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P2.64 MOS Precipitation Forecasts Formatted for the National Digital Forecast Database (NDFD)

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ABSTRACT

The National Weather Service's Meteorological Development Laboratory (MDL) has issued gridded Model Output Statistics (gridded MOS or GMOS) guidance forecasts for several years. GMOS guidance is available for most elements found in the National Digital Forecast Database (NDFD), including temperature, dewpoint, wind, and probabilistic guidance. These various forms of gridded guidance are part of the National Digital Guidance Database (NDGD). An important element in the NDFD is the element named “weather.” It is sometimes called “predominant weather.” This element contains forecasts of precipitation coverage or probability (e.g., scattered, chance, likely), precipitation type (e.g., rain, snow, ice pellets, thunder), precipitation intensity, obstruction to vision (e.g., fog), and a few other attributes. To date, gridded guidance for weather has not been available within NDGD. GMOS weather is being developed to support NWS Weather Forecast Offices (WFOs) as they prepare the NDFD. GMOS weather interprets several GMOS elements to produce a guidance grid consistent with GMOS that also closely resembles the NDFD weather forecast.

1. Introduction

National Weather Service forecasters have used station-based MOS guidance as an aid for producing forecast products issued to the user community for many years. Requirements now prompt forecasters to produce the official NWS 7-day forecasts on high-resolution grids and MOS guidance has evolved to meet those needs. Gridded MOS (GMOS) forecasts have been developed for many elements found in the National Digital Forecast Database (NDFD, Glahn and Ruth 2003). The NDFD contains a seamless mosaic of high-resolution digital forecasts from more than 120 field offices (Ruth and Glahn 2003). A variety of products is made from this database, including forecast text, forecast images at national and regional scales, and digital data compatible with Geographic Information Systems (GIS).

The various forms of GMOS guidance are part of the National Digital Guidance Database (NDGD, Glahn et al. 2009). The NDGD is a companion database to the NDFD

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that contains guidance forecasters may use as they prepare official NWS forecasts for the NDFD. The GMOS guidance available in the NDGD for NDFD products includes temperature, dewpoint, wind, and probabilistic elements. To date, gridded guidance for the NDFD element "weather" has not been available within the NDGD. This element contains forecasts of precipitation coverage or probability (e.g., scattered, 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 2009). A GMOS weather grid is being developed to support NWS Weather Forecast Offices (WFOs) as they prepare the NDFD.

Here, we present a method that uses a collection of GMOS forecasts to generate several precipitation grids to support the GMOS weather grid. The resulting precipitation probability, type, and intensity grids are combined to generate GMOS weather guidance. Though there is not currently a GMOS obstruction to visibility grid to support that component of the weather element, the GMOS weather grid remains useful without it. We expect these grids will be valuable to forecasters at NWS WFOs and throughout the weather enterprise.

2. Data and methods

GFS-based MOS grids are produced at 2.5-km resolution over the conterminous United States (CONUS) from the 0000 and 1200 UTC GFS model runs. A collection of GMOS forecasts is used to generate precipitation probability, type, and intensity grids to support the MOS weather grid as listed in Table 1. The resulting precipitation grids are then combined to create GMOS weather.

Probability of precipitation occurrence during 3-hourly intervals (PoPO3) uses the standard METAR observations valid at any one of the four hourly observations defining the 3-h interval to define the predictand (Dallavalle et al. 2005). The observations of present weather at the relevant hours are exclusively used to define the PoPO3 predictand. This is in contrast to the probability of precipitation (PoP), which requires measurable precipitation (greater than 0.01 inches of liquid-equivalent precipitation) over an interval of time (6 or 12 hours) for an event to occur (Maloney 2002). The PoP and precipitation amount predictand information are obtained from 6-h precipitation amounts in Hydrologic Rainfall Analysis Project (HRAP) 4-km grid boxes, as specified in quality-controlled River Forecast Center Stage III precipitation analyses (Charba and Samplatsky 2011).

Similar to PoPO3, the conditional probabilities of precipitation type are derived from hourly METAR observations of present weather. Considering only cases when precipitation of some form is observed, each observation is classified into one of three mutually exclusive categories to define the predictand: freezing, frozen, or liquid. Gridded climatologies and logit 50% values are used as predictors in a generalized operator equation development to capture localized effects and enhanced terrain detail (Shafer 2010). These probabilities are conditional on precipitation occurring.

GMOS thunderstorm guidance defines a thunderstorm as the occurrence of one or more cloud-to-ground lightning strikes within a 40-km grid box during a given time period (Shafer and Gilbert 2008). GMOS severe thunderstorm forecasts indicate the probability of a report of tornadoes, large hail, or thunderstorm wind gusts within an 80-km grid box during the given time period. The unconditional severe probabilities are computed from the product of the conditional probability of a severe thunderstorm and the probability of a thunderstorm in each 80-km grid box.

a. Precipitation potential index

Precipitation potential index (PPI) supports the generation of NDFD PoP12 forecasts and the categorical information provided by the NDFD weather grids (NWS 2009). PPI values range from 0 to 100 and resemble PoP12 values in magnitude. The PoP12 for any 12-hour period can be derived by taking the maximum PPI value within the desired period. PPI is not a probability forecast, which has different statistical characteristics. For example, as temporal resolution increases probability should decrease (i.e., 12-hour PoP forecasts will have a larger magnitude than 6-h PoP forecasts). As temporal resolution increases, the magnitude of PPI is unaffected.

We generate PPI from GMOS forecasts of PoPO3 (Fig. 1a), PoP6, and PoP12. We then use PPI to assign the precipitation probability (Fig. 1b) as slight chance (SChc), chance (Chc), likely (Lkly), or definite (Def). Darker shades in the weather grid image (Fig. 1c) indicate higher precipitation probability. The NDFD weather grid commonly treats probability and areal coverage as interchangeable expressions of uncertainty. Though strictly speaking this is not true, this compromise allows NDFD grids to convey the same information traditionally expressed in NWS worded forecasts. GMOS weather approximates the NDFD approach by using probabilistic terms with precipitation types and areal coverage with thunderstorms and severe thunderstorms to communicate uncertainty (Table 2).

b. Precipitation type

Multiple precipitation types may be present in the weather grid (e.g., “definite rain and chance of snow”). We use PPI, temperature, and conditional probabilities of freezing, frozen, and liquid precipitation to determine the precipitation probability for each of freezing, frozen, and liquid precipitation types. Figure 2 shows the progression from conditional probability of freezing precipitation (Fig. 2a) to freezing category (Fig. 2b) to weather (Fig. 2c). The resulting weather grid often contains hundreds of unique combinations of probability categories and precipitation types. The graphical representations of the weather grid greatly simplify this information into about a dozen colors in order to create an easily interpreted image from this complex element. The colors (green, blue, pink, etc.) in the weather grid image indicate the most likely precipitation types. “Mix” indicates combinations of liquid and frozen precipitation (i.e., rain and snow) and “Ice” indicates combinations that include freezing precipitation (i.e., sleet or freezing rain). This simplification is illustrated in Fig. 2. The weather grid in central Wisconsin and southern Michigan contains freezing precipitation as indicated in Fig. 2b, but liquid and frozen precipitation are more likely in those areas so “Mix” is displayed in Fig. 2c.

c. Thunderstorms and severe thunderstorms

Precipitation type may also include thunderstorm and severe thunderstorm categories, which we generate from a combination of PPI, TSTM3, TSTM6, TSTM12, TSVR3 and TSVR12. As part of the simplification of the weather grid to an image, thunderstorms are grouped under the colors for “Rain” and only severe thunderstorm categories of scattered or higher are displayed on the weather grid. Figure 3a shows a large area of 3-h probabilities of thunderstorms exceeding 40% over the central Mississippi valley. Figure 3b shows a more localized area of isolated and scattered severe thunderstorms. Figure 3c shows high probabilities of “Rain” (dark green) over the areas of higher thunderstorm potential and shows "Severe" (red) over the area of scattered severe thunderstorms.

d. Precipitation intensity

Precipitation intensity is obtained from the 6-h Quantitative Precipitation Forecast (QPF6). The default intensity is light, though moderate intensity is triggered by QPF6 exceeding 0.5" and heavy intensity is triggered by QPF6 exceeding 1". Precipitation intensity is not indicated on the simplified weather grid images.

3. Analysis

From 28 Feb to 1 Mar 2012, a major winter storm impacted the north central to northeastern U.S. (Otto 2012). It produced heavy snow and blizzard conditions along with some accumulations of sleet and freezing rain. In addition, there were hundreds of severe weather reports from the Central Plains to the Central Appalachians on the warmer side of this storm system. The "a" panels of Figs. 4-7 contain forecast maps of 33-h GMOS elements for 0000 UTC 28 Feb 2012. The "b" panels contain forecast maps of 30-h NDFD elements for 0600 UTC 28 Feb 2012. The GMOS and NDFD forecasts are all valid 0900 UTC 29 Feb 2012.

a. Precipitation potential index

GMOS PPI and NDFD PPI are shown in Fig. 4. Both forecasts have similar areal coverage and magnitude. The dominant feature in both is the area of precipitation associated with the winter storm over the central U.S. Discontinuities are apparent in NDFD along WFO boundaries. The low PPI values over Colorado and Wyoming result in GMOS weather forecasts of "no weather" for those areas.

b. Weather

GMOS products are intended to be guidance for NDFD forecasts, so it is reasonable to compare GMOS weather to NDFD weather. In this case, the NDFD issuance time chosen was selected because it roughly corresponds to when GMOS guidance is expected to have been available to forecasters. This means the NDFD weather forecast has the potential to contain information from several of the GMOS products used to determine GMOS weather. This comparison does not verify the GMOS forecast, but will indicate the utility of the NDGD forecasts in the overall forecast process. There are no gridded present weather observations available; however station-based METAR observations of present weather can be used to subjectively evaluate GMOS weather forecasts.

Figure 5a shows the GMOS weather 33-h forecast from the 0000 UTC cycle on 28 Feb 2012 valid for 0900 UTC 29 Feb 2012. Figure 5b shows the NDFD weather 30-h forecast from 0600 UTC 28 Feb 2012 valid at the same time. Both panels are plotted with METAR observations for the valid time of 0900 UTC 29 Feb 2012. It is evident that the GMOS probability categories (areas of light and dark shading) generally correspond well to the NDFD forecast. Both GMOS and NDFD weather resemble METAR observations. Over Michigan's Upper Peninsula, one can see fewer METAR present weather observations occur where the GMOS precipitation probability is lower. In general, both rain and snow are observed in "Mix", rain in "Rain" and snow in "Snow". GMOS has larger areas of "Ice" and "Mix" that are supported by observations. The two ice forecasts at this valid time are observed over central Wisconsin, outside of the NDFD areas of "Ice". However, GMOS has a much broader swath of "Ice" that is not supported by the observations. Due to the simplifying assumptions used to generate the weather images, one cannot tell from Figure 5 whether the GMOS "Ice" forecasts at those points contain "Definite snow, slight chance sleet" or "Definite sleet, slight chance snow" or a different combination containing freezing precipitation.

Figure 6 shows GMOS and NDFD weather forecasts for the same time as Fig. 5 plotted with METAR observations for the valid time of 0900 UTC 29 Feb 2012. While severe reports can be sparse in "Severe" areas of the weather grid, the GMOS guidance for the red area rarely exceeds the low-probability forecast of "chance of severe thunderstorms." For this particular severe event, both the GMOS and NDFD forecasts made more than a day in advance failed to correctly locate where severe weather would occur. Determining the location of severe weather a day or more in advance is a difficult task and it is anticipated that incorporating severe weather is an area where forecasters will add value to the GMOS weather guidance.

The GMOS and NDFD weather forecasts for the entire CONUS are shown in Fig. 7. GMOS lacks some coverage over the eastern Great Lakes. In the Mountain West, GMOS weather lacks both coverage and detail over the mountainous terrain. The lack of coverage and detail in the GMOS PoP and QPF grids is a chronic issue resulting in part from short development samples and the irregular distribution of MOS stations over the forecast domain (Charba and Samplatsky 2011). But overall, GMOS precipitation types (green, blue, pink, and purple colors) correspond well to the NDFD forecast. The NDFD predominant weather grid contains areas of fog in southern Texas and Florida. Because there is not yet GMOS guidance for obstruction to vision, the GMOS predominant weather grid does not contain forecasts for fog in these areas.

4. Products and future work

GMOS weather guidance will be produced on a 2.5-km grid over the CONUS. Though there is no current MOS obstruction to vision grid to support that component of the weather element, GMOS weather remains useful without it. Guidance will be available in NDGD at 0000 UTC and 1200 UTC cycles for projections every 3 hours from 6 to 192 hours. The anticipated implementation date is late 2013.

Work is underway to expand guidance to a 3-km grid over Alaska. GMOS weather for Alaska will also be available in NDGD at 0000 UTC and 1200 UTC cycles for projections every 3 hours from 6 to 192 hours. Many GMOS elements available at 2.5-km resolution over the CONUS are also available for a 3-km grid over Alaska. A few, like probability of thunderstorms and the conditional probabilities of precipitation type, have different seasonal availability over the CONUS and Alaska.

MDL is developing methods to objectively verify both GMOS and NDFD weather grids. These techniques extract weather forecasts at METAR stations from grids and compare the forecasts to observations at those stations. Preliminary results indicate GMOS and NDFD have similar scores for probability of detection, false alarm ratio, and critical success index.

5. Conclusions

A credible MOS weather grid over the CONUS has been developed to support NWS WFOs. It contains important probabilistic information about winter weather and severe weather. GMOS weather guidance performs well when compared to observations and emulates NDFD weather with respect to precipitation type and probability.

The NDFD is designed to contain a seamless mosaic of high-resolution digital forecasts from more than 120 field offices (Glahn and Ruth 2003). GMOS guidance can assist forecasters with collaboration across WFO boundaries. Forecasters add value to the guidance by interpreting external information and inserting precipitation types and attributes the MOS weather grid does not yet forecast (obstruction to vision, dry thunderstorms, hail, and others). We expect these grids will be valuable to forecasters at NWS WFOs and throughout the weather enterprise.

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Table 1. GMOS elements used to generate the MOS weather grid.

GMOS Element	**Weather Component**
3-h Probability of Precipitation Occurrence (PoPO3)	Precipitation probability
6- and 12-h Probability of Precipitation (PoP6, PoP12)	Precipitation probability
Temperature	Precipitation type
Conditional Probability of Freezing Precipitation (POZR)	Precipitation type
Conditional Probability of Frozen Precipitation (POFR)	Precipitation type
Conditional Probability of Liquid Precipitation (PORA)	Precipitation type
6-h Quantitative Precipitation Forecast (QPF6)	Precipitation intensity
3-, 6-, and 12-h Probability of a Thunderstorm (TSTM3, TSTM6, TSTM12)	Thunder probability
3- and 12-h Unconditional Probability of a Severe Thunderstorm (TSVR3, TSVR12)	Severe probability

Table 2. Precipitation potential indices and associated categories.

Precipitation Potential Index	**Probability Category (for precipitation types)**	**Coverage Category (for thunder and severe)**
0-14	None	None
15-24	Slight Chance (SChc)	Isolated (Iso)
25-54	Chance (Chc)	Scattered (Sct)
55-74	Likely (Lkly)	Numerous (Num)
75-100	Definite (Def)	Definite (Def)

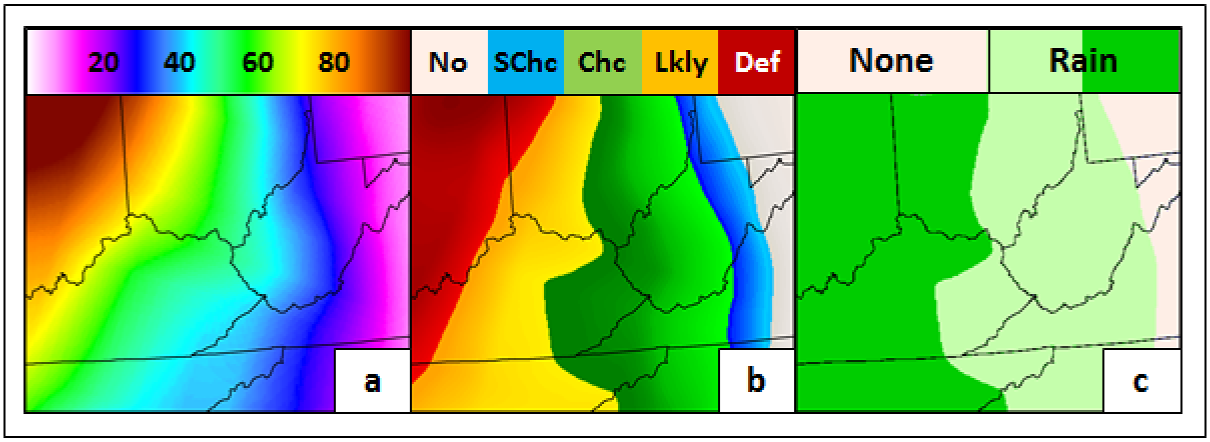

Figure 1. 0000 UTC 28 Feb 2012 33-h forecasts of GMOS (a) PoPO3 (in percent), (b) PPI, and (c) weather (valid 0900 UTC 29 Feb 2012).

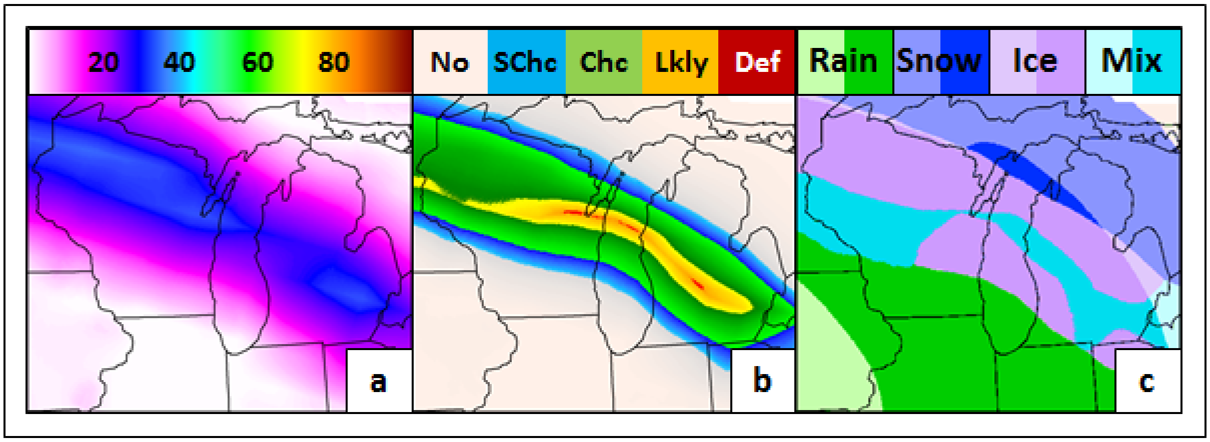

Figure 2. 0000 UTC 28 Feb 2012 33-h forecasts of GMOS (a) POZR (in percent), (b) freezing category, and (c) weather (valid 0900 UTC 29 Feb 2012).

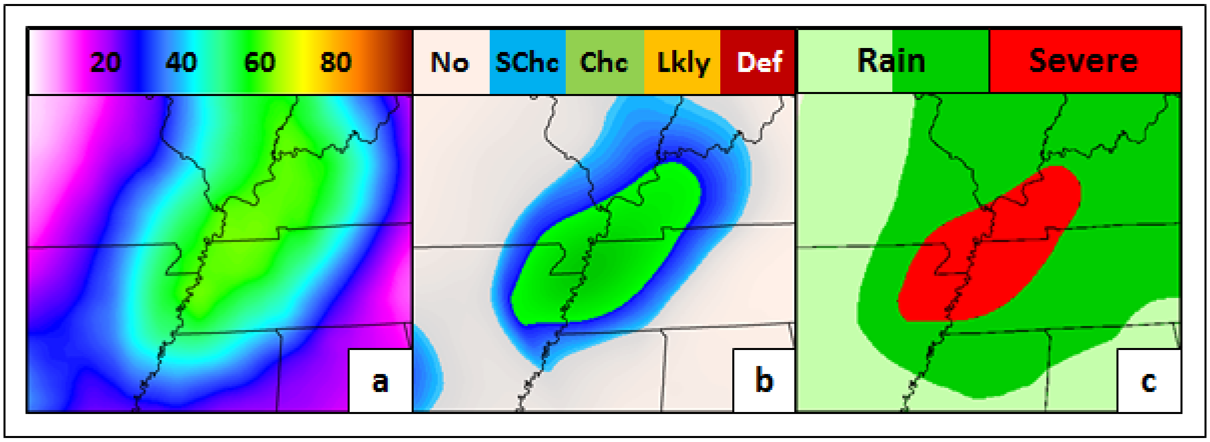

Figure 3. 0000 UTC 28 Feb 2012 33-h forecasts of GMOS (a) TSTM3 (in percent), (b) severe category, and (c) weather (valid 0900 UTC 29 Feb 2012).

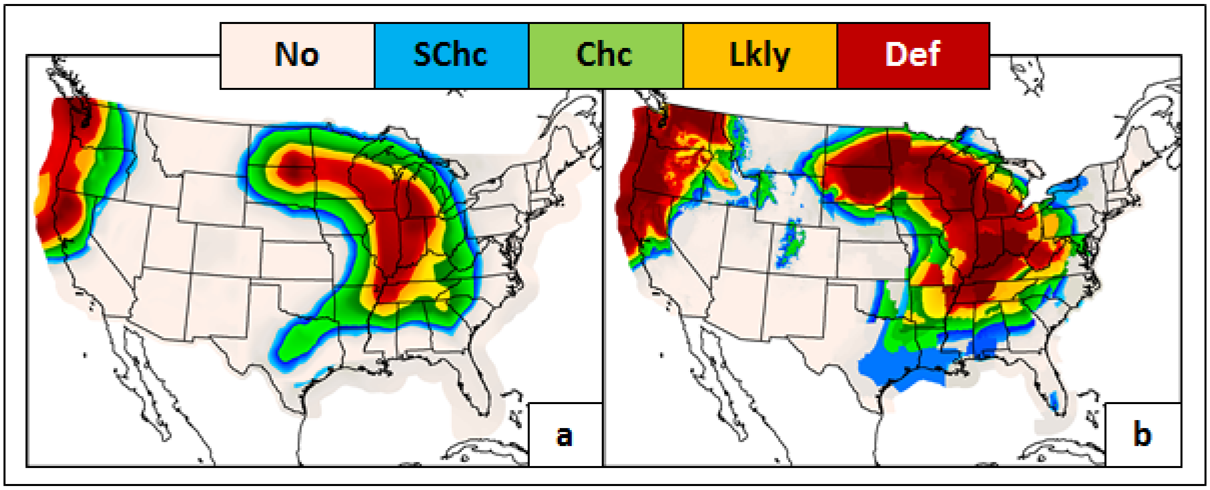

Figure 4. (a) 33-h GMOS PPI for 0000 UTC 28 Feb 2012 (b) 30-h NDFD PPI for 0600 UTC 28 Feb 2012. (Both forecasts valid 0900 UTC 29 Feb 2012.)

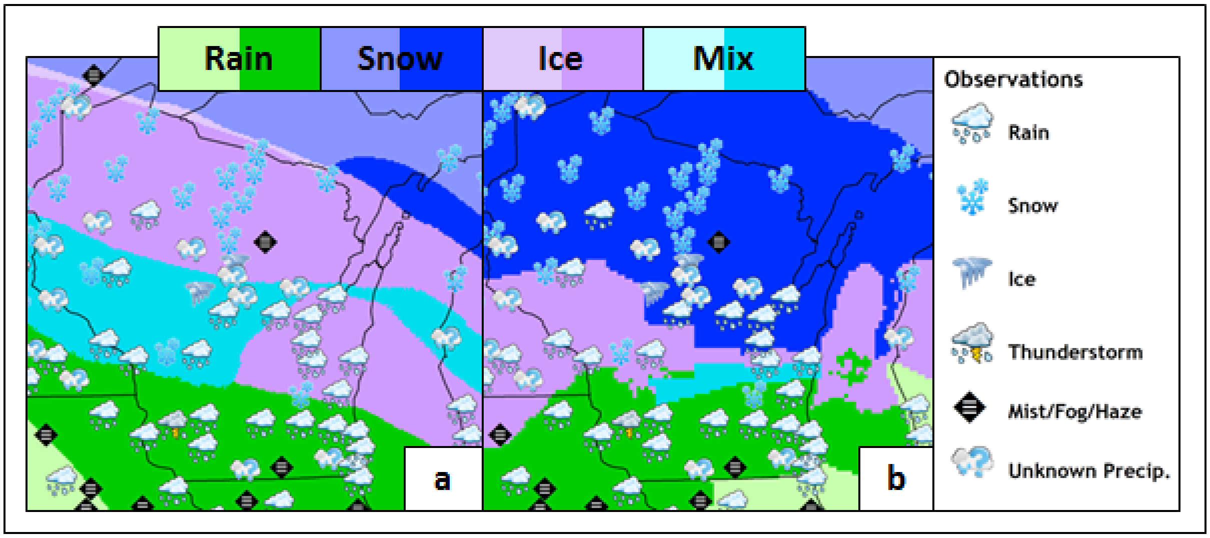

Figure 5. (a) 33-h GMOS PPI 0000 UTC 28 Feb 2012 (b) 30-h NDFD PPI 0600 UTC 28 Feb 2012. Corresponding METAR observations for the valid time of 0900 UTC 29 Feb 2012 are also plotted.

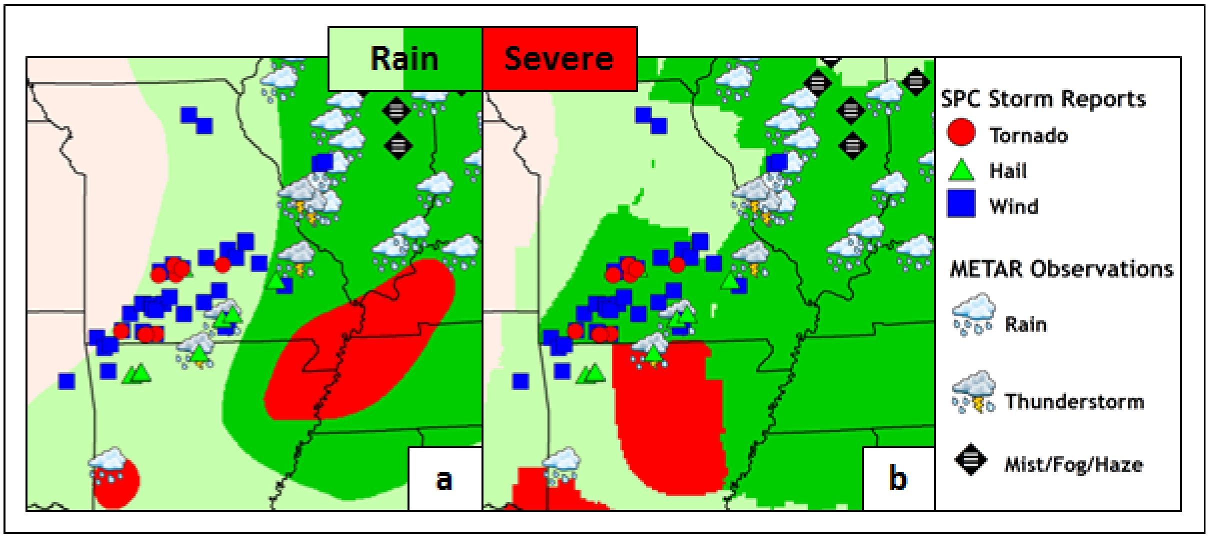

Figure 6. (a) 33-h GMOS weather for 0000 UTC 28 Feb 2012 (b) 30-h NDFD weather for 0600 UTC 28 Feb 2012. SPC storm reports from 0600-0900 UTC 29 Feb 2012 and METAR observations from 0900 UTC 29 Feb 2012 are also plotted.

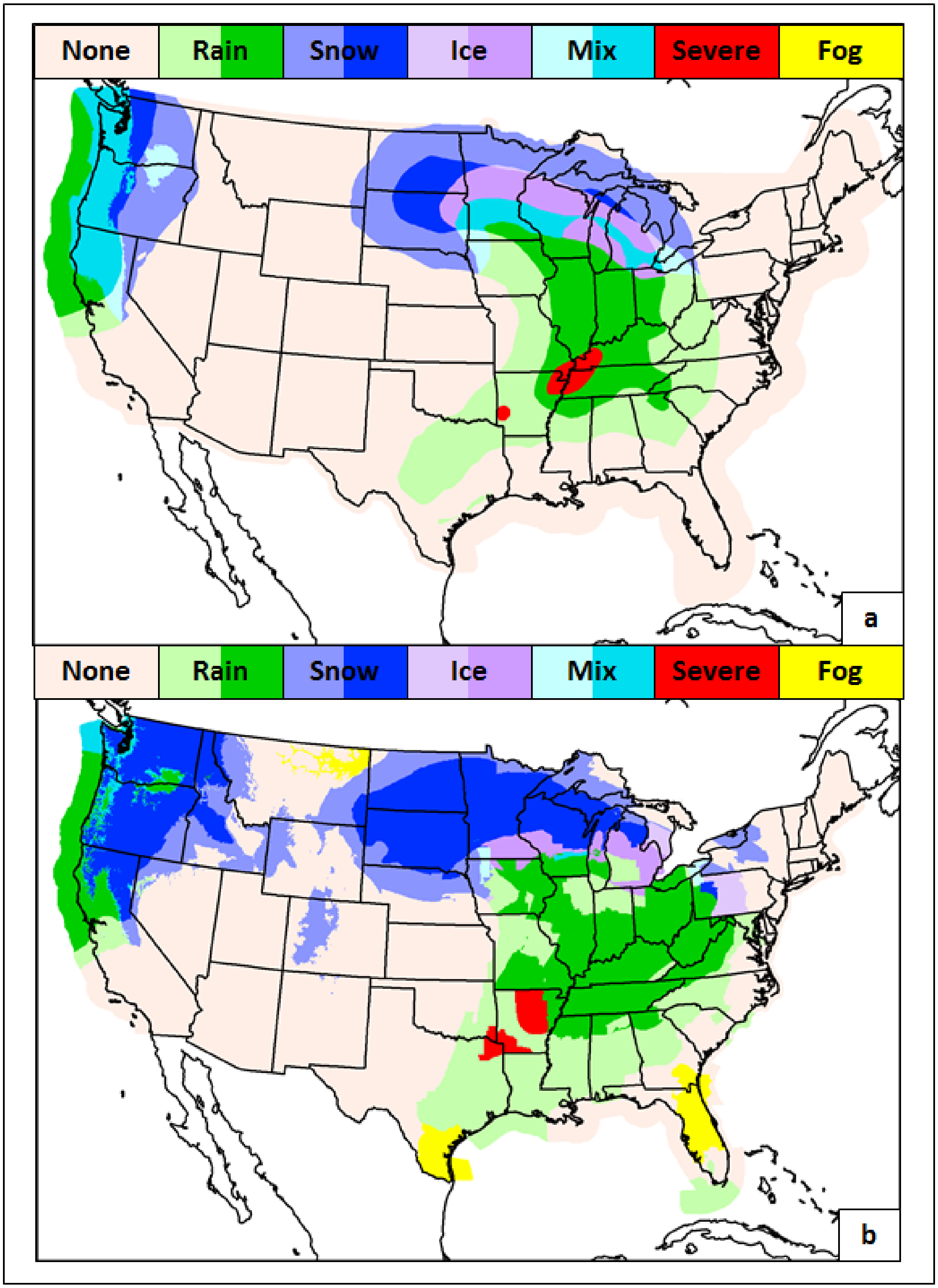

Figure 7. (a) 33-h GMOS weather for 0000 UTC 28 Feb 2012 (b) 30-h NDFD weather for 0600 UTC 28 Feb 2012. (Both forecasts valid 0900 UTC 29 Feb 2012.)