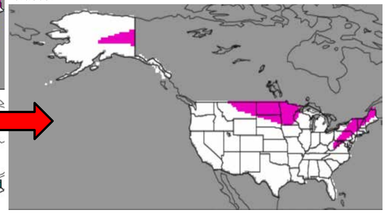


Figure 4 (above) Clustered WWAs after the areas defined by the convex hulls are filled in.

Wk-2 Hazard Forecast/Raw WWA Grid Points (2015-2021)* (# Days For Each Category)

	Outlook Risk Probability			
		20%	**40%**	**60%**
Category	**Forecast>Obs**	693 → 609	329 → 215	89 → 44
	Forecast<Obs	42 → 127	74 → 187	81 → 126
	Forecast=Obs	1 → 0	0 → 1	0 → 0
	Total	**736**	**403**	**170**

Table 3 (left) Number of forecast/observation pairs that meet the specified criteria. Rows represent the relationship between the number of forecast objects and observed objects, and columns represent the forecasted probabilistic risk area. The numbers in red font indicate the number of forecast/observation pairs after clustering similar WWAs together. Only valid dates are considered where forecast and WWA objects were present.

Verification Results

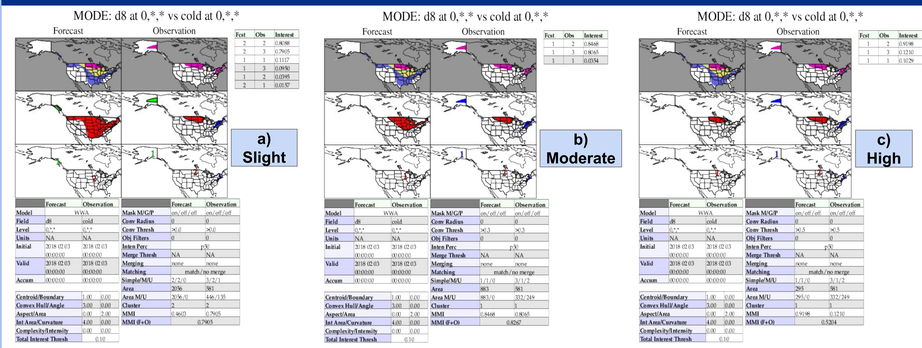
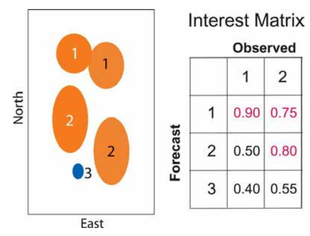


Figure 5 (above) METPlus output of the Day-8 cold hazard outlook verification using the MODE tool. The clustered WWAs are used to verify each probabilistic risk area: **a)** 20%, **b)** 40%, and **c)** 60%. Object-pair interest scores are shown in the top right or each image. Forecast/observed objects are separated by object cluster and thresholded by probabilistic risk area in the middle row of images.

Median of Maximum Interest (MMI) takes the maximum score for each pair and then computes the median to reduce impact of outliers (scores range from 0 to 1).

- *MMI for above example → Slight Risk ≈ 0.79, Moderate Risk ≈ 0.83, Above Risk ≈ 0.52*



Interest Matrix

Forecast \ Observed	1	2
1	0.90	0.75
2	0.50	0.80
3	0.40	0.55

MMI = median(0.9,0.8,0.9,0.8,0.55) = **0.8**

Figure 6 (left) Adapted from *Davis et al. (2009)*: Example of an MMI calculation using three forecast objects and two observed objects.

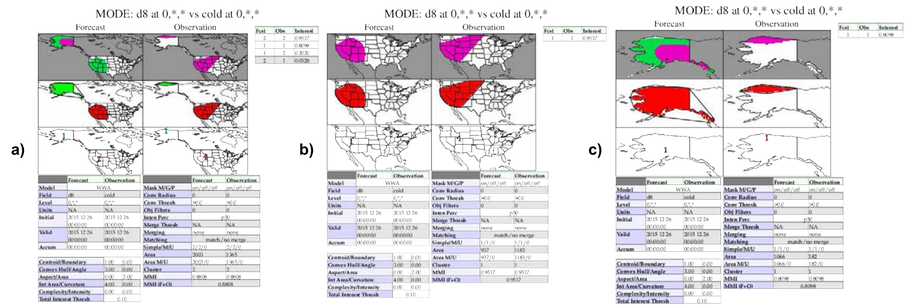


Figure 7 (above) METPlus output of the Day-8 cold hazard outlook verification using the MODE tool. The clustered WWAs are used to verify the slight risk area (20%) for a) CONUS + Alaska, b) CONUS, and c) Alaska.

Future Work

So far, we have verified cold hazard outlooks for all week-2 lead times and for all probabilistic risks from 2014 to realtime. Separating the CONUS/Alaska verification (which works best with spatial uniformity) will allow us to better fine-tune the interest weights/maps. Website creation is currently in progress for displaying verification results. Furthermore, other verification metrics, like Heidke Skill Score (HSS) and area-weighted interest, will also be computed, and we will verify the other hazard fields noted in Figure 2.

References

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