JP3.10 WINTER WEATHER GUIDANCE FROM REGIONAL HISTORICAL ANALOGS

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1. INTRODUCTION

A blend of knowledge and experience is critical for effective interpretation of model output. However, even experienced forecasters can fail to identify significant weather events such as the surprise western New York snowstorm (Lackmann 2001) and the 24–25 January 2000 snowstorm along the East Coast (Zhang et al. 2002). Failure to recognize these and similar events may be due to a variety of meteorological reasons, but an overreliance on deterministic Quantitative Precipitation Forecast (QPF) values and placement may be the primary cause. Conceptual models (e.g., Keyser and Shapiro 1985; Martin 1998), composite analyses (e.g., Beebe 1956; Moore et al. 2003; Thomas and Martin 2007), and forecast analogs (e.g., Vislocky and Young 1989; Root et al. 2007; Evans and Murphy 2008) can all be utilized to support the identification and analysis of these weather events. These techniques have been proven successful because their underlying foundation is based on the quasi-repeatability of atmospheric fields and their resultant sensible weather outcomes.

If the current state of the atmosphere resembles a previous state then the two are termed analogs, and for a period of time, the current state may evolve in a similar fashion as the past state (Lorenz 1969). The two states of the atmosphere should be considered similar only if they occur at the same time of the year and if the three-dimensional global distribution of wind, pressure, temperature, water vapor and clouds, and the geographical distributions of environmental factors such as sea-surface temperature and snow cover are similar (Lorenz 1969). Lorenz (1969) concluded that finding a good analog, one that has an error that is initially "small," is difficult. Furthermore, van den Dool (1994) showed that a dataset with approximately 10^{30} years would be required to find a 500-mb height hemispheric analog within instrument error. However, finding a good analog is possible over a smaller domain with a limited dataset (van den Dool 1994). Studies such as Vislocky and Young (1989), Roebber and Bosart (1998), and Root et al. (2007) have found successful applications using analogs on a regional domain.

Most of the early research that utilizes analogs as a forecasting tool is centered around using the current state of the atmosphere as their starting point to find analogs (e.g., Gutzler and Shukla 1984; Toth 1989; van den Dool 1989). These studies found limited success with this method, as persistence forecasting usually produced a more accurate short-term forecast. More recently, the analog method has transformed with the availability of more skillful numerical weather prediction (NWP) models. Studies by Hansen (2007), Root et al. (2007), Diomede et al. (2008), and Evans and Murphy (2008) have used the perfect prognostic ("perfect prog") approach. Here, analogs are found using NWP forecast fields as a pattern-recognition tool in contrast to using analysis maps as a forecast tool (Root et al. 2007). The Cooperative Institute for Precipitation Systems (CIPS) analog guidance (F036–F072) is produced twice a day (1200 and 0000 UTC) on regional domains in the Midwest and along the East Coast. In this paper, guidance for winter weather events is presented for two cases from the winter of 2008–2009. Unlike previous studies, the focus of the analog guidance is not to provide a deterministic forecast but to give the scale and intensity of historical events that are similar to the current forecast.

2. METHODOLOGY

The basis for analog guidance is to search a climatological dataset for maps that resemble the current forecast, and then assume that the atmosphere will evolve in a similar fashion as the historical analogs (adapted from Wilks 1995). In the present study, forecasts from the

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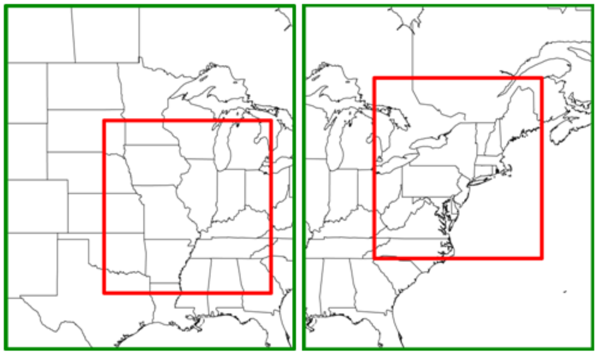

FIG. 1. The domains (synoptic [green] and mesoscale [red]) in the Midwest (left) and East Coast (right) used to find historical analogs.

National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) model were used to search the North American Regional Reanalysis (NARR; Mesinger et al. 2006) dataset for analogs. The 40-km GFS was chosen because it was hypothesized by the authors, and now supported by recent research by Charles and Colle (2009), that this model's forecasts were more skillful than the North American Mesoscale (NAM) model with mid-latitude synoptic-scale systems. To find the historical analogs, the NARR dataset was utilized because of its horizontal grid spacing (32 km) and temporal (3 h) resolution.

Determining what constitutes an analog can be done statistically using the following techniques: pattern correlation (Gutzler and Shukla 1984), mean absolute error, root-mean-square error (Gutzler and Shukla 1984), and anomalies (Root et al. 2007). In the current research, spatial pattern correlations (PC) and area-average mean absolute errors (MAE) over the domains (Fig. 1) were utilized to find the historical analogs.

During the complete pass through the NARR dataset, potential analogs were found using the 28 winters (October–March) included in the NARR dataset (October 1980–March 2008) at a 6-h temporal resolution to give ∼20,384 potential analogs. First, on the synoptic domain, a 300-hPa height PC was computed to see if the date and time passed a threshold (Table **2.**). If the 300-hPa height PC passed the threshold, then the 500-hPa height PC was computed on the synoptic domain to determine if that field's threshold was surpassed. This procedure continued on the mesoscale domain using 850-hPa temperature PC, 850-hPa temperature MAE, mean sea-level pressure PC, and 850-hPa height PC in that order on a movable subdomain that was approximately 67% of the original mesoscale domain. The choice to use a movable mesoscale subdomain to find statistics during the complete pass through the NARR dataset was to capture cases that may be potentially good analogs but have spatial variability with respect to the GFS forecast. If the date and time of the potential analog did not pass the thresholds of all six fields it was no longer considered a potential analog.

Field	Threshold
300-hPa HGHT PC	0.85
500-hPa HGHT PC	0.83
850-hPa TMPC PC	0.88
850-hPa TMPC MAE	3.8
PMSL PC	0.83
850-hPa HGHT PC	0.70

TABLE 1. Thresholds for the six fields that are used to reduce the potential analogs.

The thresholds were determined by using heavy snow cases (greater than 15 cm or 6 in.) over 28 winters that occurred in the National Weather Service St. Louis, MO County Warning Area. Composite fields were created for 30 heavy snow cases and then statistics were generated comparing the composite fields against the 30-member database. The resulting thresholds were determined as the member with the lowest individual statistic for each of the six meteorological fields listed above. Once the ∼20,384 potential analogs were reduced, "duplicate event" times were removed. "Duplicate event" times occurred due to the variability in system speed (e.g., a slow historical system may exhibit similar patterns to the forecast over a longer period of time). Therefore, the best analog was found over a 24-h period by using

$$SUM(PC) - SUM(MAE/3). \qquad (1)$$

It was necessary to reduce the potential analogs so that more of the meteorological fields that make up heavy snow conceptual models could be used to rank the potential analogs. Using these fields on the complete pass of the NARR dataset would have made computational time on the order of hours instead of minutes for each GFS forecast.

Once the complete pass through the NARR dataset was completed and "duplicate event" times were removed, a set of analogs was left that was two orders of magnitude smaller than the original set of potential analogs. Next, the procedure was rerun on the reduced set of analogs using the fields in Table **2.**. These meteorological fields represent those that are included in conceptual models and forecasting of heavy snow (e.g., Nicosia and Grumm 1999; Moore et al. 2005; Novak et al. 2006). After new statistics were determined for the complete set of meteorological fields, a results score was computed using

$$\begin{aligned}&850HGHT(PC*3) + PMSL(PC*2) + \\ &SUM(remainingPC) - SUM(MAE/3). \qquad (2)\end{aligned}$$

The 850-hPa height and mean sea-level pressure fields were weighted higher than the other PC fields based on research that correlates the tracks of these mass fields to the axis of heavy snow with synoptic-scale systems (Goree and Younkin 1966; Browne and Younkin 1970; Gravelle 2007). In addition, the 850-hPa height field was

Field	Statistic	Domain
300-hPa HGHT	PC	Synoptic
500-hPa HGHT	PC	Synoptic
700-hPa FRNT	PC	Mesoscale
850-hPa HGHT	PC	Mesoscale
850-hPa TMPC	PC	Mesoscale
850-hPa TMPC	MAE	Mesoscale
850-hPa FRNT	PC	Mesoscale
850-hPa THTEADV	PC	Mesoscale
2-m TMPC	PC	Mesoscale
2-m TMPC	MAE	Mesoscale
PMSL	PC	Mesoscale
PWTR	PC	Mesoscale

TABLE 2. Fields that are used to compute statistics to rank the historical analogs.

weighted slightly more than the mean sea-level pressure field due to less variability between the track of that mass field and the axis of heaviest snow.

In order to find analogs that have systems that propagate similar to the forecast, statistics were computed using the twelve variables in Table **2.** for ±12 h from the time of the best analog using the matching forecast. For example, if 1200 UTC 3 February 2006 was an analog for a 48-h forecast then statistics were also computed using 0000 UTC 3 February 2006 against the 36-h forecast and 0000 UTC 4 February 2006 against the 60-h forecast. If the resulting scores computed using Equation 2 were high at all three times, then the historical analog has also potentially captured system propagation. The final results score for each historical analog was the average of the three scores at the corresponding forecast hours. Finally, products that are useful for operational guidance were derived from the top fifteen analogs. Based on experiences from utilizing the heavy snow climatology, the top fifteen analogs were considered because those analogs ranked lower were found to be of lesser quality.

3. MIDWEST CASE – 19 DECEMBER 2008

During 18 and 19 December 2008, a long and relatively narrow swath of heavy snow (greater than 15 cm or 6 in.) fell from the northeastern portions of Nebraska through southern lower Michigan (Fig. 2). Within this band, maximum snowfall amounts of ∼35 cm (14 in.) were observed in portions of southeastern Wisconsin. The heavy snow fell approximately 400 km to the northwest and north of a relatively strong surface cyclone (∼1002 hPa), that formed over southeastern Colorado and tracked to central Indiana. Strong winds accompanied the heavy snow; near-blizzard conditions were common across Iowa and southern Wisconsin. In addition to the heavy snow, a major ice storm (∼0.75–1.0 in. of glaze) took place across northeast Missouri, southeast Iowa, western and central Illinois, and into northern Indiana. Widespread tree damage and power outages were common with some of the power outages lasting for over a week (NCDC 2008).

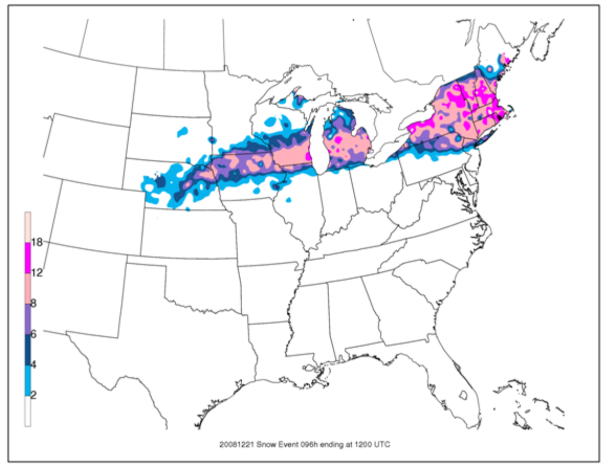

FIG. 2. NCDC COOP event snowfall for the 96-h period ending at 1200 UTC 21 December 2008.

The 48-h forecast of the GFS 1200 UTC 17 December 2008 model run was predicting a surface low centered over central Illinois with high pressure anchored to the north over east-central Ontario (Fig. 3, upper-left panel). The forecast shows strong southerly low-level flow and an 850-hPa 55-kt low-level jet (Fig. 3, upper-right panel) was bringing warm and moist air poleward along the warm conveyor belt. In the mid-troposphere, a compact short-wave trough located over west-central Illinois (Fig. 3, lower-left panel) was predicted to be responsible for providing synoptic-scale lift ahead of the surface system. The interaction of upper-level jet streaks located over northern New England and the mid-Mississippi Valley were forecast to enhance large-scale lift (Fig. 3, bottom-right panel). These forecasts of the synoptic-scale environment in the Midwest suggest that the potential for heavy snow existed in the region.

3.1 *Midwest Case Analog Guidance*

The CIPS analog guidance that was generated using the 48-h forecast of the GFS 1200 UTC 17 December 2008 model run produced the top fifteen analogs shown in Table **3.1**. Within the top fifteen analogs, scores ranged from 7.741 to 6.109 and there was a separation between the first- (7.741) and second- (6.859) ranked analogs (Table **3.1**). The quality of the top fifteen analogs can be determined qualitatively by examining the GFS forecast against the mean of the top fifteen analogs using mass fields. Figure 4 (left) shows the GFS 500-hPa height forecast had a short wave embedded in broad southwest flow over the Midwest synoptic domain while the mean of the top fifteen analogs had a trough in the northern portion of the domain. This discrepancy implies that the mean storm track associated with the top fifteen analogs and axis of heaviest snow is more poleward than the forecast. The GFS 850-hPa height forecast

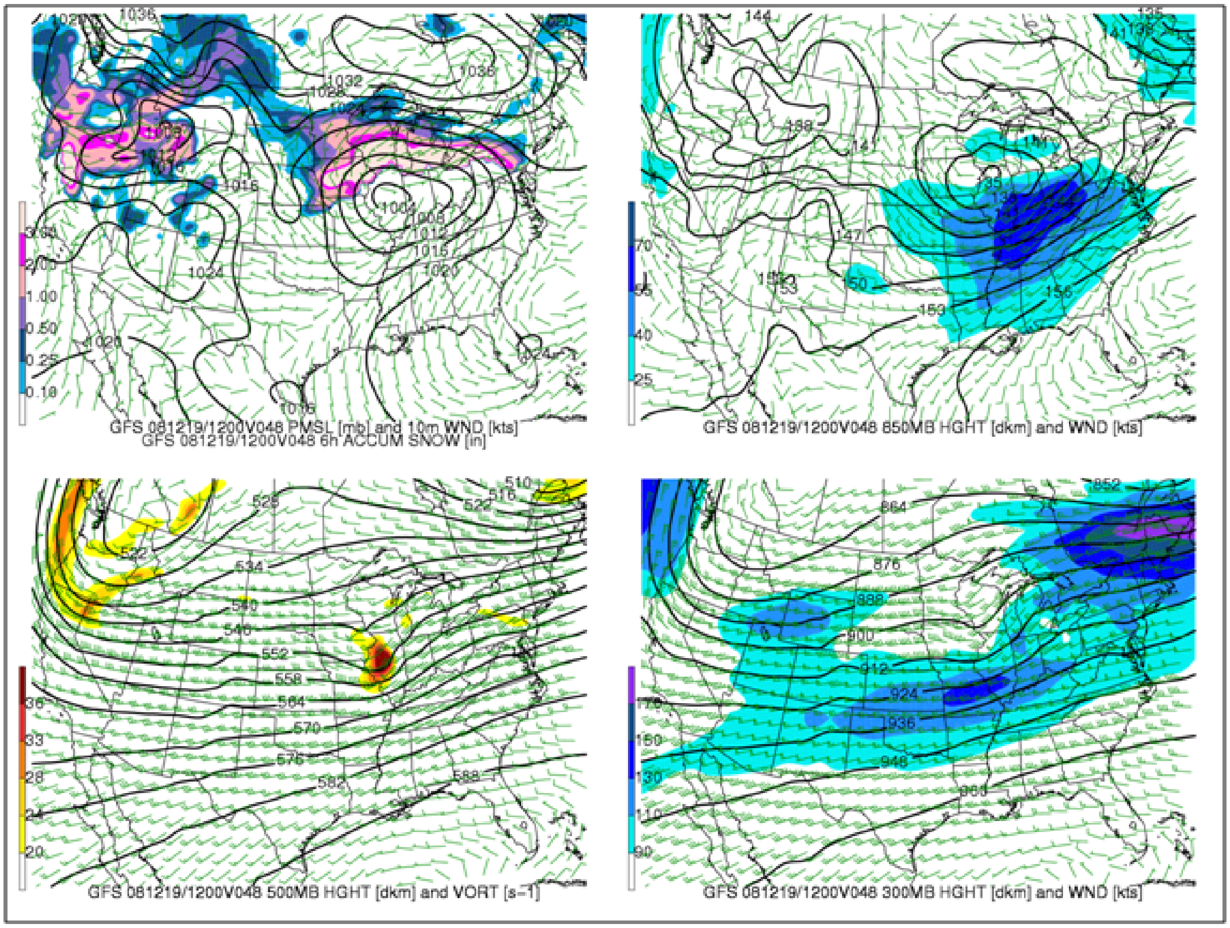

FIG. 3. GFS212 20081217/1200F048 PMSL [black,mb], 10-m WND [barbs,kts], and 6-h ACCUM SNOW [shaded,in,13:1] (top left); 850-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (top right); 500-hPa HGHT [black,dkm], WND [barbs,kts], and ABS VORTICITY [shaded,s^{-1}] (bottom left); 300-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (bottom right).

has a closed circulation in the Midwest mesoscale domain and the mean of the top fifteen analogs has a strong trough in the same area (Fig. 4, right). This suggests that the locations of the 850-hPa troughs/closed circulations from the individual analogs are roughly positioned across a similar longitude but their strength and/or latitudinal position is damping the mean field.

Probabilistic products were also produced based on the top fifteen analogs. These products were generated using event snowfall grids that were created using the National Climatic Data Center (NCDC) Cooperative Summary of the Day (COOP) snowfall data. Using the event snowfall grids allows the probabilistic products to highlight the snowfall potential from the historical analogs that is associated with a forecast winter weather event and not just the 24-h snowfall centered around the analog date. Figure 5 shows the probabilities that the COOP event snowfall was greater than 2 (left) and 4 (right) in. within 25 km of a grid point based on the top fifteen analogs. Both probabilistic products showed a major axis of higher probabilities from eastern South Dakota across central Minnesota and into northern Wis-

Rank	Date	Final Score
1	19941207/1200	7.741
2	19901215/1200	6.859
3	20000218/1800	6.813
4	19930221/1200	6.758
5	19841219/1200	6.717
6	19950215/1800	6.625
7	19881224/1200	6.588
8	20000113/0600	6.586
9	19941209/1200	6.465
10	20000216/0600	6.363
11	19841222/0000	6.297
12	19890106/0600	6.286
13	19920215/0600	6.267
14	19871220/0600	6.184
15	19890112/0600	6.109

TABLE 3. Top 15 analogs based on the GFS 48-h forecast valid at 20081219/1200.

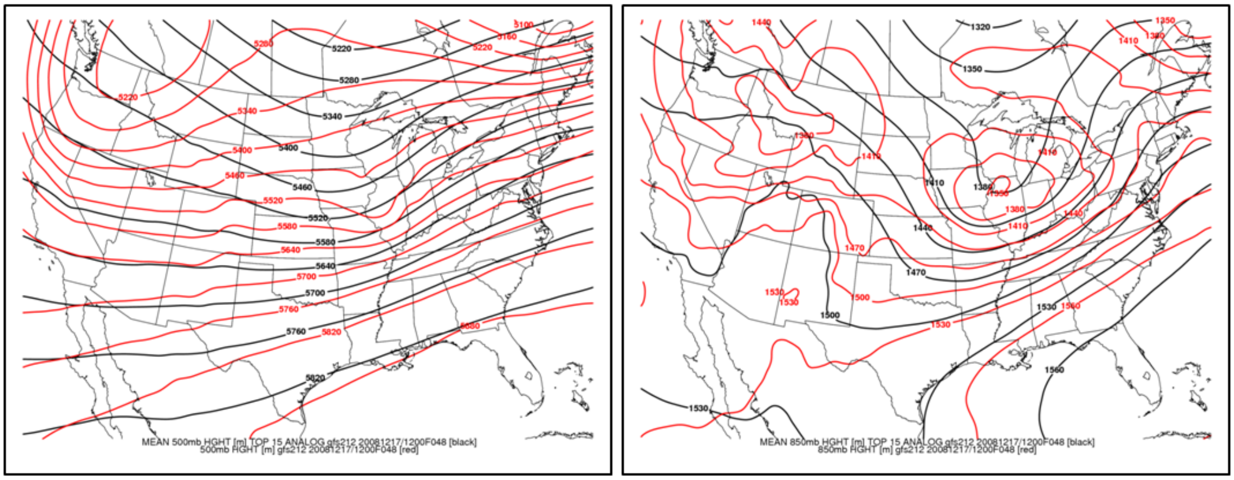

FIG. 4. GFS212 48-h forecast (m, red) and mean (m, black) of 500- (left) and 850-hPa heights (right) based on the top 15 analogs valid at 20081219/1200.

consin and Michigan. A secondary axis of lower probabilities extended along a line from northern Iowa into southern Wisconsin and Lower Michigan. The major axis correlates well with the 500-hPa height top fifteen analog mean shown in Fig. 4 (left), which implied that the mean storm track representative of the top fifteen analogs was potentially further to the north than the GFS forecast. However, the secondary axis of lower probabilities correlated better with the observed snow from this event (Fig. 2).

Examining some of the top historical analogs for the Midwest case demonstrates the importance of using the generated analog products with the individual analogs. The top historical analog for the Midwest case was 0600 UTC 7 December 1994 (7.741; Table **3.1**). The NARR had a relatively weak surface low over central Illinois (Fig. 6, top-left panel) with a strong 850-hPa 55-kt low-level jet just north of the Ohio Valley (Fig. 6, top-right panel). Broad southwest flow aloft with an embedded short-wave trough over the mid-Mississippi Valley occurred at 500 hPa (Fig. 6, bottom-left panel) with upper-level coupled jet streaks enhancing large-scale lift at 300 hPa (Fig. 6, bottom-right panel). A narrow band of greater than 15 cm of snow fell from northeast Nebraska through north-central Iowa to southern Lower Michigan (Fig. 7, top-left panel). Maximum snowfall amounts within this band of ∼30 cm (12 in.) were observed in portions of eastern Iowa. Furthermore, a major ice storm (∼1.0 in. of glaze) occurred from northeastern Kansas through northern Missouri and into northern Illinois, where widespread tree damage and power outages lasting over a week were common (NCDC 1994). The heavy snow for this historical analog and the accumulated snow for the 19 December 2008 event fell in approximately the same locations. Furthermore, similar synoptic-scale features that occurred in the Midwest case also took place with the 7 December 1994 historical analog. The score for the 7 December 1994 analog was higher than the remaining top fifteen analogs because the speed of this system was very similar for the GFS 60-h forecast (not shown). In contrast, the other top fifteen historical analogs were slower as the systems progressed eastward.

The next three historical analogs (1200 UTC 15 December 1990 [2nd, 6.859], 1800 UTC 18 February 2000 [3rd, 6.813], and 1200 UTC 21 February 1993 [4th, 6.758]) were also similar to the GFS forecast. The second, third, and fourth analogs all had surface lows that were similar in strength with low-level jets greater than 55 kts in the same areas. All three historical analogs had broad southwest flow with short-wave troughs over the mid-Mississppi Valley, while upper-level jet streak interaction occurred with the 18 February 2000 analog. The axis of heavy snow occurred slightly further to the north in the 15 December 1990 analog (Fig. 7, top-right panel) due to a more northerly track of the mass fields (not shown). While event snowfall for the 18 February 2000 and 21 February 1993 analogs placed the axis of heaviest snow roughly in the same location as the 19 December 2008 case (Fig. 7, bottom-left and bottom-right panels). In addition, the third and fourth analogs were also similar in snow swath amounts and widths. The 18 February 2000 and 21 February 1993 analogs had considerable freezing rain in southern Iowa and north-central Illinois (NCDC 1993 and NCDC 2000), where amounts approached 0.5 in. and tree damage and power outages were common.

4. EAST COAST CASE – 31 DECEMBER 2008

During 31 December 2008, an east-west oriented narrow swath of heavy snow (greater than 15 cm or 6 in.) fell from western New York through eastern Massachusetts (Fig. 8). Maximum snowfall amounts of ∼28 cm (11 in.) were observed across eastern New York. The heavy snow fell to the north of an Alberta clip-

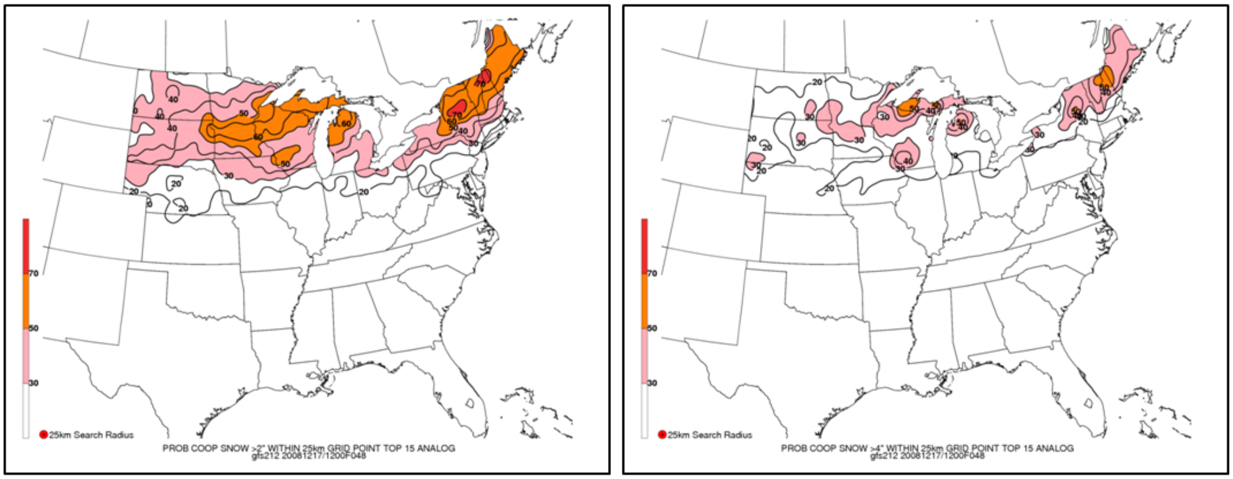

FIG. 5. Probability of COOP event snowfall >2" (left) and >4" (right) within 25 km of a grid point based on the top 15 analogs valid at 20081219/1200.

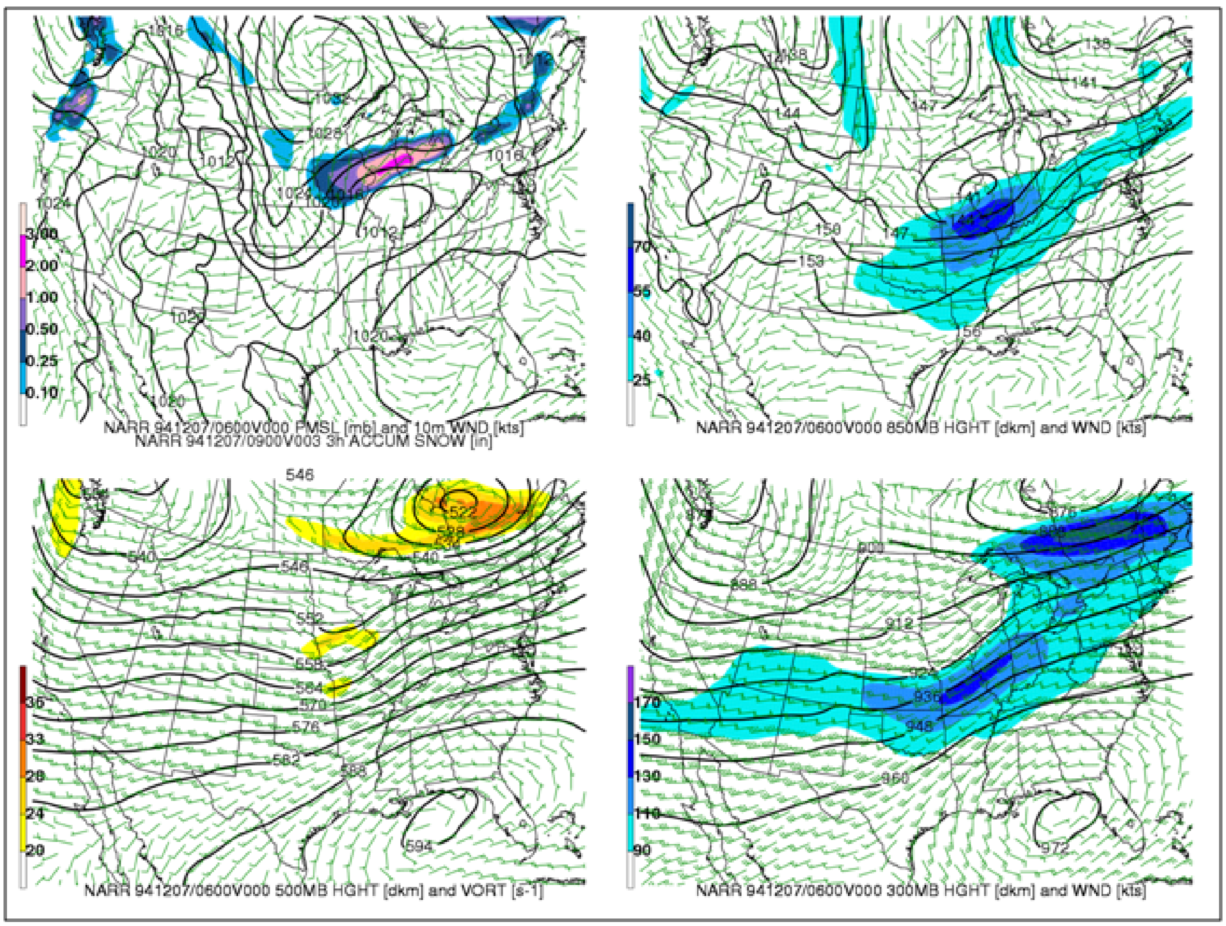

FIG. 6. NARR 19941207/0600V000 PMSL [black,mb], 10m WND [barbs,kts], and 3-h ACCUM SNOW [shaded,in,13:1] (top left); 850-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (top right); 500-hPa HGHT [black,dkm], WND [barbs,kts], and ABS VORTICITY [shaded,s^{-1}] (bottom left); 300-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (bottom right).

per that tracked from the northern Rockies through the upper-Mississippi Valley and across northern Pennsylvania (NCDC 2008).

The 1200 UTC 29 December 2008 GFS model run tracked a 996-hPa surface low from northern Indiana to the vicinity of southeastern New York by 1200 UTC 31

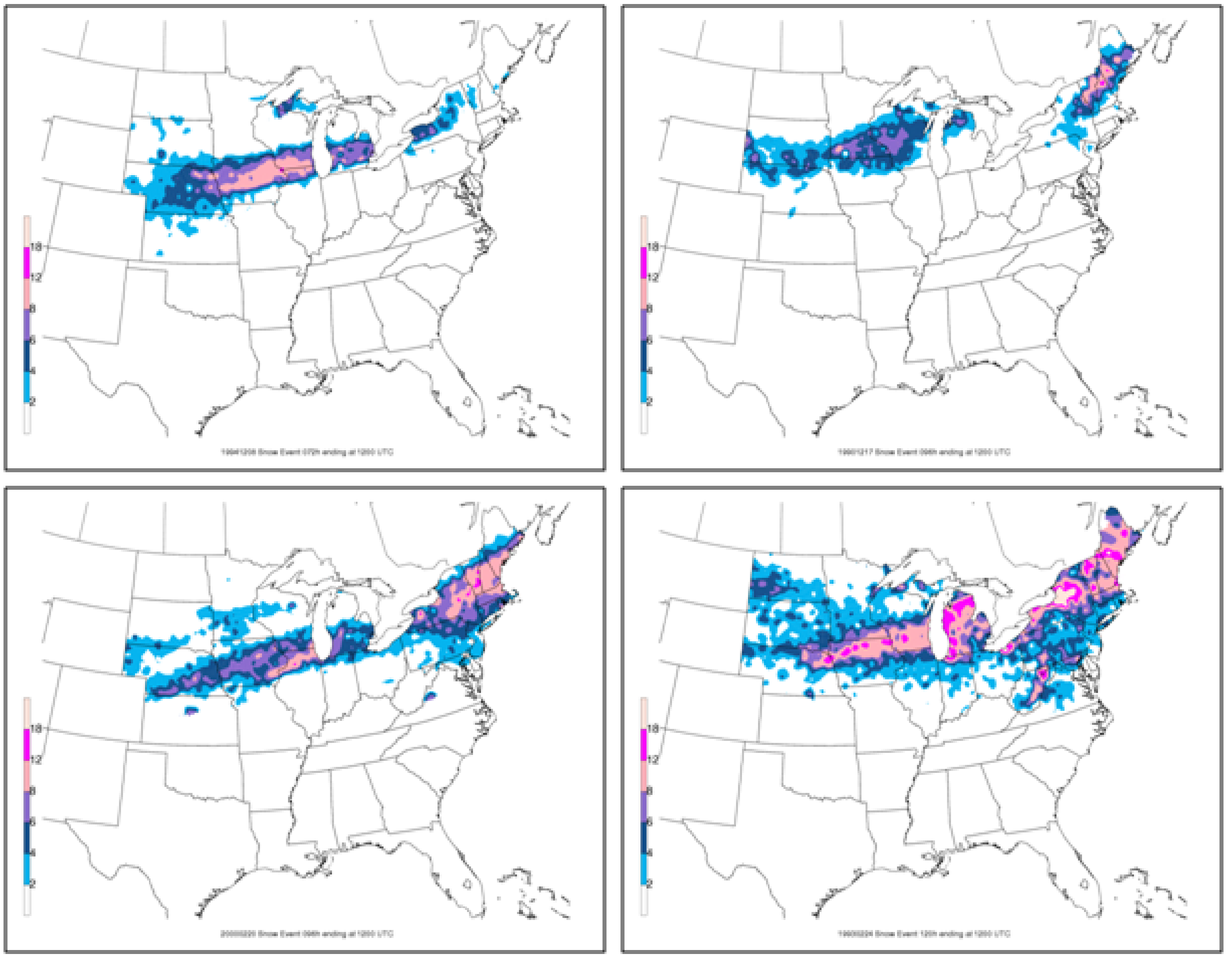

FIG. 7. NCDC COOP event snowfall for the 72-h period ending at 1200 UTC 08 December 1994 (top left), 96-h period ending at 1200 UTC 17 December 1990 (top right), 96-h period ending at 1200 UTC 20 February 2000 (bottom left), 120-h period ending at 1200 UTC 24 February 1993 (bottom right).

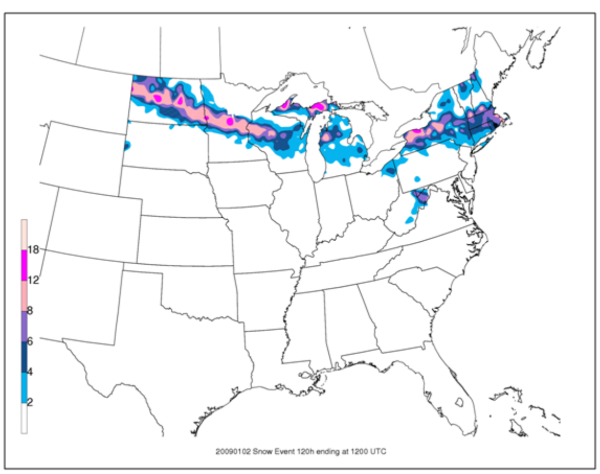

FIG. 8. NCDC COOP snowfall for the 120-h period ending at 1200 UTC 2 January 2009.

December (Fig. 9, upper-left panel). The 48-h forecast had a strong trough centered over central New York with broad 40-kt southwesterly low-level flow at 850 hPa (Fig. 9, upper-right panel). In the middle and upper troposphere, troughs tilted westward towards the Great Lakes were forecast to provide large-scale ascent over the surface low and allow moderate to heavy precipitation to take place over central New York and interior New England (Fig. 9, lower-left and lower-right panels). The GFS forecasts of the large-scale environment and thermal profiles (not shown) suggested that the potential for a band of heavy snow existed over the Northeastern United States.

4.1 *East Coast Case Analog Guidance*

The top fifteen analogs from the 48-h forecast of the GFS 1200 UTC 29 December 2008 model run are shown in Table **4.1**. Scores ranged from 8.447 to 6.849 with the top two analogs almost a point higher than the remaining analogs. The 500-hPa height mean of the top fifteen analogs and the GFS forecast both had a trough over the eastern Great Lakes with similar magnitudes (Fig. 10, left). Comparing the two 850-hPa height fields shows

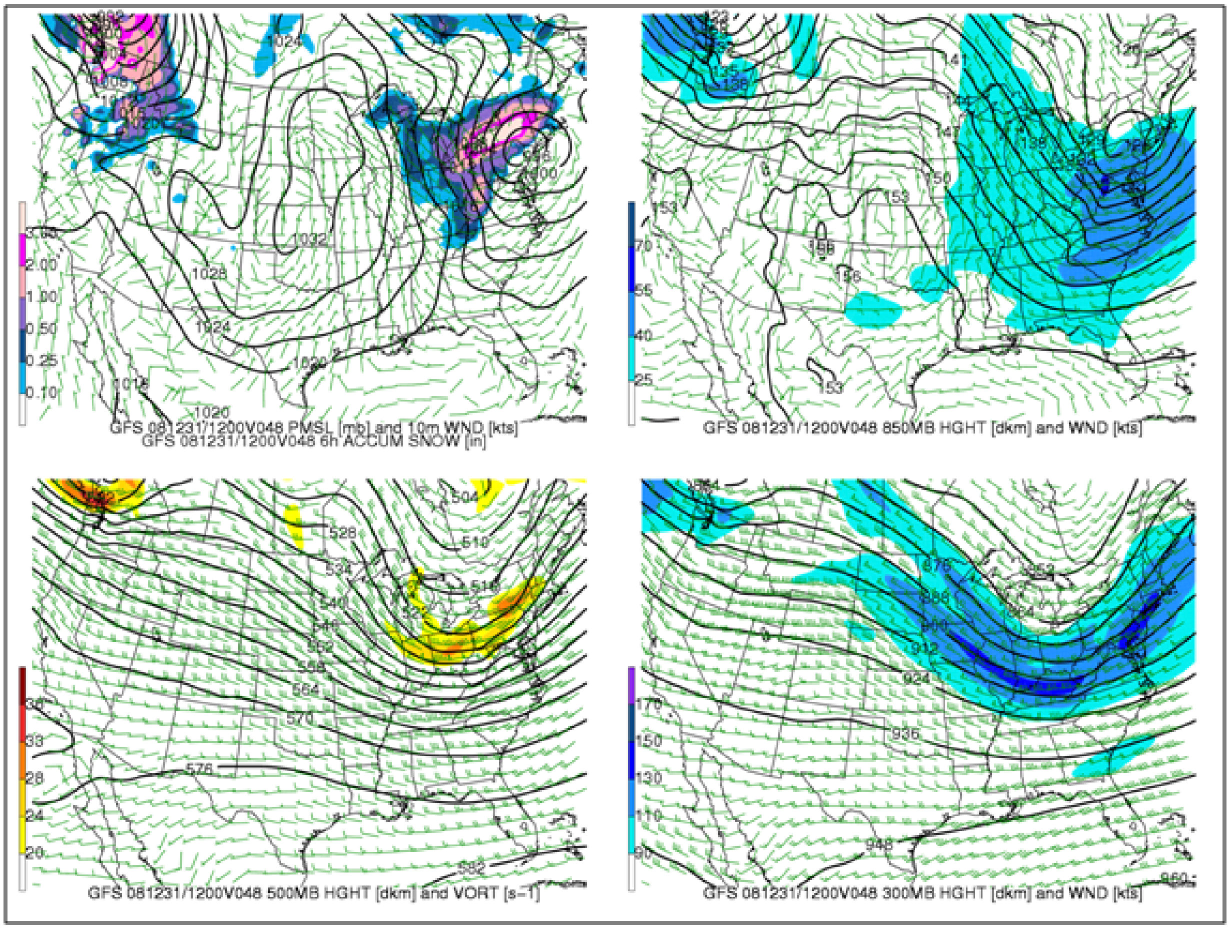

FIG. 9. GFS212 20081229/1200F048 PMSL [black,mb], 10-m WND [barbs,kts], and 6-h ACCUM SNOW [shaded,in,13:1] (top left); 850-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (top right); 500-hPa HGHT [black,dkm], WND [barbs,kts], and ABS VORTICITY [shaded,s^{-1}] (bottom left); 300-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (bottom right).

that the positions of the trough axes were similar with the mean field slightly weaker (Fig. 10, right). As in the Midwest case, this is most likely due to differences in latitudinal position of the troughs and/or closed circulations. It is important to note that even outside of the East Coast analog domains, the mass fields were very similar east of the Rocky Mountains. These similarities give confidence that the top fifteen analogs were representative of the GFS forecast.

The probabilistic event snowfall products derived from the top fifteen analogs in Fig. 11 highlighted interior New York and New England with the potential for accumulating snow. In both the greater than 2 and 4 in. probabilistic products, a major axis of higher probabilities extended west-east from western New York through central Massachusetts. The greater than 4 in. 40% contour that extended from Buffalo, New York to Boston, Massachusetts suggests that at least six of the top fifteen analogs had at least 4 in. of snow along that axis (Fig. 11, right).

The top two historical analogs for the East Coast case, 1800 UTC 13 January 2000 (Fig. 13, 1st, 8.447) and

Rank	Date	Final Score
1	20000113/1800	8.447
2	19940226/1200	8.135
3	20021203/0600	7.367
4	19960110/0600	7.288
5	20060226/0000	7.224
6	19940319/0000	7.169
7	19890120/1800	7.134
8	20070218/1200	7.112
9	19880204/1800	7.017
10	19921205/1200	6.936
11	19910121/1200	6.926
12	20030110/1200	6.919
13	19900225/0600	6.883
14	20060303/0000	6.870
15	19910211/1800	6.849

TABLE 4. Top 15 analogs based on the GFS 48-h forecast valid at 20081231/1200.

1200 UTC 26 February 1994 (not shown, 2nd, 8.135), are both analogous to the GFS forecast. Both analogs had surface cyclones, mid- and upper-level troughs, and upper-level jet streaks that were similar in strength and location to the forecast. In both analogs, there was a west-east oriented heavy snow (greater than 15 cm or 6 in.) axis that extended eastward from western New York into New England (Fig. 12). The event snow from these analogs was similar in location and strength to the heavy snow that fell in the East Coast case.

5. DISCUSSION

The importance of analyzing the CIPS analog guidance products (measures of center and probabilities) based on the top fifteen analogs in conjunction with an assessment of individual cases is presented. By comparing the mass fields of the GFS forecast and the mean of the top fifteen analogs, the overall viability of the analogs to provide guidance for the forecast can be assessed. In the Midwest case, there were considerable differences between the GFS forecast and the analog mean at 500 hPa. Knowing that these differences exist, a forecaster should question the snowfall potential provided by the probabilistic products. Here, the primary axis of highest snow probabilities were found to the north of where the axis of heaviest snow fell. By solely utilizing the derived products from the top fifteen analogs, a forecaster may have been guided too far north with the snowfall potential of this system. This may have led the forecaster to scrutinize the placement and strength of the GFS QPF because the conditional climatology (i.e., top fifteen analogs) was further poleward. However, when the top four historical analogs are examined they place the axis of heaviest snow further to the south along the secondary axis of lower snow probabilities. This, along with an assessment of the synoptic patterns associated with these individual analogs, showed that these were better "matches" when compared to the forecast. The information provided by the top four analogs provided the scale and intensity of these historical events to the forecaster.

In the East Coast case, there were only small differences between the mass fields of the GFS forecast and the analog mean. Both the GFS forecast and analog mean had a strong trough over the eastern Great Lakes at 500 hPa, while there were differences in the intensity of the trough at 850 hPa over the northeast. These differences were primarily due to the 850-hPa trough strength of the individual analogs and not due to location. The agreement between the GFS forecast and analog means coupled with the fact that the top analogs both had axes of heavy snow in the location where the derived probabilities were high should give confidence that the top fifteen analogs are representative of the GFS forecast. Here, the probabilistic guidance shows the most likely locations and magnitudes for snowfall, based on the current forecast. However, it is still important to examine the top few analogs so the scale and intensity of the historical events can be determined. Since snow swath location can vary between synoptic-scale systems due to their intensities, the derived probabilities may not fully give the scale and intensity of the top fifteen analogs.

The CIPS analog guidance also allows NCDC storm data from the individual historical analogs to be used to quickly gather more information on the potential impacts associated with the GFS forecast. In the Midwest case, there was a damaging ice storm to the south of the heavy snow band. By utilizing the storm data reports with each historical analog, a forecaster could see that three of the top four analogs had considerable freezing rain and two of the analogs were major ice storms. Individually analyzing some of the top historical analogs can allow the forecaster to understand the potential impacts associated with the model-derived forecast.

6. CONCLUSIONS

The goal of the CIPS analog guidance is not to make a forecast, but to provide observation-based guidance for winter weather and heavy snow events by using a historical dataset. The output can allow a forecaster to quickly gain historical experience while becoming familiar with the meteorological patterns associated with past similar events. In turn, this information can provide a range of scales and intensities of sensible weather that are potential outcomes of the current forecast. A deterministic framework is not recommended because meteorological events never truly repeat, however using analogs as guidance to provide forecast confidence can be a successful approach. Specifically, probabilistic information can be obtained on the most likely locations and magnitudes for snowfall based on the current forecast. Using this information together with examining the individual analogs can give a forecaster a sense of the scale and impact of an upcoming event. The analog guidance was initially developed to capture heavy snow events; however, it has also been successful at other winter weather events such as ice storms, arctic outbreaks, and cool-season severe outbreaks. The next step with this project will be to explore the possibility that the analog guidance can be successful with all winter weather events. For example, low-level temperature fields may need to be emphasized more strongly to best capture ice storms or arctic outbreaks. If this occurs, additional products will be created that will quickly and efficiently allow forecasters to use this historical guidance when relaying the forecast and impact potential to their users.

Acknowledgments. The authors would like to thank Scott Rochette (SUNY Brockport) for taking the time to review this manuscript. William Davis (MIC, NOAA/NWS Springfield, MO), Wes Browning (MIC, NOAA/NWS St. Louis, MO), Barbara Watson (MIC, NOAA/NWS Binghamton, NY), Ron Przybylinski (SOO, NOAA/NWS St. Louis, MO), and Dave

Gaede (SOO, NOAA/NWS Springfield, MO) for supporting this project and allowing their forecasters to continually improve and enhance the analog guidance.

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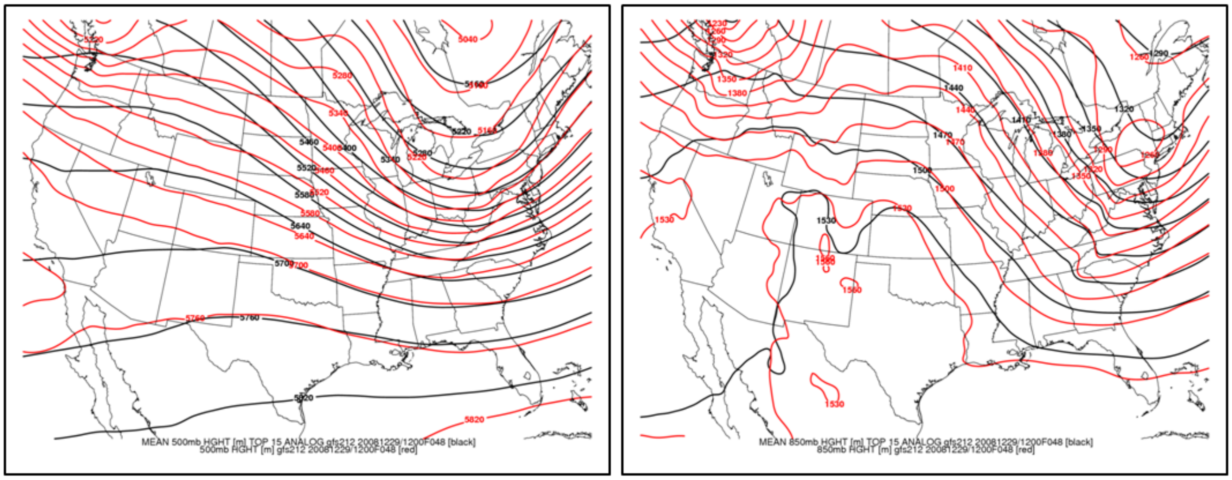

FIG. 10. GFS212 48-h forecast (m, red) and mean (m, black) of 500- (left) and 850-hPa heights (right) based on the top 15 analogs valid at 20081231/1200.

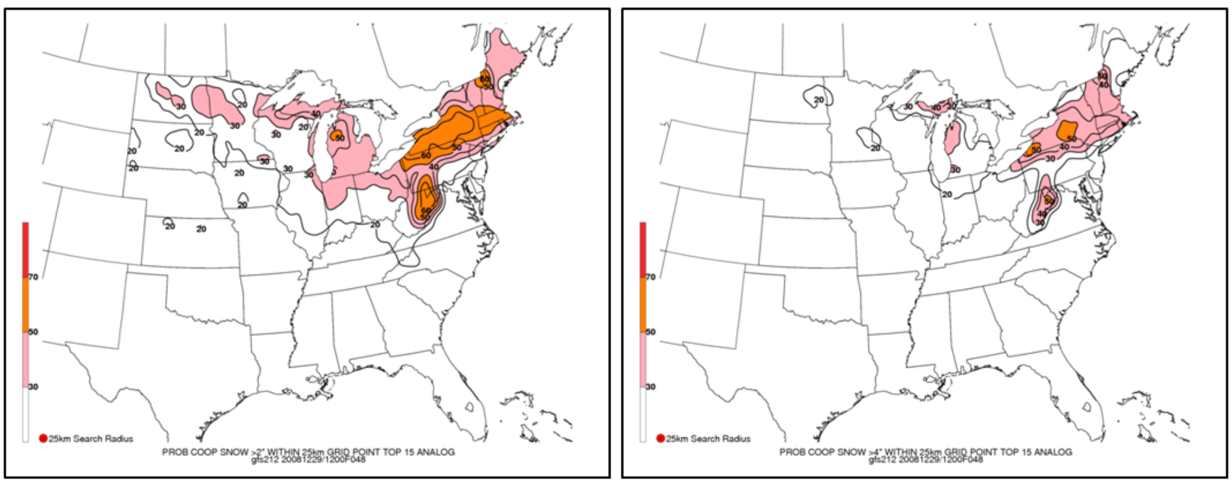

FIG. 11. Probability of COOP event snowfall >2" (left) and >4" (right) within 25 km of a grid point based on the top 15 analogs valid at 20081231/1200.

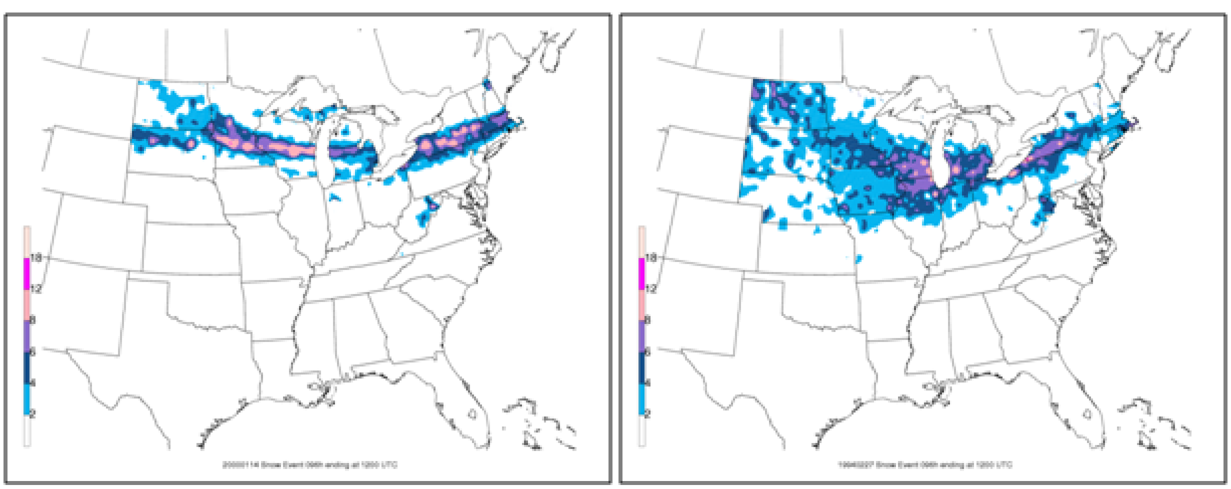

FIG. 12. NCDC COOP event snowfall for the 96-h period ending at 1200 UTC 14 January 2000 (left) and 96-h period ending at 1200 UTC 27 February 1994 (right).

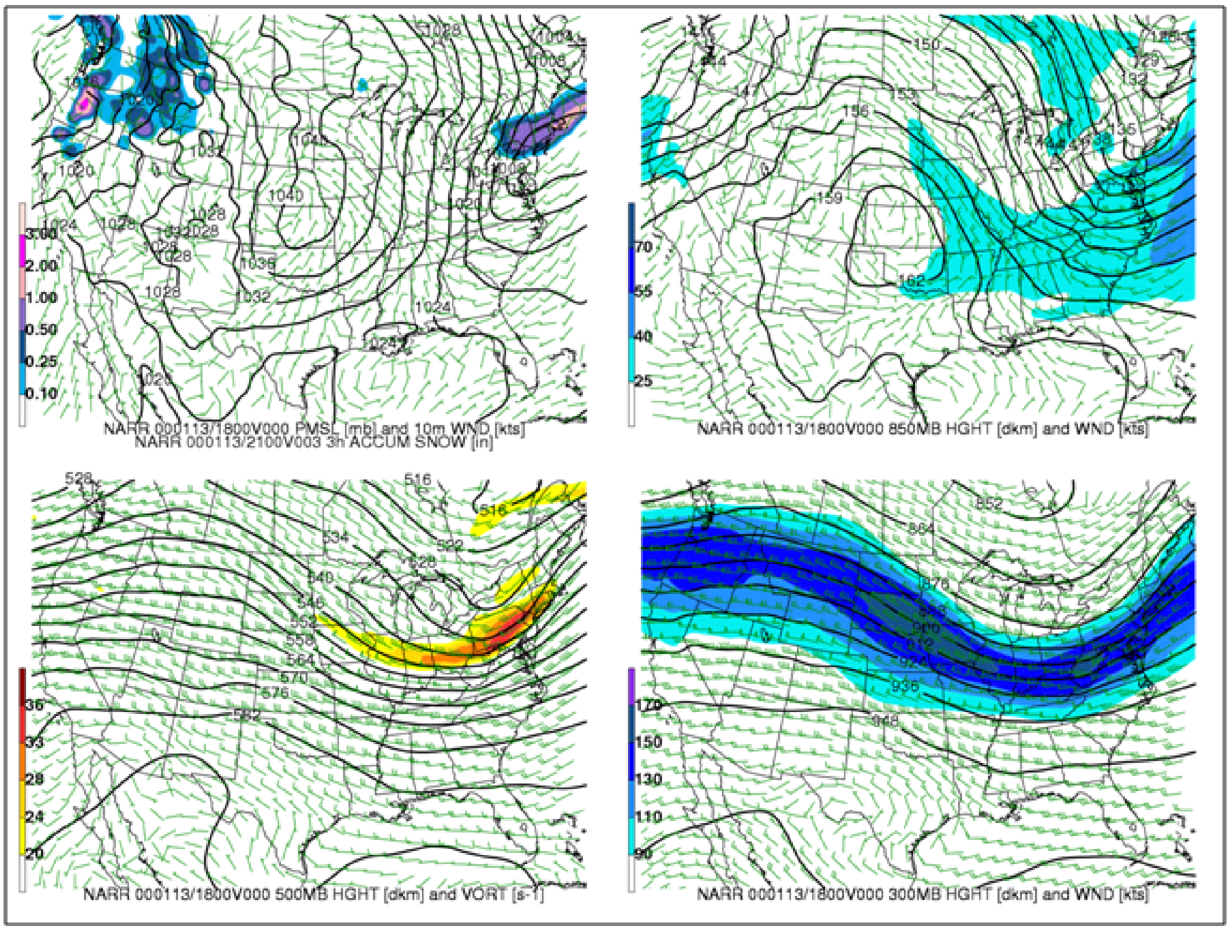

FIG. 13. NARR 20000113/1800V000 PMSL [black,mb], 10m WND [barbs,kts], and 3-h ACCUM SNOW [shaded,in,13:1] (top left); 850-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (top right); 500-hPa HGHT [black,dkm], WND [barbs,kts], and ABS VORTICITY [shaded,s^{-1}] (bottom left); 300-hPa HGHT [black,dkm], ISOTACHS [shaded,kts], and WND [barbs,kts] (bottom right).