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P1.64 Verification of Precipitating Weather Type Forecasts in the National Digital Forecast Database and National Digital Guidance Database

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ABSTRACT

The National Digital Forecast Database (NDFD) contains official National Weather Service (NWS) forecasts produced by forecasters at local Weather Forecast Offices (WFO) and national centers on a fine-resolution grid from the next hour to 7 days in the future. To provide NDFD forecasters and users with feedback regarding the skill and accuracy of these forecasts, the Meteorological Development Laboratory (MDL) regularly verifies NDFD forecasts and gridded guidance from the National Digital Guidance Database (NDGD). An important element in the NDFD and NDGD is the element named "weather." This element contains forecasts of precipitation coverage or probability, precipitation type, precipitation intensity, obstruction to vision, and a few other attributes. To date, there has been no method to verify the weather element. MDL has begun developing methods to objectively evaluate these weather grids.

1. Introduction

The NDFD provides convenient access to weather forecasts in digital form from a central location (Glahn and Ruth 2003). Anyone with an internet connection can download information from the NDFD to suit his or her needs. Many products are created from this database, including forecast text, forecast images at national and regional scales, and digital data compatible with Geographic Information Systems (GIS).

Grids available in NDGD provide guidance for the WFOs as they prepare the NDFD. The Weather Prediction Center (WPC) produces gridded guidance for several NDFD elements (Weather Prediction Center 2014). MDL issues gridded model output statistics (GMOS) guidance for most elements found in the NDFD, including temperature, dewpoint, wind, and probabilistic forecasts (Glahn et al. 2009). In addition, GMOS forecasts are used to complete the NDFD when WFOs are unable to send their grids to the NDFD for extended periods.

The "weather" element in NDFD and NDGD contains forecasts of precipitation coverage or probability (e.g., scattered,

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chance, likely), precipitation type (e.g., rain, snow, ice pellets, thunder), precipitation intensity, obstruction to vision (e.g., fog), and a few other attributes (NWS 2014). GMOS guidance for weather became available in NDGD in April 2014. WPC also issues gridded guidance for weather. Figure 1 shows an example 27-h NDFD weather forecast for the conterminous United States (CONUS). Current weather forecasts and guidance can be viewed online:

- NDFD: http://graphical.weather.gov/sectors/conus.php?element=Wx
- GMOS: http://www.mdl.nws.noaa.gov/~wxgrid
- WPC: http://www.hpc.ncep.noaa.gov/5km_grids/5km_gridsbody.html

MDL's Evaluation Branch verifies NDFD, GMOS, WPC, and other guidance to provide NDFD forecasters and users with feedback regarding the relative skill and accuracy of the gridded forecasts and guidance (Dagostaro et al. 2004). Here, we present a process to compare gridded weather forecasts interpolated to stations with METAR observations of present weather at those stations. For forecasts of liquid precipitation (e.g., rain, drizzle) and freezing or frozen precipitation (e.g., snow, ice pellets), contingency tables are used to determine probability of detection, false alarm rate, bias, and the critical success index for NDFD, GMOS, and WPC weather forecasts.

2. Data

NDFD weather forecasts for the CONUS from 01 July 2013 to 30 June 2014 were collected for the 0000 UTC and 1200 UTC forecast cycles. The NDFD forecasts issued at 0000 and 1200 UTC are matched with the GMOS and WPC guidance from the prior 1200 or 0000 UTC model cycle. GMOS guidance is generally available to forecasters 4-5 hours after model cycle time. WPC guidance is generally available to forecasters 3 hours after model cycle time. This matching allows a comparison of NDFD forecasts to GMOS and WPC guidance available to forecasters at the time the NDFD forecasts were prepared.

The sampled NDFD data has 5-km resolution and is available every 3 hours out to 72 hours from 0000 UTC Day 1 then every 6 hours out to 168 hours from 0000 UTC Day 1. In August 2014, the operational NDFD was updated to 2.5-km resolution. The WPC weather guidance has 5-km resolution and is available every 6 hours for days 4 through 7 (Weather Prediction Center 2014). In July 2014, WPC was also updated to 2.5-km resolution. GMOS weather is produced at 2.5-km resolution over the CONUS from the 0000 and 1200 UTC Global Forecast System (GFS) model runs (Huntemann et al. 2012). GMOS weather is available every 3 hours from the 6 to 192-hour projection. The WPC and GMOS guidance were verified at only projections coincident with available NDFD projections.

Since no gridded present weather dataset is available, METAR present weather observations at 1319 stations throughout the CONUS were collected for the valid times spanned by the NDFD sample. Present weather forecasts from each data source were then extracted at the METAR stations using a nearest neighbor technique. There are approximately 415,000 forecast-observation pairs per projection for each model.

3. Methods

Present weather forecasts are classified as "yes" or "no" forecasts. For simplicity, we have verified high-probability "liquid" and "freezing/frozen" weather types. In the weather grid, "high probability" means probability categories corresponding to a 12-h probability of precipitation (PoP12) of 55% or greater. These categories include "likely", "definite", "numerous", "widespread", and others. Therefore, a "yes" forecast contains a high-probability term for a specified weather type. METAR weather observations are also classified as "yes" or "no" for the given weather type. For each weather type, these forecast-observation pairs are sorted into a contingency table containing hits, misses, false alarms, and correct rejections.

The two weather types considered in this study are "liquid" and "freezing/frozen". Liquid weather type forecasts contain rain, rain showers, or drizzle. Liquid weather type METAR observations contain liquid precipitation (e.g., RA, TSRA, RASN). Freezing/frozen weather type forecasts contain snow, snow showers, sleet, freezing rain, or freezing drizzle. Freezing/frozen weather type METAR observations contain freezing or frozen precipitation (e.g., SN, RASN, PE, FZRA). METAR observations of unknown precipitation (UP) verify both liquid and freezing/frozen weather type forecasts. We do not consider intensity, visibility, or attributes in this verification.

Figure 2 provides a schematic of how the contingency table is populated. The shaded areas indicate the 24-h GMOS weather forecast for 0000 UTC 07 September 2013. Darker green shading indicates high liquid probability categories, lighter green shading indicates low liquid probability categories, and the off-white shading indicates no liquid probability categories. Corresponding METAR observations for the valid time of 0000 UTC 08 September 2013 are plotted as icons. Examples of each cell in the contingency table are highlighted. For example, Salt Lake City, UT has a "yes" forecast ("Definite rain") and a "yes" observation ("Rain"), so it is considered a hit. Price, UT has a "no" forecast ("Chance rain") and a "yes" observation ("Rain"), so it is considered a miss.

Several statistics can be derived from the contingency table (Wilks 2006). The probability of detection (POD, also known as hit rate) is the ratio of correct forecasts to the number of times the event occurred. The false alarm rate (FAR) is fraction of yes forecasts that turn out to be wrong. Bias is the ratio of the number of yes forecasts to the number of yes observations. The critical success index (CSI, also known as threat score) is the proportion correct for the event being forecast, after removing correct no forecasts from consideration. The ideal POD, bias, and CSI are 1. A perfect FAR is 0.

4. Results

a. Liquid weather type

The left panel of Fig. 3 shows the CSI for liquid weather type by projection for 0000 UTC NDFD, 1200 UTC GMOS, and 1200 UTC WPC. The right panel of Fig. 3 is the related performance diagram. A performance diagram graphically relates verification statistics (Roebber 2009). Success ratio (SR) is 1-FAR. POD (y-axis), SR (x-axis), bias (diagonal green lines), and critical success index (curved blue lines) will approach unity for good forecasts. A perfect score will be located in the upper right of the diagram. In the performance diagrams shown in this paper, scores for individual projections within a day have been aggregated (i.e., day 1 spans 3-h to 24-h projections, day 2 spans 27-h to 48-h projections, etc.). The axes in these performance diagrams have also been cropped.

In days 1 through 3, both NDFD and GMOS weather overforecast liquid weather type. NDFD has a lower FAR and GMOS has a higher POD. This results in similar CSI for GMOS and NDFD liquid weather type. POD, bias, and CSI decline for all forecast sources in later forecast periods. SR declines more gradually over the forecast period. In days 4 through 7, NDFD and WPC both underforecast liquid weather type. GMOS overforecasts day 4 and underforecasts days 5 through 7. All sources have gradual increase of FAR, with NDFD having the lowest FAR. GMOS and WPC have similar FAR in days 4-7. GMOS has a higher POD. The net effect is that in days 5 through 7, GMOS has a slightly higher CSI than NDFD and WPC.

Figure 4 shows verification scores for liquid weather type for 1200 UTC NDFD, 0000 UTC GMOS, and 0000 UTC WPC. Similar patterns are noted, with NDFD and GMOS having similar CSI in days 1 through 3 and GMOS having higher CSI than NDFD and WPC at later projections. Early projections are overforecast by NDFD and GMOS and later projections are underforecast by all forecast sources. In general, NDFD has a lower FAR than GMOS and WPC. GMOS generally has a higher POD than NDFD and WPC.

b. Freezing/frozen weather type

The left panel of Fig. 5 shows the CSI for freezing/frozen weather type by projection for 0000 UTC NDFD, 1200 UTC GMOS, and 1200 UTC WPC. The right panel of Fig. 5 is the related performance diagram, where day 1 again spans 3-h to 24-h projections. Figure 6 contains the verification scores for freezing/frozen weather type for 1200 UTC NDFD, 0000 UTC GMOS, and 0000 UTC WPC. POD, SR, bias, and CSI decline in later forecast periods. All sources underforecast freezing/frozen weather type across the entire forecast period.

On days 1 through 3, NDFD and GMOS freezing/frozen weather type have similar POD, FAR, and CSI. Both models underforecast freezing/frozen weather. The CSI over this early period is similar to liquid weather type forecasts. On days 4 through 7, NDFD, GMOS, and WPC all underforecast freezing/frozen weather type. GMOS CSI is greater than NDFD and WPC in days 4-7. NDFD has a large decline in POD and a slight decline in FAR, resulting in a sharp drop in CSI.

The low NDFD and WPC scores for freezing/frozen weather type forecasts at later projections may be due to very few cases. There are fewer than 1000 "yes" forecasts per projection for freezing/frozen weather type at several projections after day 5 compared to over 10,000 "yes" forecasts per projection on day 1. The number of "yes" forecasts per projection for liquid weather type declines at a similar rate, but goes from 25,000 "yes" forecasts to approximately 2500. Forecasters at WFOs and WPC issue freezing/frozen weather type forecasts at these long lead times but at lower probabilities ("slight chance" or "chance") that this verification does not consider as “yes” forecasts.

5. Future Work

NDFD verification is available via a website to internal NWS users and updated monthly (Dagostaro et al. 2004). NDFD scores for weather are available on this website as plotted images and ASCII files. GMOS and WPC weather verification is planned to be added in early 2015. The methods outlined in this paper could be applied to the available NDFD and GMOS weather grid forecasts issued for Alaska.

The verification method described in this paper has only been computed on higher-probability weather type categories corresponding to PoP12s greater than 55%. Scores computed from contingency tables are unlikely to be useful on lower-probability categories. For example, a "slight chance" forecast is equivalent to a PoP12 of about

20%. If the forecast is reliable, one of every five "slight chance" forecasts would be a "hit". That is, many false alarms are expected from a "slight chance" forecast and thus will result in a high FAR and a low CSI. To better assess the performance of weather grid forecasts for the lower-probability categories, the reliability of these categories (i.e., the number of yes observations in the category to the number of forecasts in that category) should be determined.

The weather grid contains additional weather types that have not yet been verified, such as thunderstorms and obstructions to vision. Methods to verify those elements will need to be developed.

6. Conclusions

A method for verifying liquid and freezing/frozen present weather forecasts has been developed. Objective verification is intended to provide NWS forecasters and external users with feedback regarding the relative skill and accuracy of the gridded forecasts. Forecaster-generated NDFD forecasts have similar scores to GMOS guidance for days 1-3. GMOS guidance has statistically better scores than the NDFD and WPC guidance at later projections.

GMOS and WPC weather grids serve as valuable guidance for forecasters at NWS WFOs and throughout the weather enterprise. Forecasters improve on the guidance and use the NDFD weather grid to communicate the weather forecast to the public. Objective verification is intended to provide NWS forecasters and external users with feedback regarding the relative skill and accuracy of the gridded forecasts.

REFERENCES

Dagostaro, V. J., W. A. Shaffer, M. J. Schenk, J. L. Gorline, and A. A. Taylor, 2004: A prototype verification system for examining NDFD forecasts. Preprints, 17th Conference on Probability and Statistics in the Atmospheric Sciences, Seattle, WA, Amer. Meteor. Soc., 2.7.

Glahn, B., K. Gilbert, R. Cosgrove, D. P. Ruth, and K. Sheets, 2009: The gridding of MOS. *Wea. Forecasting*, **24**, 520-529.

Glahn, H. R., and D. P. Ruth, 2003: The new digital forecast database of the National Weather Service. *Bull. Amer. Meteor. Soc.*, **84**, 195-201.

Huntemann, T. L., P. E. Shafer, K. K. Gilbert, M. R. Peroutka, 2012: MOS precipitation forecasts formatted for the National Digital Forecast Database (NDFD). Preprints, *37th Natl. Wea. Assoc. Annual Meeting*, Madison, WI, Natl. Wea. Assoc., P2.64. [Available online at http://nwas.org/meetings/nwa2012/extendedabstracts/NWA2012_P2.64_Huntemann_etal.pdf.]

National Weather Service, 2014: National Digital Forecast Database and Local Database Description and Specification. National Weather Service Instruction 10-201, 21 pp. [Available online at http://www.nws.noaa.gov/directives/sym/pd01002001curr.pdf.]

Roebber, P. J., 2009: Visualizing Multiple Measures of Forecast Quality. *Wea. Forecasting*, **24**, 601–608.

Weather Prediction Center, cited 2014: WPC Day 4-7 Medium Range 5-km Grid Methodology. [Available online at http://www.hpc.ncep.noaa.gov/5km_grids/medr_5km_methodology_newparms.pdf.]

Wilks, D.S., 2006: *Statistical Methods in the Atmospheric Sciences*. Elsevier, 627 pp.

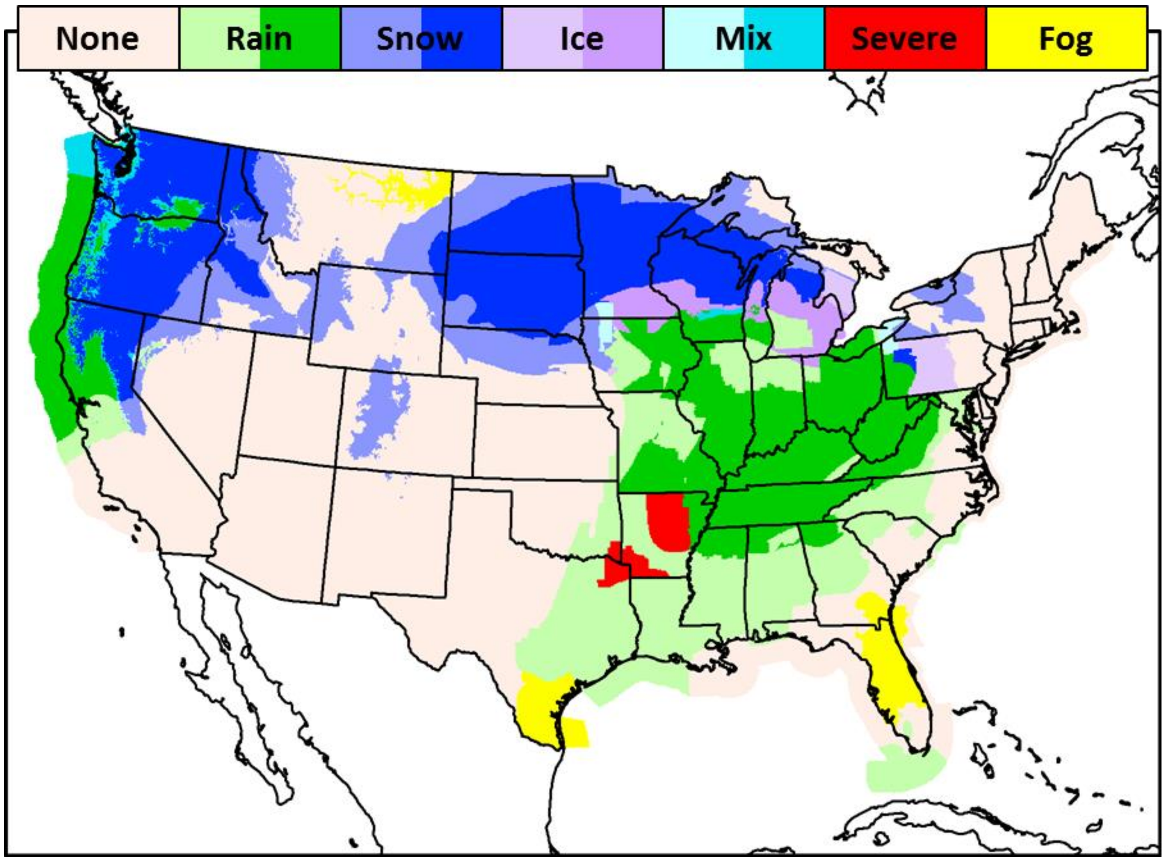

Figure 1. 27-h NDFD Weather 0600 UTC 28 February 2012. (Valid 0900 UTC 29 February 2012.)

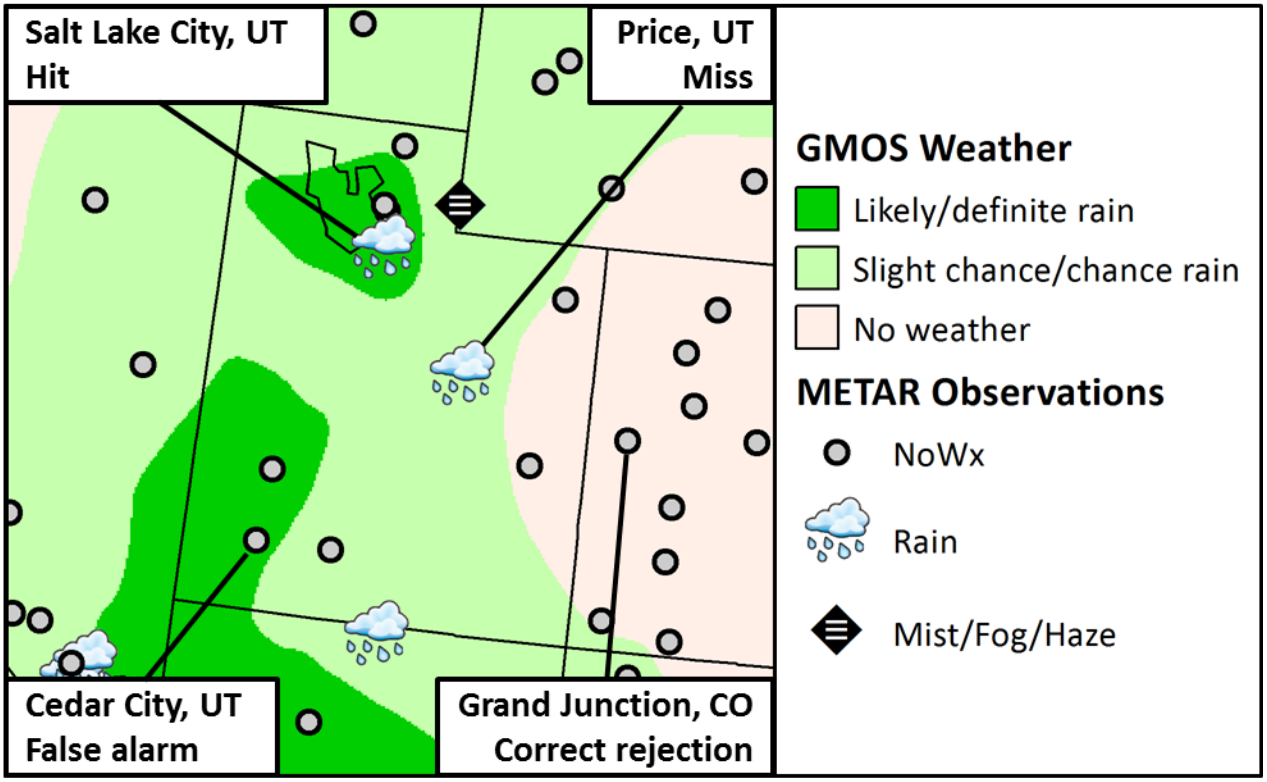

Figure 2. 24-h GMOS Weather 0000 UTC 07 September 2013. Corresponding METAR observations for the valid time of 0000 UTC 08 September 2013 are also plotted. Examples of each cell in the contingency table are highlighted. For example, Salt Lake City, UT has a "yes" forecast ("Definite rain") and a "yes" observation ("Rain"), so it is considered a hit.

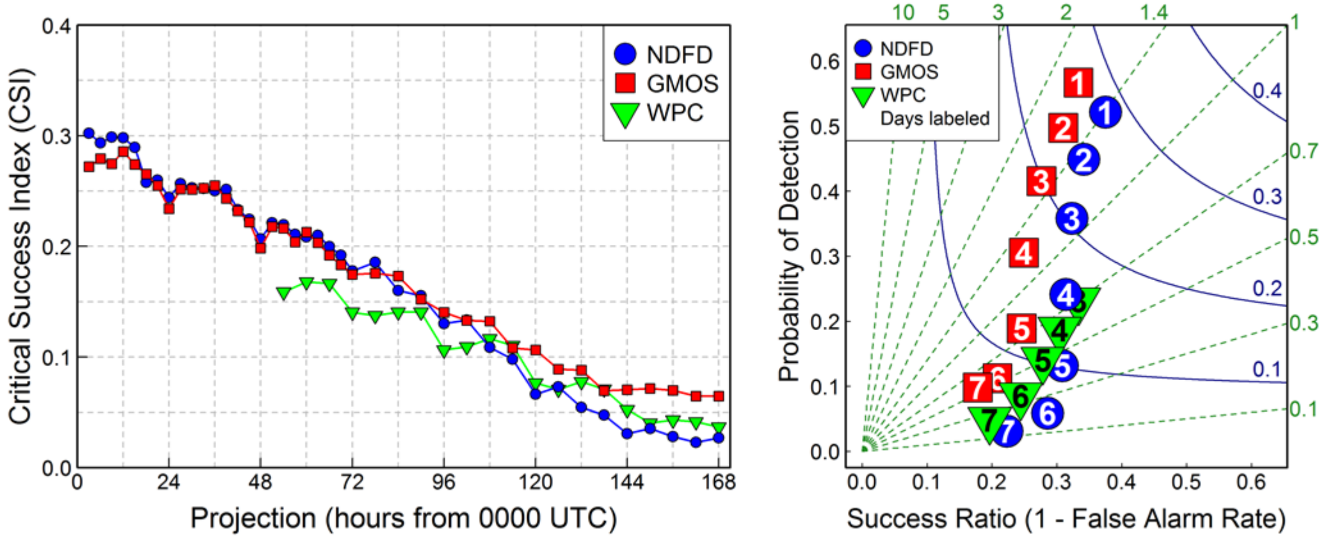

Figure 3. Verification scores for 0000 UTC NDFD, 1200 UTC GMOS, and 1200 UTC WPC liquid weather type.

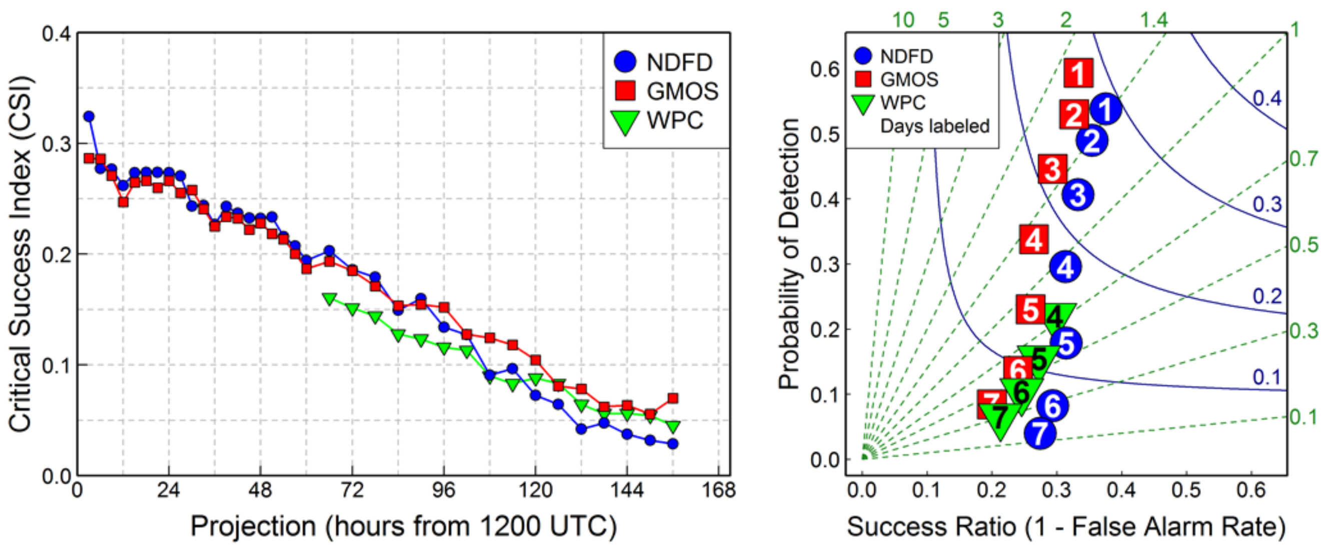

Figure 4. Verification scores for 1200 UTC NDFD, 0000 UTC GMOS, and 0000 UTC WPC liquid weather type.

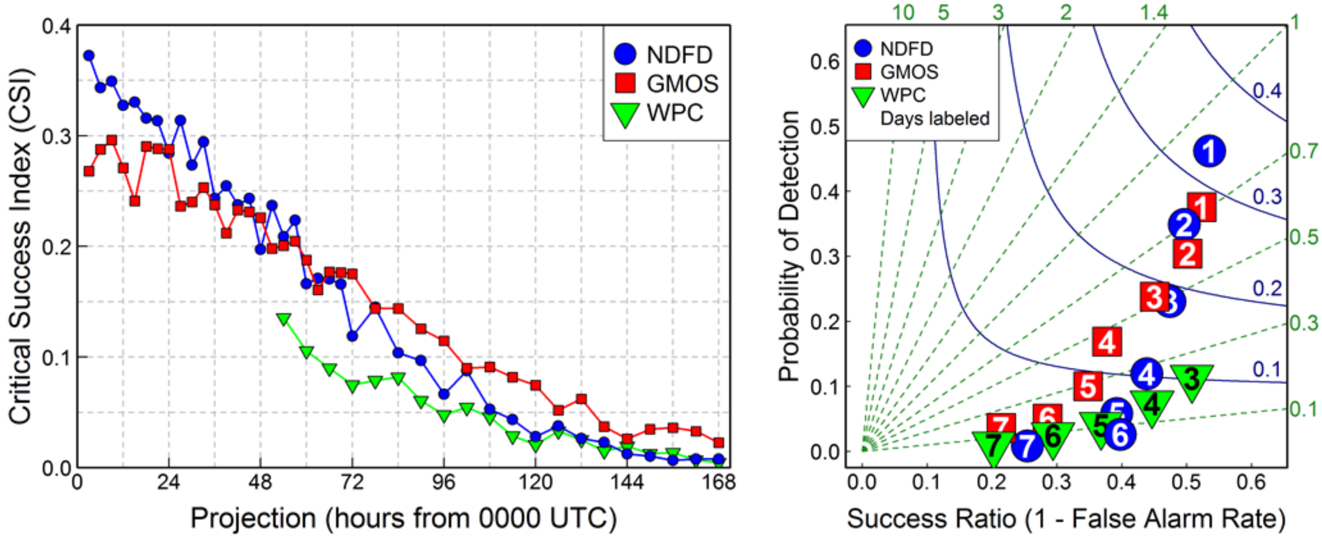

Figure 5. Verification scores for 0000 UTC NDFD, 1200 UTC GMOS, and 1200 UTC WPC freezing/frozen weather type.

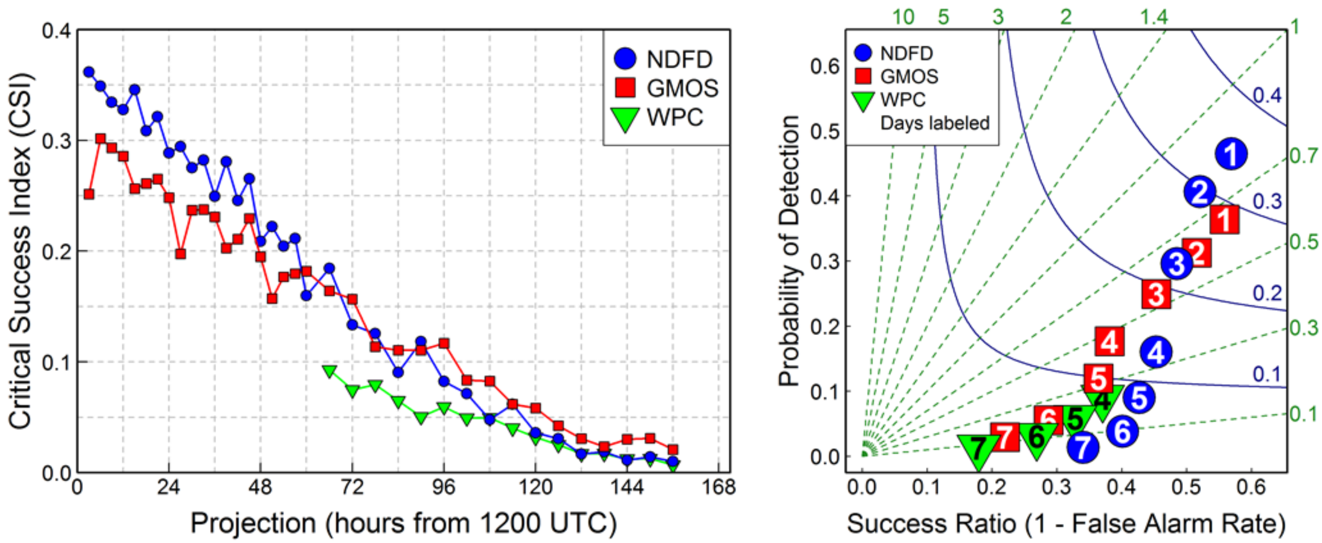

Figure 6. Verification scores for 1200 UTC NDFD, 0000 UTC GMOS, and 0000 UTC WPC freezing/frozen weather type.