The Historic Storm of 24-26 October 2010-Draft

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1. INTRODUCTION

An historic storm impacted much of the United States from 24-26 October 2010. It is yet to be confirmed if this storm set a new record low pressure value for an extra-tropical cyclone in the continental United States. A pressure value of 955.2 hPa (28.24inches) was recorded in Bigfork, Minnesota. This set a State record breaking the previous record set by the storm of 10 November 1998[1].

This storm broke pressure records set by notable storms such as the "Super storm" of 13 March 1993 (Kocin et al. 1995;Uccellini et al. 1995) 28.38 inches (961 hPa), the Columbus Day Storm of October 1962 28.35 in (960 hPa: Lynott and Cramer 1966[2]) and the Edmund Fitzgerald Storm of 1975. The Cleveland "superbomb" (Gaza and Bosart 1990; Hakim et al. 1995) with a surface pressure of 28.28 inches (957.6hPa) may likely the storm for comparison.

This was a high impact storm producing winds, rain, snow, and an impressive severe weather outbreak (Fig. 1). The system produced 315 reports of severe weather to include 24 tornadoes on 25 October. The storm produced over 100 reports of severe weather from southern Wisconsin across Illinois and Missouri on 24 October and one tornado in Illinois.

It will be shown that this storm was relatively predictable by the National Centers for Environmental Predictions (NCEP) numerical models and ensemble forecast systems. This storm had all the signals of being a massive cyclone with significant potential for high impact weather.

The NCEP models predicted the strong pacific jet (Fig. 2) which played a critical role in the cyclone evolution. The wind maximum in this

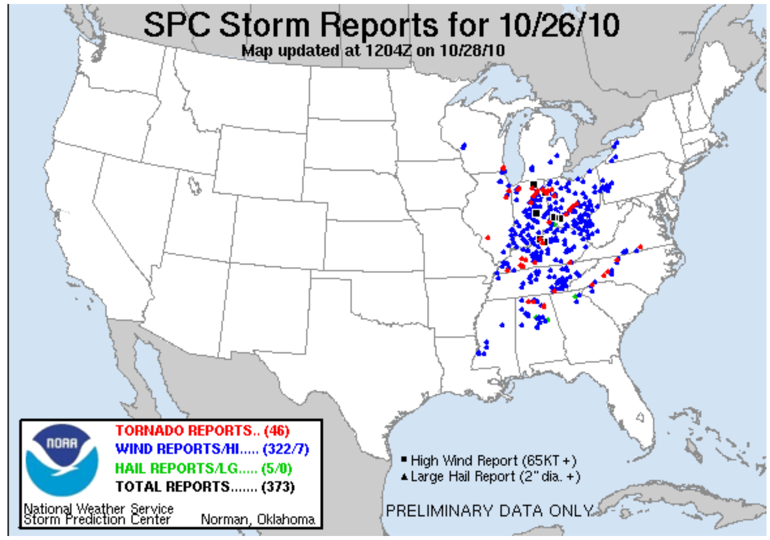

Figure 1. Storm reports from the Storm Prediction Center (SPC) for 25 October 2010. Reports color coded by report type.

jet was 4 to 5σs above normal near the onset of rapid cyclogenesis. The use of anomalies to diagnose the potential significance of weather events was demonstrated by Hart and Grumm (2001) and Grumm and Hart (2001). Recent work by Graham and Grumm (2010) has shown that many significant and historical western United States events are associated with systems with large anomalies in critical meteorological fields.

Junker et al (2008;2009) showed the value of anomalies in forecast fields to aid in predicting heavy and near record rain events. The anomalies associated with this case may aid in putting this storm in a historical perspective. Forecasts of these anomalies and tools to display them may aid in forecasting similar events with more confidence and skill in the future.

Thus, this case is documented here from an anomaly perspective. This case will be compared to the Cleveland Superbomb. And forecasts from NCEP EFSs are presented to show how storms like this can be predicted and

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[1] Based on LaCrosse, WI website information http://www.crh.noaa.gov/arx/?n=oct2610
[2] Also known as the Big Blow.

how we can predict these outcomes with some modicum of confidence.

2. METHODS AND DATA

The 500 hPa heights, 850 hPa temperatures and winds, other standard level fields were derived from the NCEP GFS, GEFS, and the NCEP/NCAR (Kalnay et al. 1996) reanalysis data. The means and standard deviations used to compute the standardized anomalies were from the NCEP/NCAR data as described by Hart and Grumm (2001). Anomalies were displayed in standard deviations from normal, as standardized anomalies. All data were displayed using GrADS (Doty and Kinter 1995).

The standardized anomalies computed as:

$$\sigma = (F - M)/\sigma \quad (1)$$

Where **F** is the value from the reanalysis data at each grid point, **M** is the mean for the specified date and time at each grid point and σ is the value of 1 standard deviation at each grid point.

Model and ensemble data shown here were primarily limited to the GFS and GEFS. The 1.25x1.25 degree JMA data may be used when it becomes available. The NAM and SREF data were also available for use in this study. Displays will focus on the observed pattern and some forecast issues associated with the pattern.

For brevity, times will be displayed in day and hour format such at 25/0000 UTC signifies 25 October 2010 at 0000 UTC.

Comparisons to the 1978 Cleveland Superbomb will compare the NCEP/NCAR re-analysis data to the storm here. These data are on a coarser grid than the GFS. As the global re-analysis data is updated, better comparative images will be produced.

3. RESULTS

i. Synoptic scale pattern

Figure 2 showed the evolution of the 250 hPa jet and synoptic pattern. The key feature was the strong jet which came out of the Pacific Ocean. It is beyond the scope of this paper to relate this feature to the tropical activity and significant Typhoons which were present over the tropical Pacific. The accompanying 500 hPa pattern is shown in Figure 3. These data show a wave along the Pacific Northwest which moved into the central United States and was clearly associated with the rapid cyclogenesis. Height anomalies were in the -2 to -3σ range at the time of peak development.

The initial surge of high precipitable water (PW) air came from the Pacific (Fig. 4). A plume of moisture ahead of this system from the Gulf did not merge with the initial plume of high PW air and the developing storm was unable to ingest a significant plume of high PW air from the Gulf of Mexico.

ii. Regional pattern and anomalies

The GFS MSLP and MSLP anomalies are shown in Figure 5. These data are in 6-hour increments. The impressive feature in these data is the closed 960 hPa contour (Figs 5f-g) with -6σ pressure anomalies. The depth of the cyclone in the analysis is impressive. The recorded value was 956 hPa at the nearest station to the cyclone center. These forecasts of a rapid cyclone are rather impressive and in close proximity to where the lowest pressure was observed in northeastern Minnesota.

The 850 hPa winds (Fig. 6) and PW (Fig. 7) about the cyclone show strong winds and a surge of high PW air. A strong southerly jet at 850 hPa moved into Illinois then across Kentucky, Indiana, and Ohio, delineating the area of significant severe weather shown in Figure 1. The total wind anomalies were 3-4σs above normal ahead of the front and peaked at +5σs above normal.

The PW field shows the frontal zone and the deep moist air in the warm sector. The juxtaposition of the warm air and the low-level likely kept the moisture and shear aligned and produced enough CAPE to support the convection and severe weather that progressed from the Midwest into western Pennsylvania and New York.

The 850 hPa temperatures are shown in Figure 8. These data show above normal 850 hPa temperatures in the warm air ahead of the frontal system. There was a limited amount of cold air with this cyclone and only minor areas of -1σ temperature anomalies. The lack of cold air likely limited the snowfall associated with this system.

iii. Historical comparison

This cyclone broke the US surface pressure record and will replace the Cleveland superbomb (Fig. 9). The NCEP/NCAR reanalysis of this storm is shown in Figure 9. This storm moved northward out of the Gulf of Mexico into the Ohio Valley. The lowest pressure was 964 hPa and it showed -5σ MSLP anomalies. The Cleveland "*superbomb*" clearly showed several 6-hour period of 8-12 hPa pressure falls as it moved into Ohio and then into Ontario.

The Big Blow or the Columbus Day windstorm MSLP is shown in Figure 10. These data show this strong storm persisted for several days. The -6 σ pressure anomalies endured for several time periods though they were accompanied by 976 to 980 hPa pressure anomalies.

The superstorm of March 1993 is shown in Figure 11. Each of these storms was impressive and all were deep cyclones. The March storm had a closed 968 hPa contour which at times was -5 σ below normal.

iv. Impacts and weather

Figure 12 shows the composite reflectivity at discrete times these data show the north-south line of convection which moved across Missouri and into Pennsylvania. This feature and the multiple evolutions it went through produced the severe weather shown in Figure 1. These data show that the frontal convection was far removed from the strong cyclone in Minnesota.

The rainfall data are shown in Figure 13. These data reflect the effect of propagating convection and suggest that this system was not a particularly potent producer of rainfall.

The pattern at 1200 UTC 26 January is shown with plots of the severe weather from 25-27 October 2010 is shown in Figure 14. These data show the extensive area of severe weather from Illinois and Missouri eastward to the Virginia and Carolina Coast. There were 3, 46 and 14 tornadoes respectively on 25, 26 and 27 October and there were 175, 373, and 32 reports of severe weather. Around 50 reports of severe weather on the 25th in the southeast and a tornado in Washington State were not associated with this storm system. Over 3 days this system likely produced around 500 severe weather reports.

v. EFS cyclone predictions

Figure 15 shows 9 GEFS forecasts of MSLP and MSLP anomalies valid at 0000 UTC 27 October 2010. The ensemble mean is used here but the large anomalies imply relative high agreement amongst members placing the cyclone in northern Minnesota with a 984 to 972 hPa cyclone depth. The deeper solutions, with less spread are from forecasts of shorter ranges and thus they have large departure anomalies. These 9 forecasts consistently predicted a deep cyclone over Minnesota and southwestern Ontario.

The SREF cyclone forecasts are shown in Figure 16. These forecasts are of shorter range and the core models are of finer resolution, thus short range forecasts showed a 964 hPa closed contour. The large anomalies imply consistency amongst EFS members.

Figure 17 shows GEFS forecasts initialized at 0000 UTC 26 October 2010 showing the probability of key anomalies associated with deep cyclones. The lower panel shows the ensemble mean MSLP and the probability that the pressure in each member will be less than -4.5σ below normal. Clearly, all the members successfully achieved this value. The 3σ wind anomalies showed good forecasts of the areas for strong winds (Fig. 16c) and convection. The deep 850 hPa cyclone was well predicted too. Despite the lower threshold, the 500 hPa heights were not forecast to be deeper than -3.5σ this storm seemed to be focused lower in the troposphere.

4. CONCLUSIONS

A deep extratropical cyclone (Fig. 18) may have set a new record low pressure value for the continental United States. It surpassed several notable historic storms, such as the SuperStorm of March 1993, the Cleveland Superbomb of January 1978 and the Columbus Day Storm of October 1962. Each of these storms was more memorable for the high impact weather produced than the low pressure values associated with them. The event of October 2010 will likely be remembered for the large multi-day severe weather event is initiated and the relatively predictable nature of the event.

The features associated with this event, including the deep cyclone (Figs.5) the strong LLJ (Fig.6) and the surge of high PW air (Fig. 7) all contributed to the high impact weather associated with this storm. The strong shear within the warm moist warm sector ahead of the cold front produced a significant severe weather outbreak form Missouri to North Carolina (Fig. 14). The data here show how well aligned the severe weather was with the strong low-level jet. Though not shown, CAPE values were not overall impressive with this event.

The strong winds south of the cyclone center produced widespread non-convective high winds and in the limited cold air north and west of the cyclone center, there were modest areas of heavy snowfall typically on the order of 3-9 inches. This storm had something to be memorable for form the Dakotas to the Carolinas.

Comparative storms, such as the Cleveland superbomb, Superstorm March 1993 and the Columbus Day storm were impressively deep cyclones. Each storm was worthy of study after the event and would be worthy tests of the current state of NWP. This storm too will likely be the focus of numerical studies and studies related to the storms impact.

The deep pressure center alone does not make for a memorable storm. The impacts on the public and the perceptions of those affected make lasting impressions in the minds of those affected. The wind with the Columbus Storm and the cold and snow associated with the Cleveland Superbomb make these events memorable. Similarly the deep snow and blizzard conditions make the 13-14 March 1993 storm memorable. The severe weather event associated with this storm will likely make it a memorable event.

From a predictability perspective, 9 GEFS and 9 SREF forecasts were shown here. These data showed a deep cyclone in the ensemble mean and significant anomalies. The anomalies suggest a convergence of forecasts. If the forecasts had diverged in terms of track, timing and intensity, it would have been difficult to get the -4 to -5SD anomalies produced by these EFSs. Overall, as for cyclone intensity and track the forecasts were consistent and this system appeared to show a relatively high degree of predictability.

Figure 17 clearly shows how the probabilistic data from an EFS can be used to highlight potentially significant weather. These types of data could be used to identify a range of high risk weather from flooding to tornadoes and everything in between.

This 6σ event and others are often used to evaluate the rarity of an event. However, the skewness of the data and the relatively small, 30 year POR, may not make the assessment of rarity something which can be accomplished with confidence. The 30 year period of record used for determining the means and standard deviations may not be representative of the longer term climatology. These data do not account for large scale pattern changes such as the ENSO,PDO and other larger scale flow indices. These data also may not reflect the impacts of climate change during the course of the past 30 years.

Perhaps the potential impact of an event is what these anomalies can aid us in capturing. Systems with large anomalies in critical fields may provide a measure of the significance of the event but not as much information as to the rarity of the event[3].

5. Acknowledgements

Aaron Tyburski and John LaCorte for information on the records and storm impacts. Ryan Maue for information and input related to rarity and the application and limitations of Climatic anomalies. And finally Mike Kozar for satellite imagery and data.

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[3] Personal dialog with Ryan Maue, NRL Monterey, CA.

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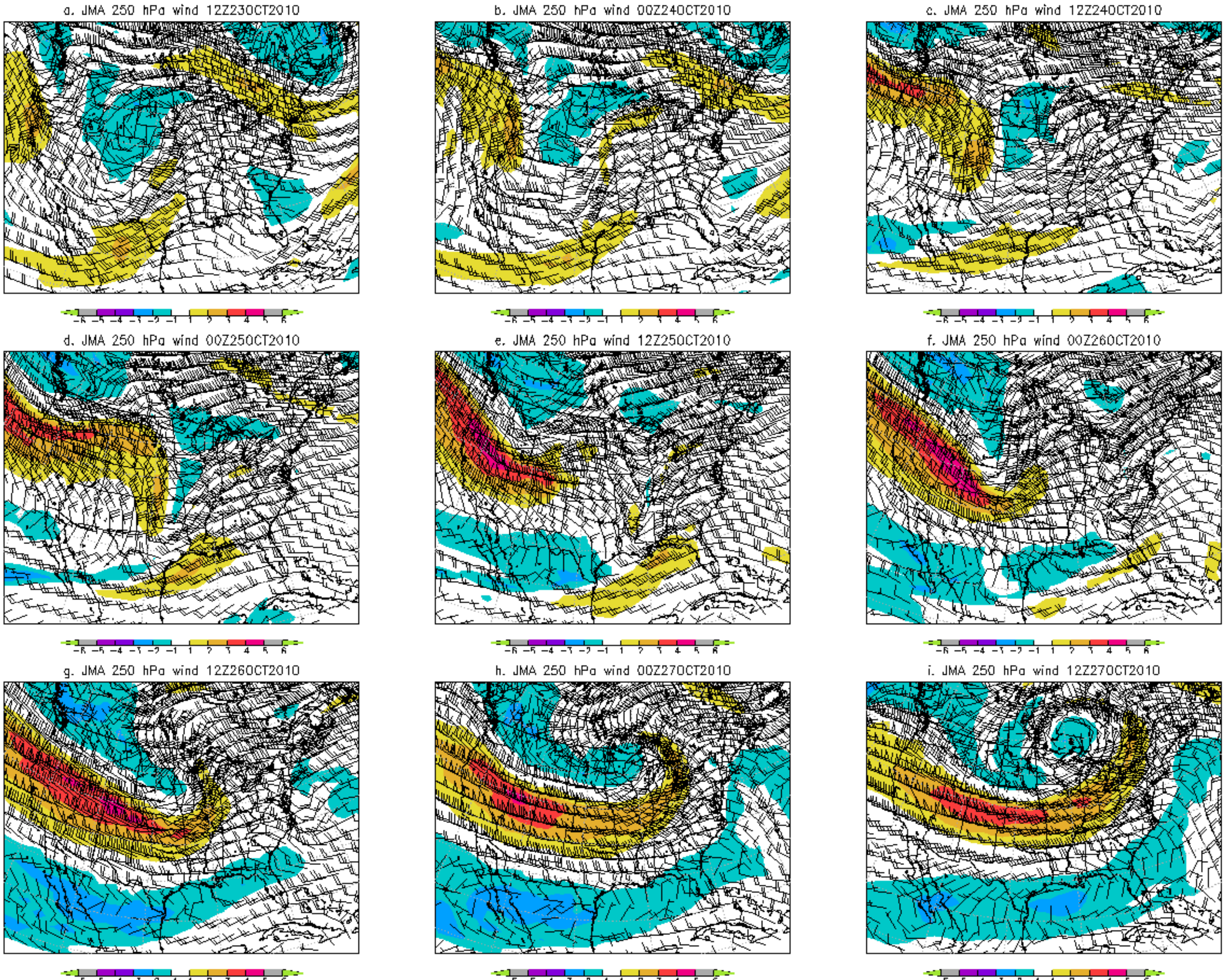

Figure 2. GFS 00hour forecasts of 250 hPa winds and wind anomalies from a) 1200 UTC 23 to i) 1200 UTC 27 October 2010 in 12-hour increments.

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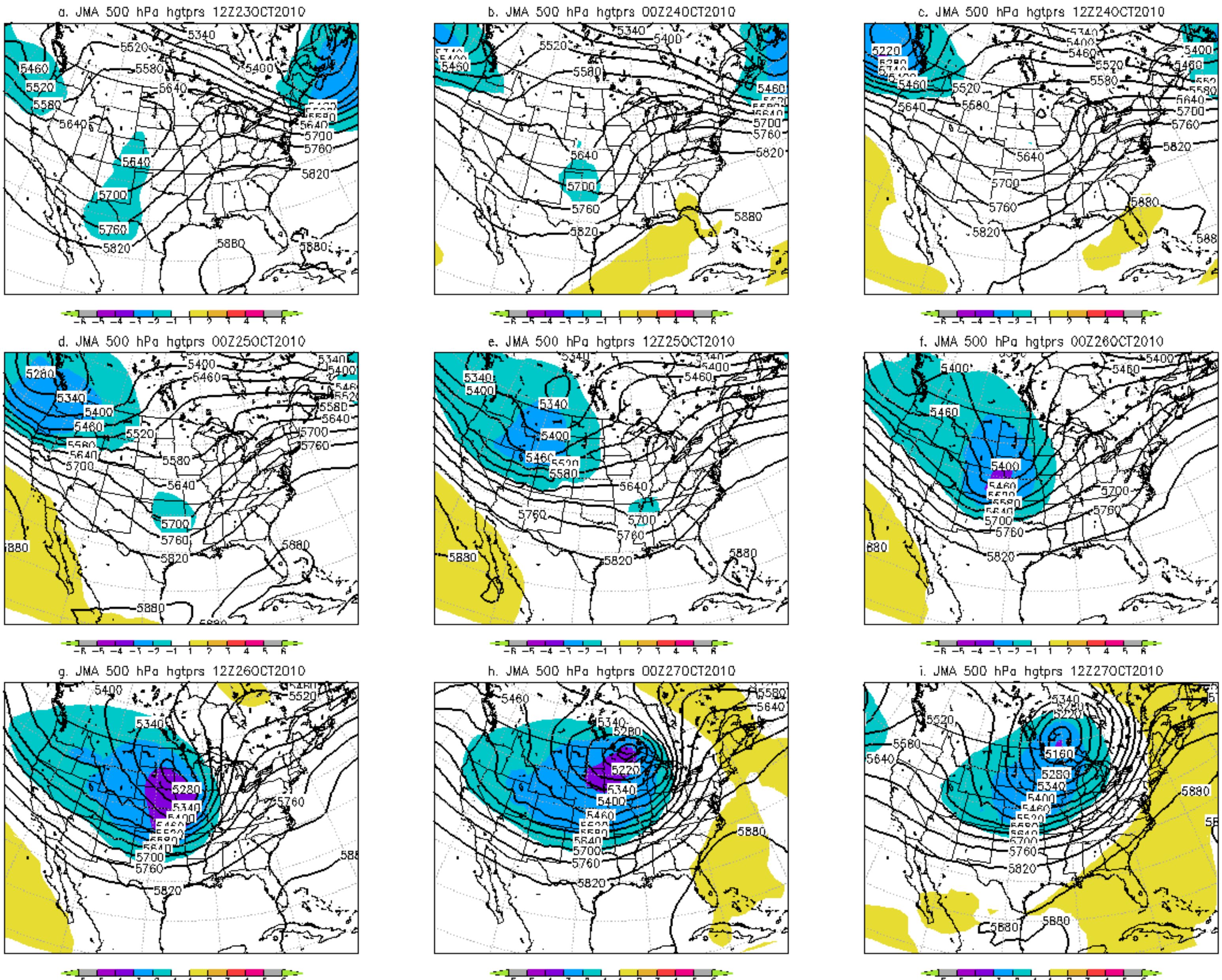

Figure 3. As in Figure 3 except for 500 hPa heights (m) and anomalies. . **Return to text.**

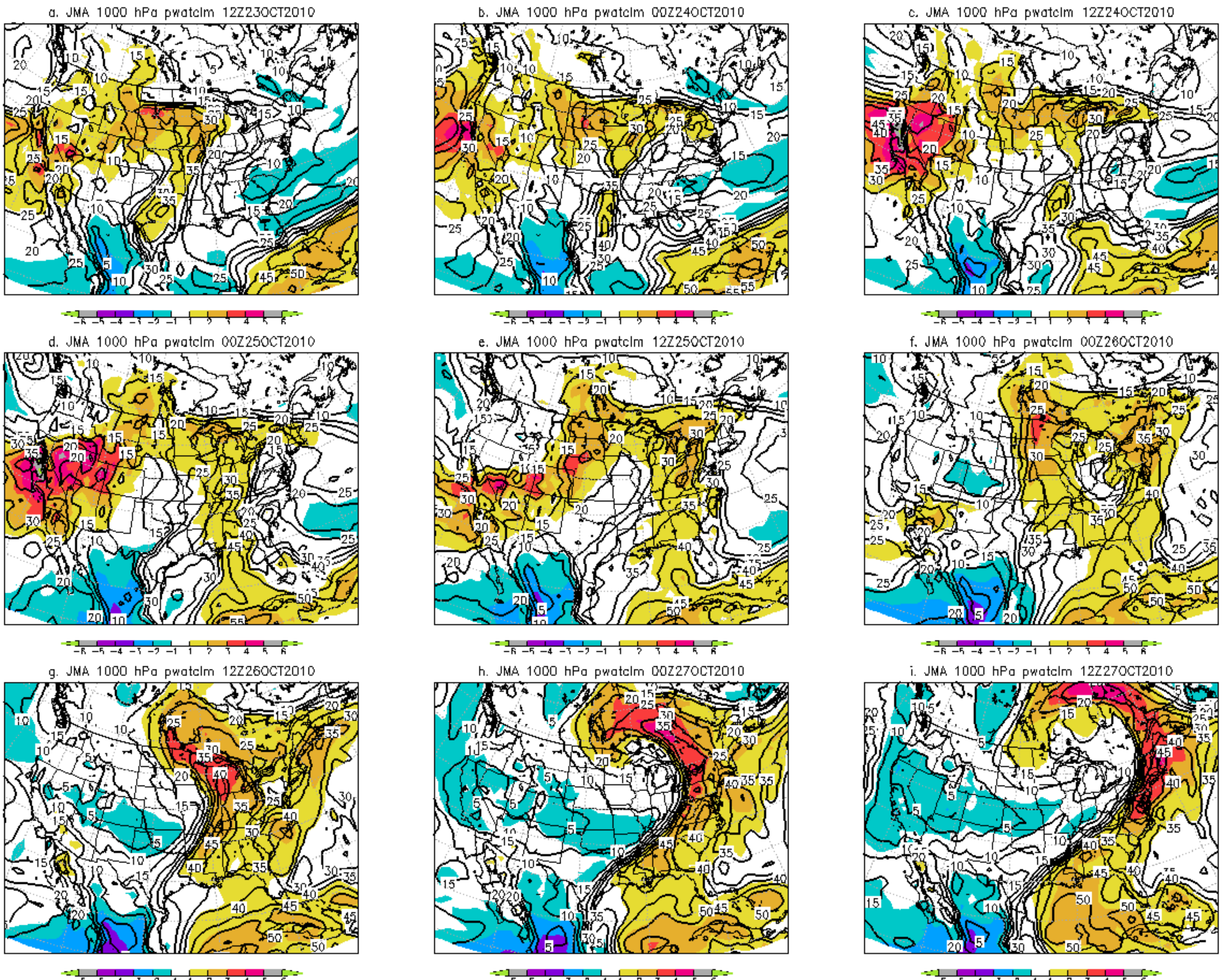

Figure 4. As in Figure 2 except for precipitable water (mm) and precipitable water anomalies. **Return to text.**

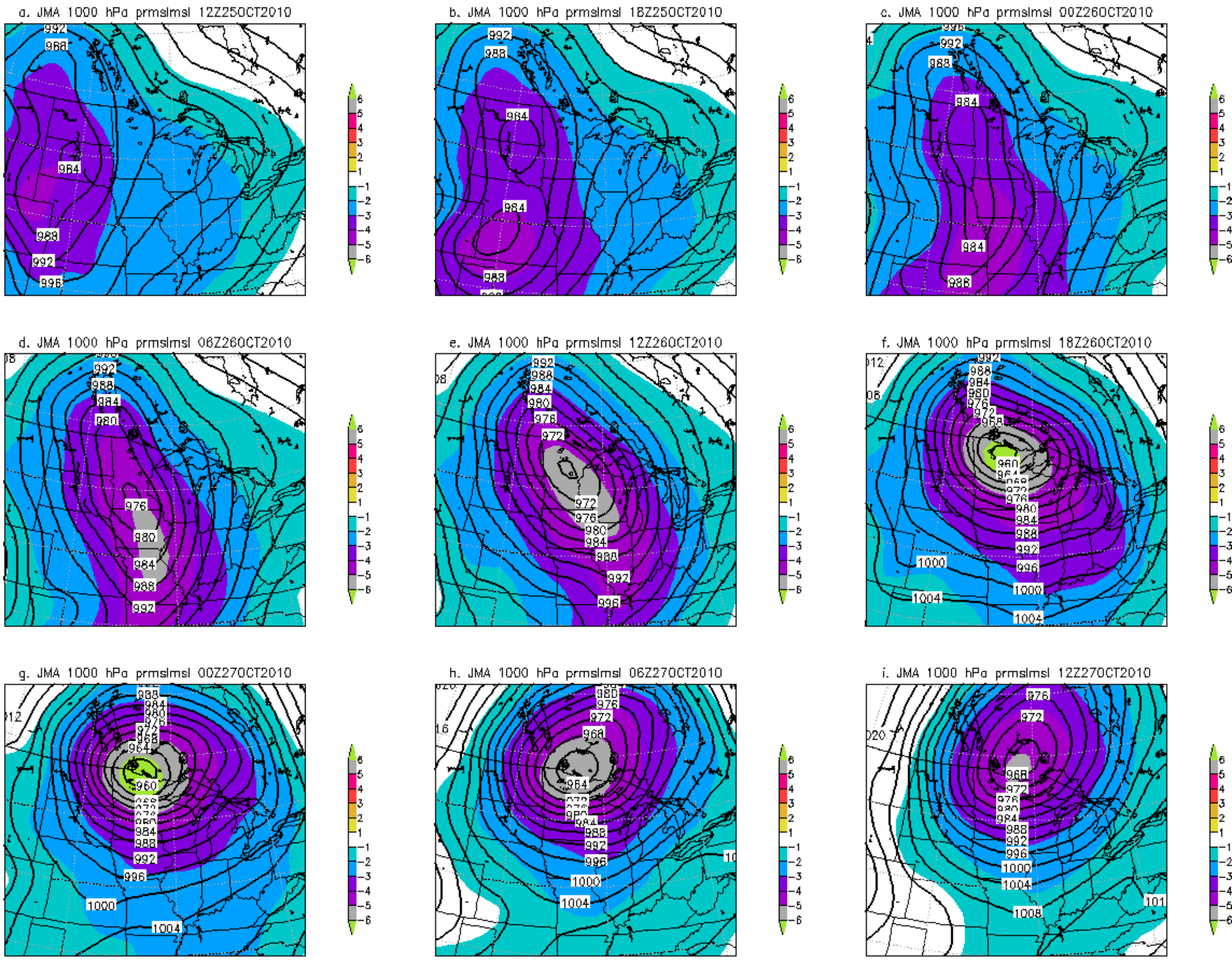

Figure 5. As in Figure 2 except for GFS MSLP (hPa) and pressure anomalies. Data are in 6-hour increments from a) 1200 UTC 25 October 2010 through i) 1200 UTC 27 October 2010. . <u>Return to text.</u>

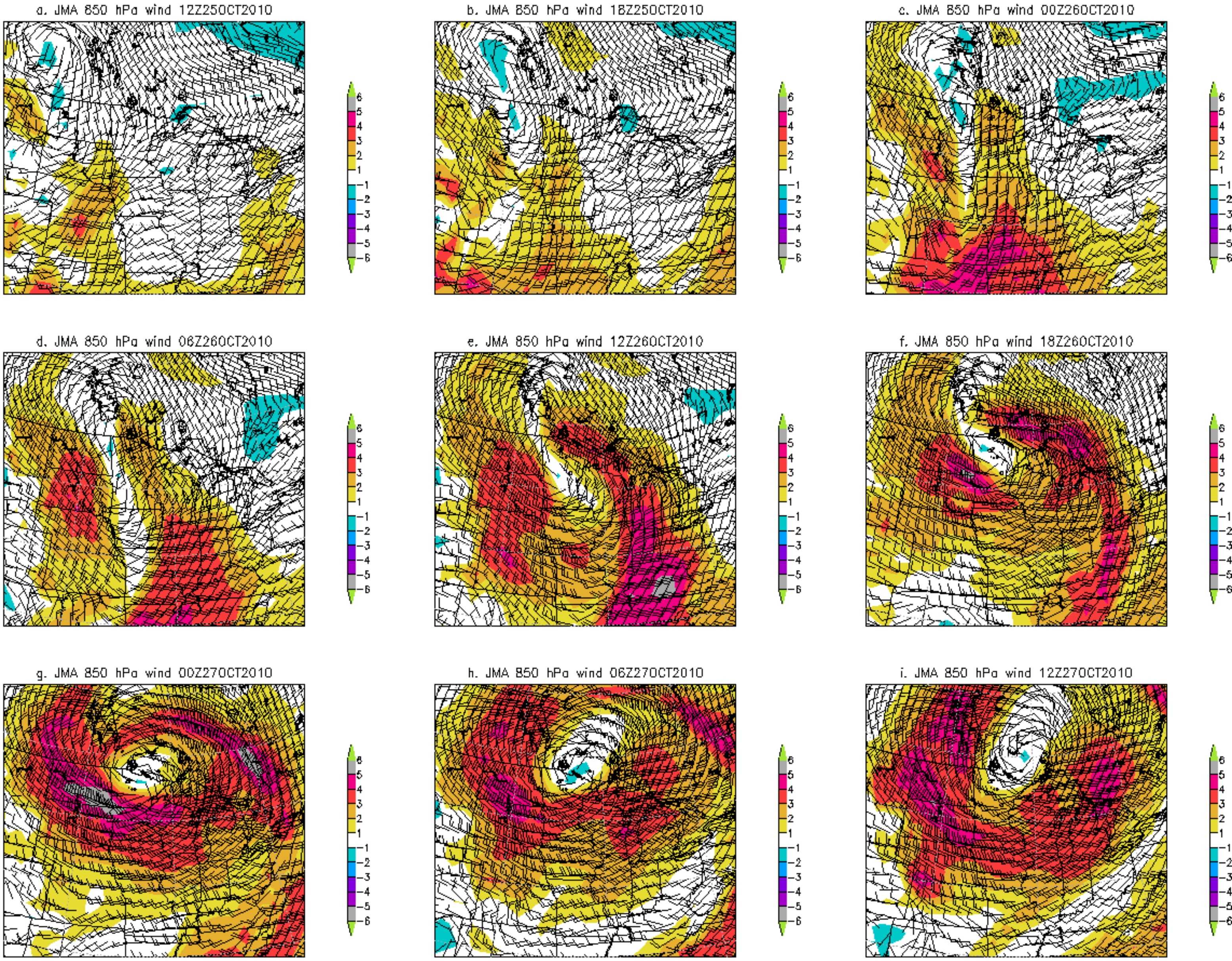

Figure 6. As in Figure 5 except for 850 hPa winds (KTS) and wind anomalies. . Return to text.

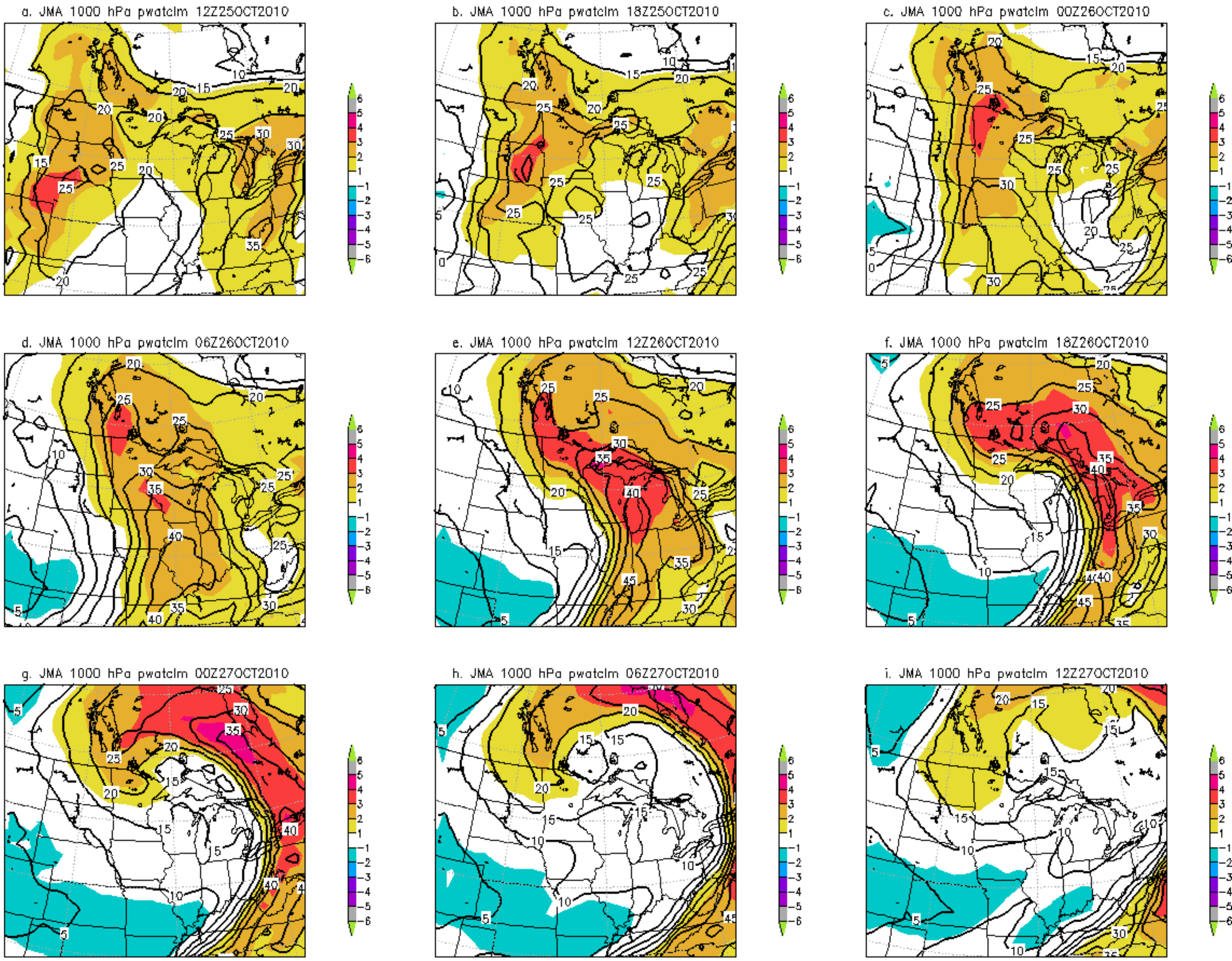

Figure 7. As in Figure 5 except for precipitable water and precipitable water anomalies. [Return to text.]

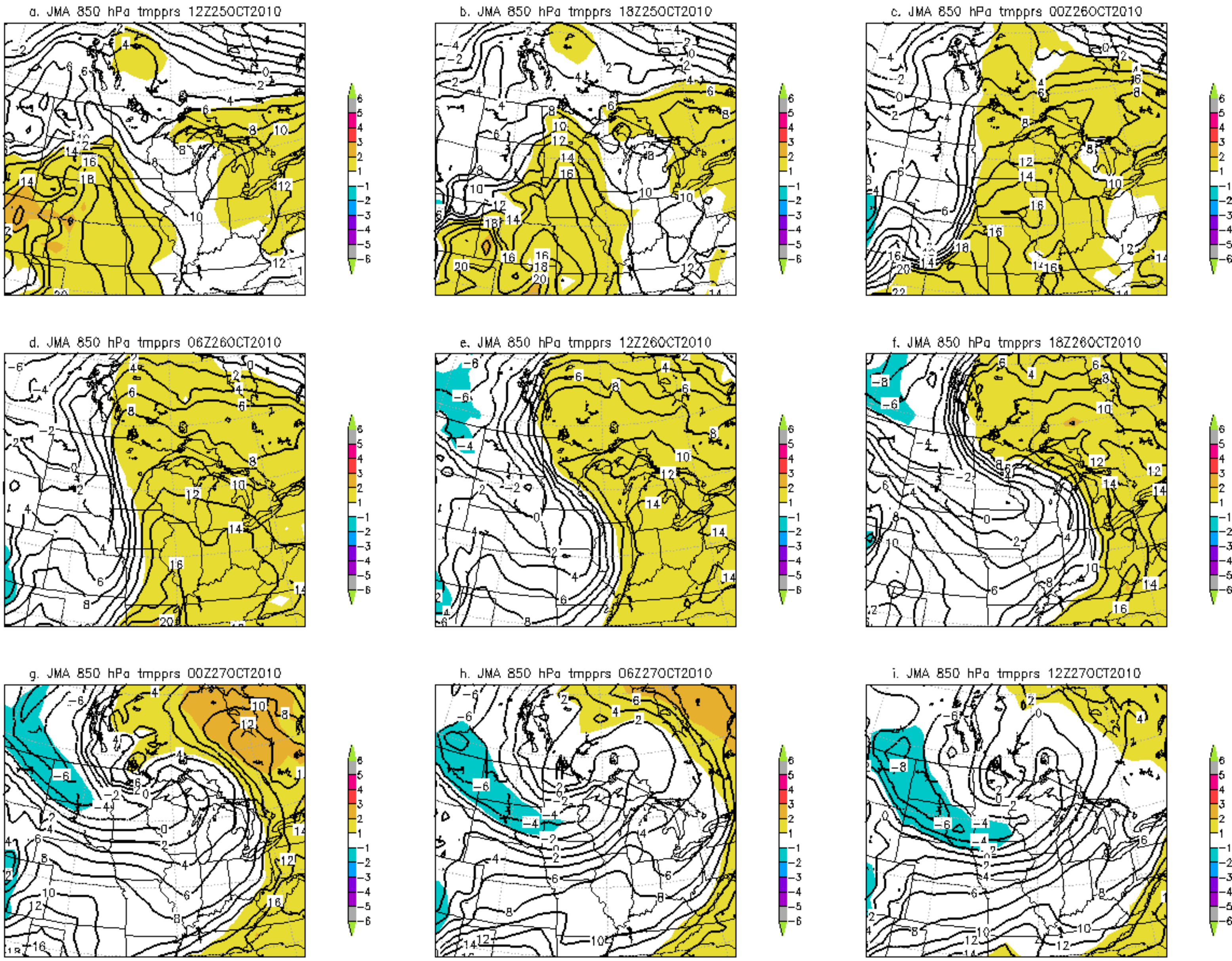

Figure 8. As in Figure 6 except for 850 hPa temperatures and temperature anomalies.

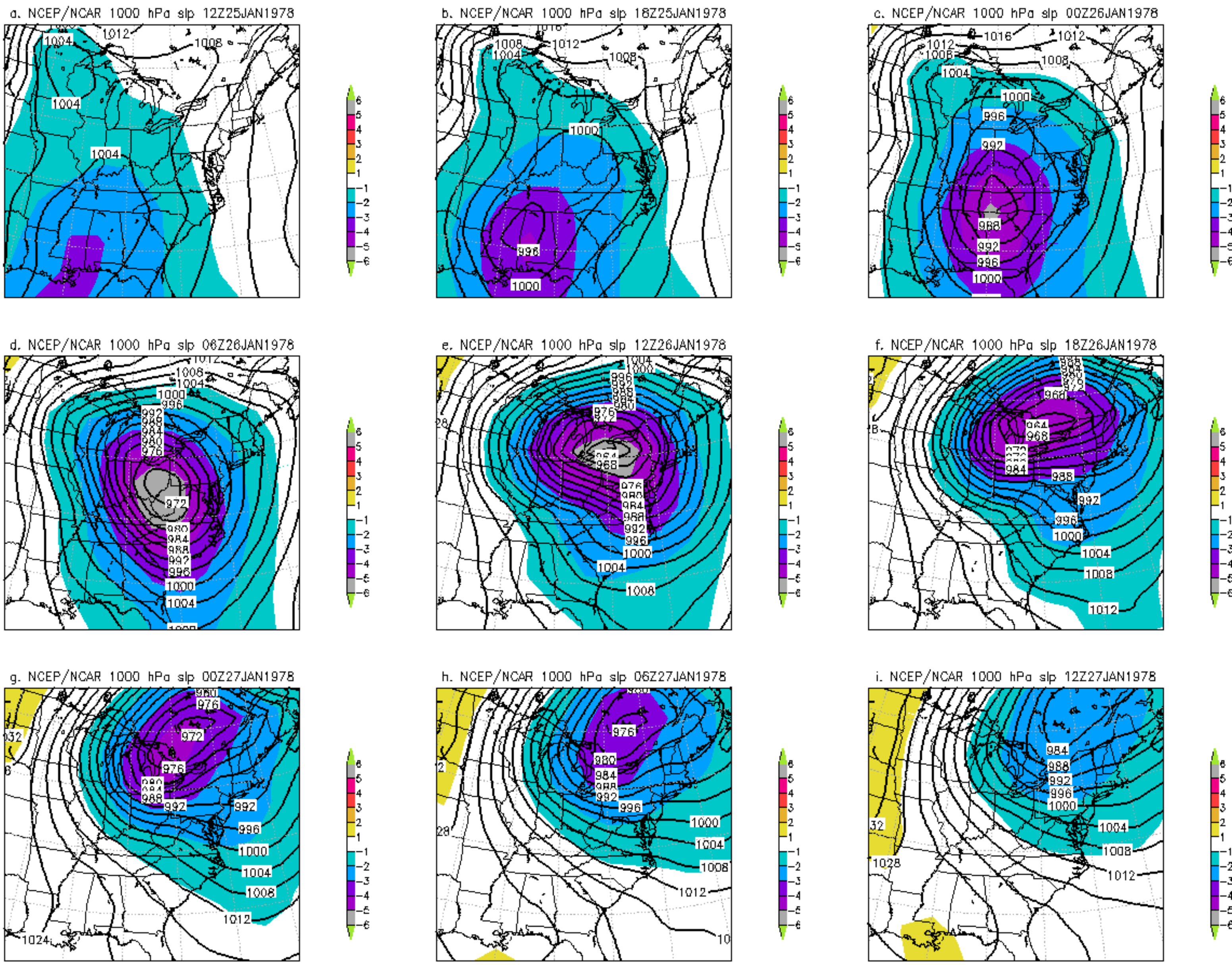

Figure 9. NCEP/NCAR re-analysis of the conditions from a) 1200 UTC 25 January 1978 through i) 1200 UTC 27 January 1978.

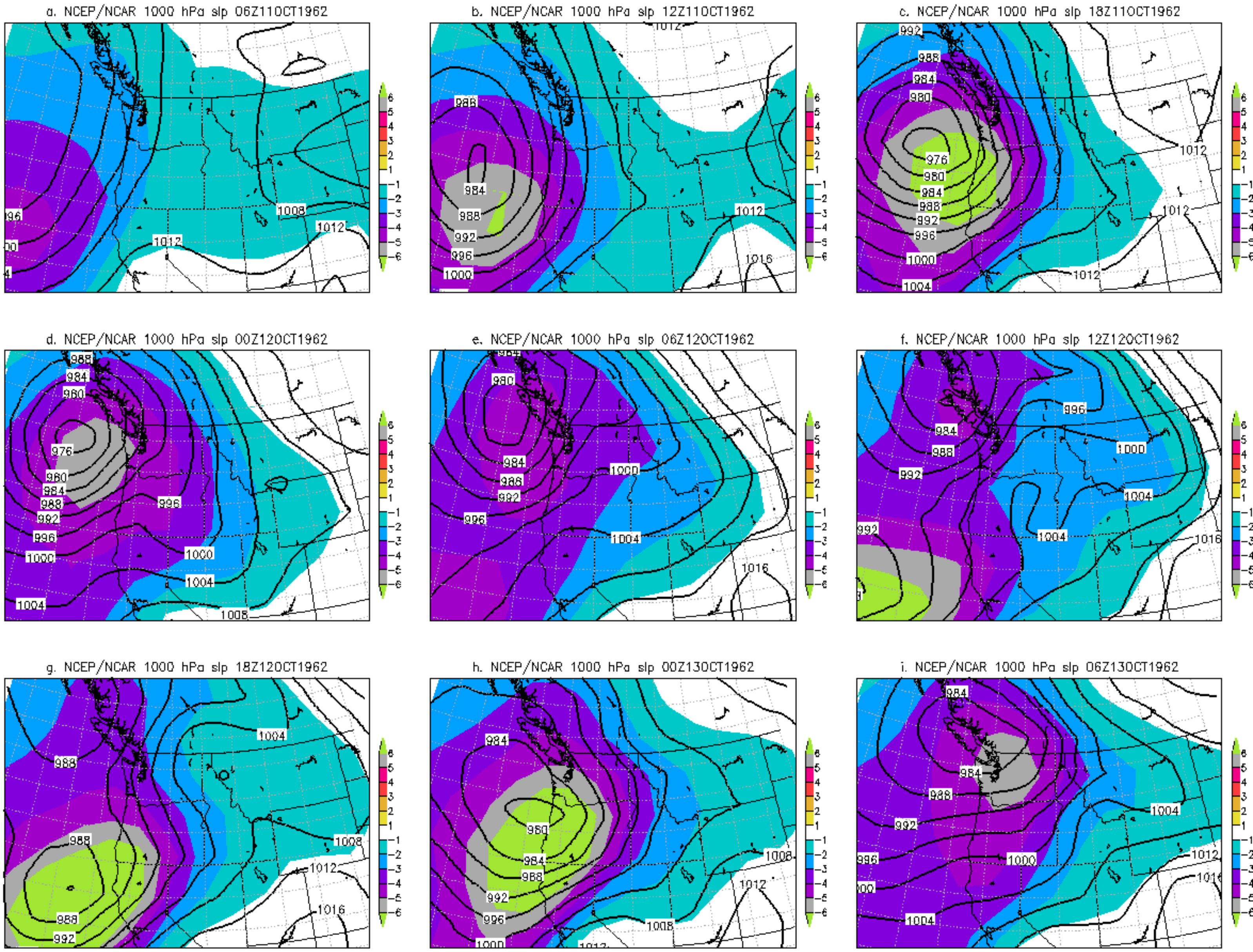

Figure 10. As in Figure 9 except for a) 0600 UTC 11 October 1962 through i) 0600 UTC 13 October 1962.

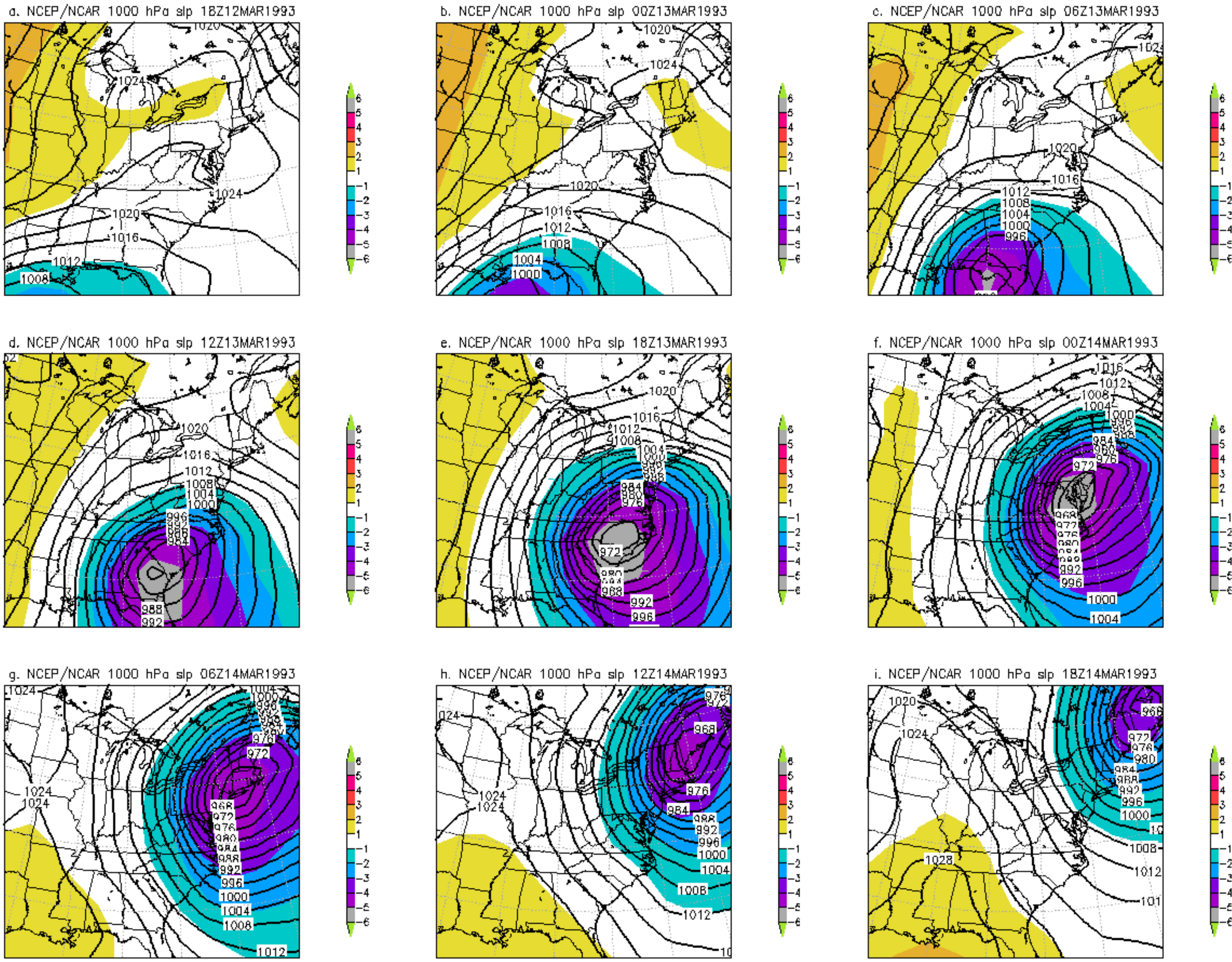

Figure 11. As in Figure 9 except for the period of a-i) 1800 UTC 12 March 1993 through 1800 UTC 14 March 1993.

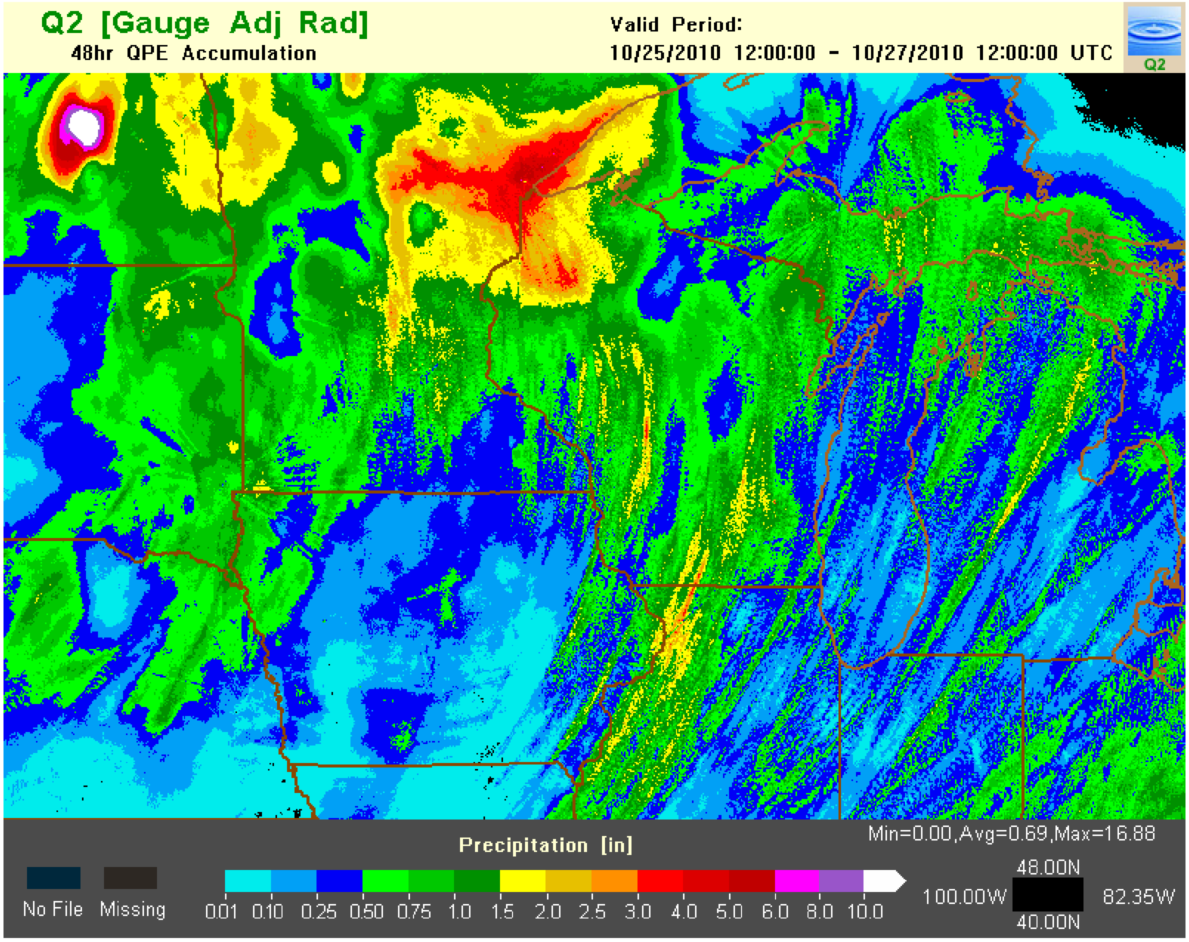

Figure 13. Total precipitation from NMQ site. Data will be replaced by Stage-IV when processed.

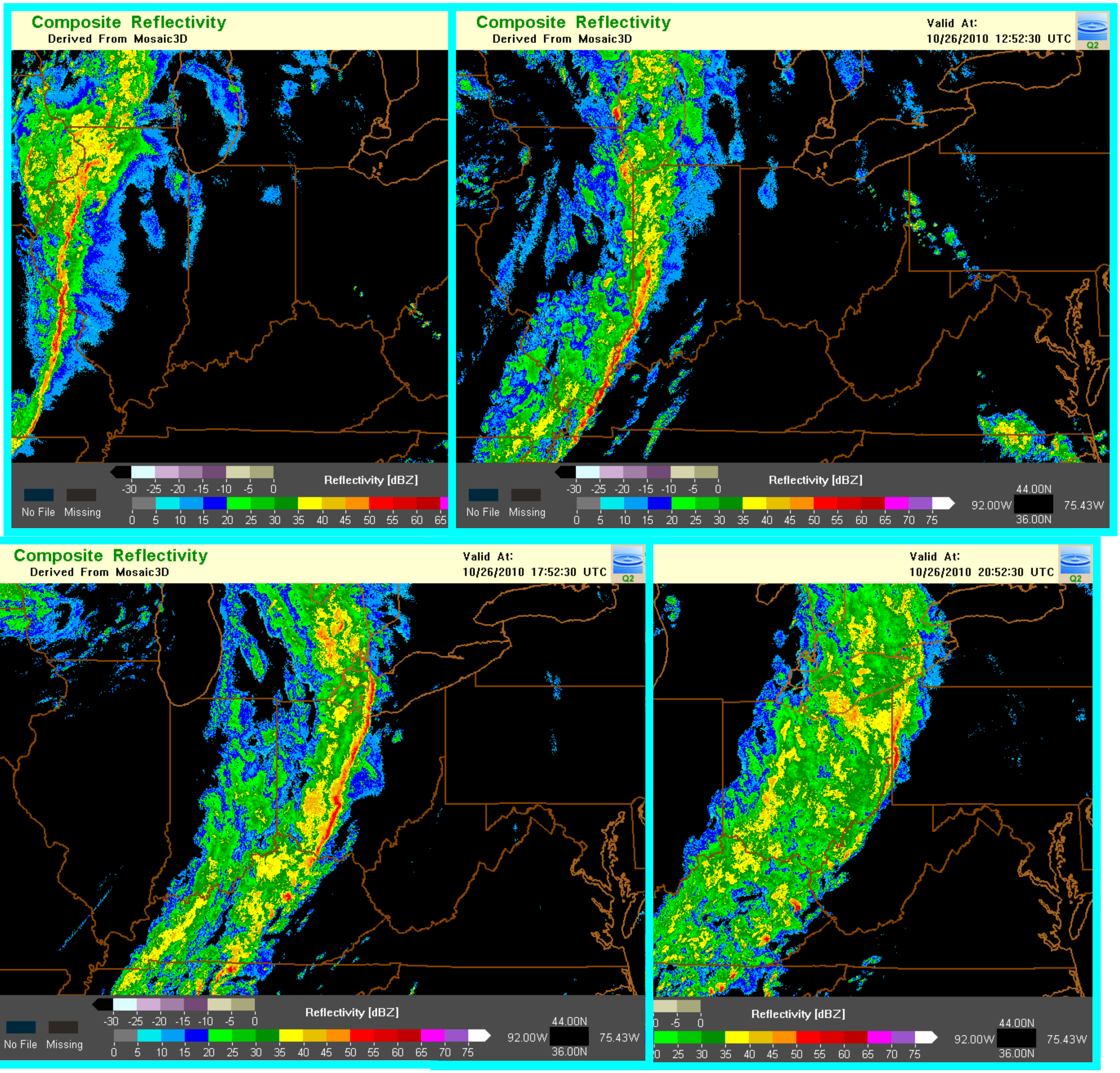

Figure 12. Select composite reflectivity images from the Multi-sensor precipitation site. Clockwise from top left 0852 UTC 26 October, 1252 26 October, bottom 1752 UTC and 2052 UTC 26 October 2010.

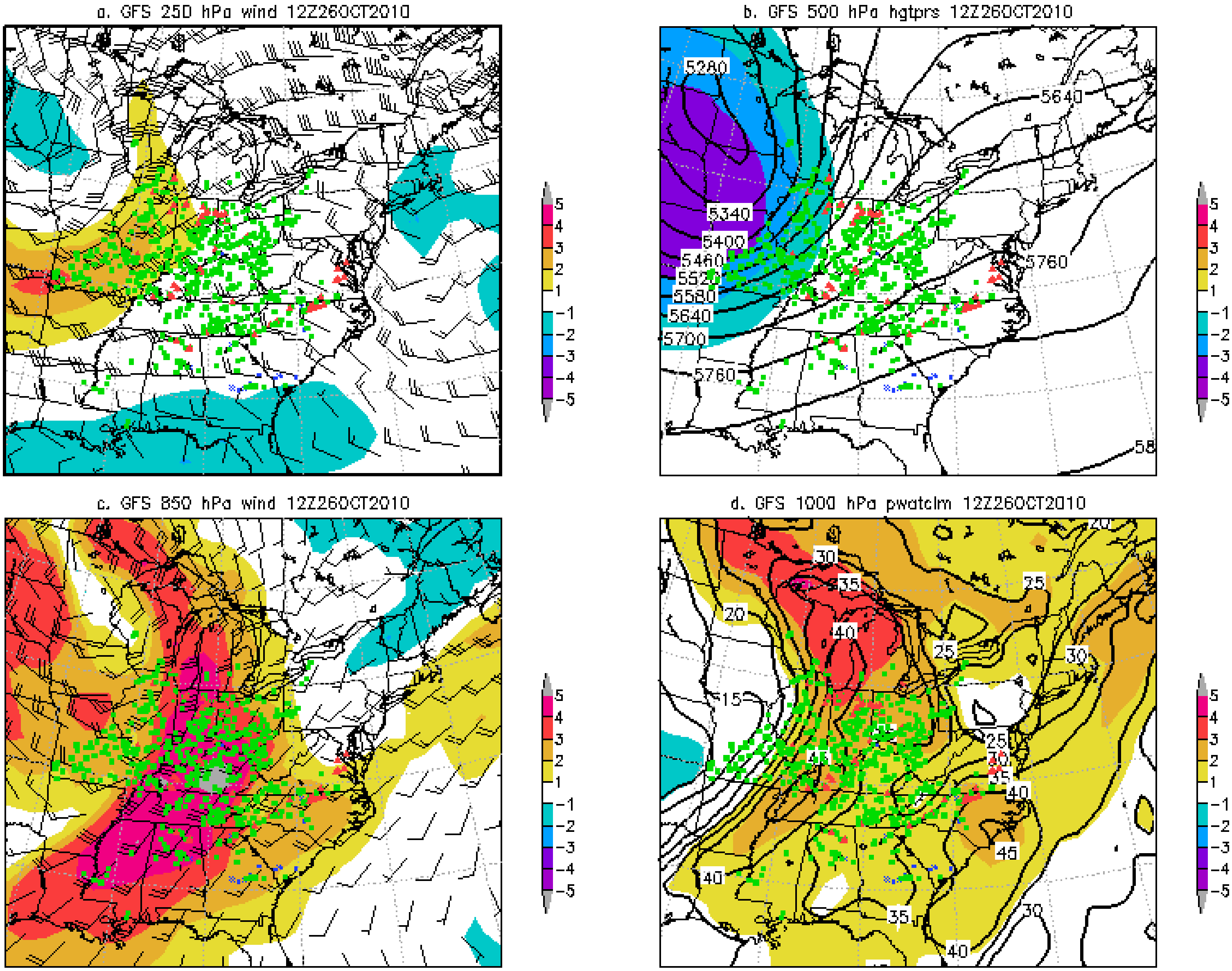

Figure 14. The conditions at 1200 UTC 26 October and plots of all severe weather, by type from 25-27 October 2010. Data in each panel include a) 250 hPa winds and anomalies, b) 500 hPa heights and anomalies, c) 850 hPa winds and anomalies, and d) precipitable water and anomalies. Severe weather from the SPC website green shows wind, blue shows hail and red shows tornadoes. There were 3,4 6 and 14 tornadoes respectively on 25,26 and 27 October. **Return to text.**

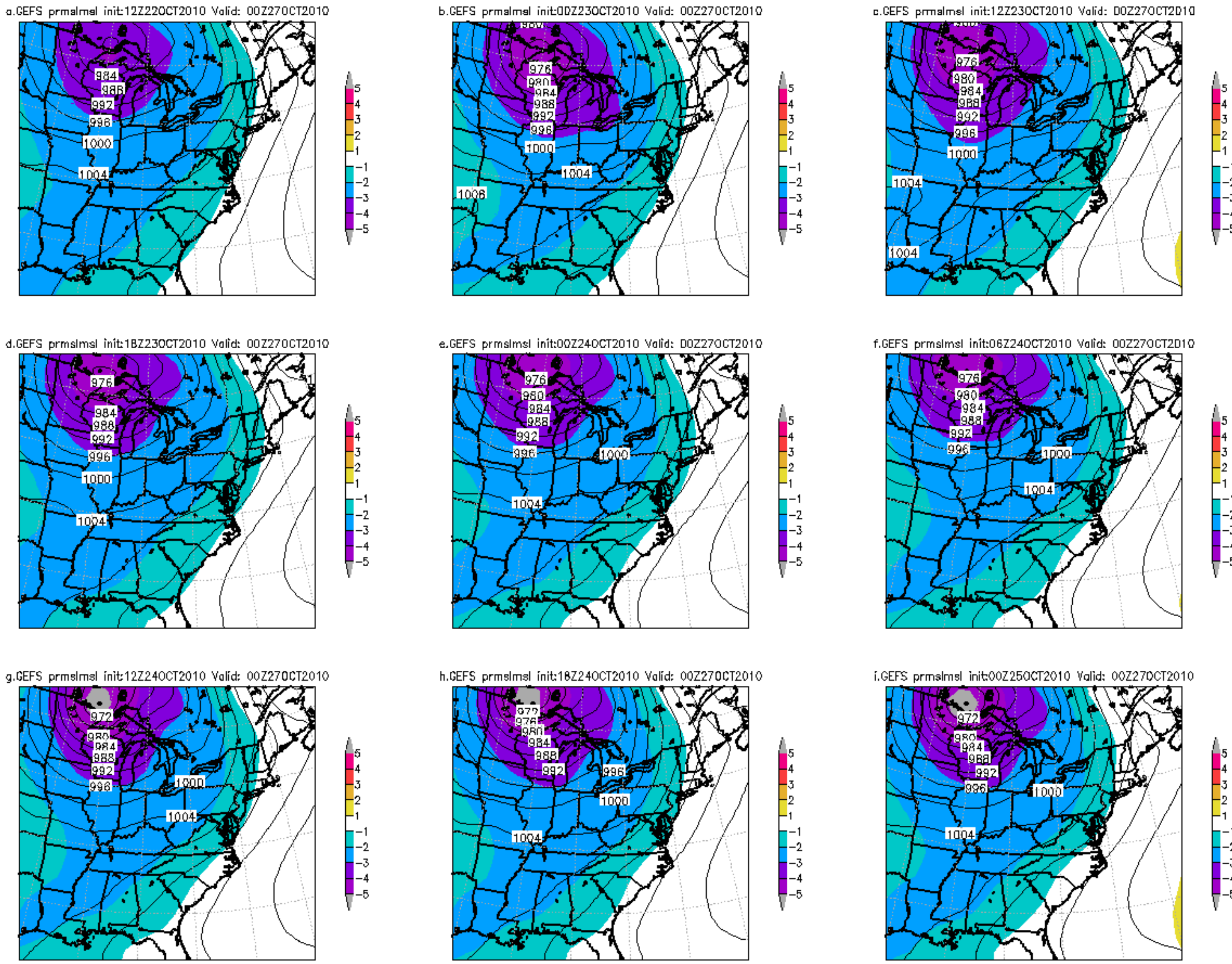

Figure 15. GEFS forecasts valid at 0000 UTC 27 October 2010 showing mean sea level pressure and pressure anomalies from forecasts initialized at a) 1200 UTC 22 October, b) 0000 UTC 23 October, c) 1200 UTC 23 October, d) 1800 UTC 23 October, e) 0000 UTC 24 October, f) 0600 UTC 24 October, g) 1200 UTC 24 October, h) 1800 UTC 24 October and i) 0000 UTC 25 October 2010. **Return to text.**

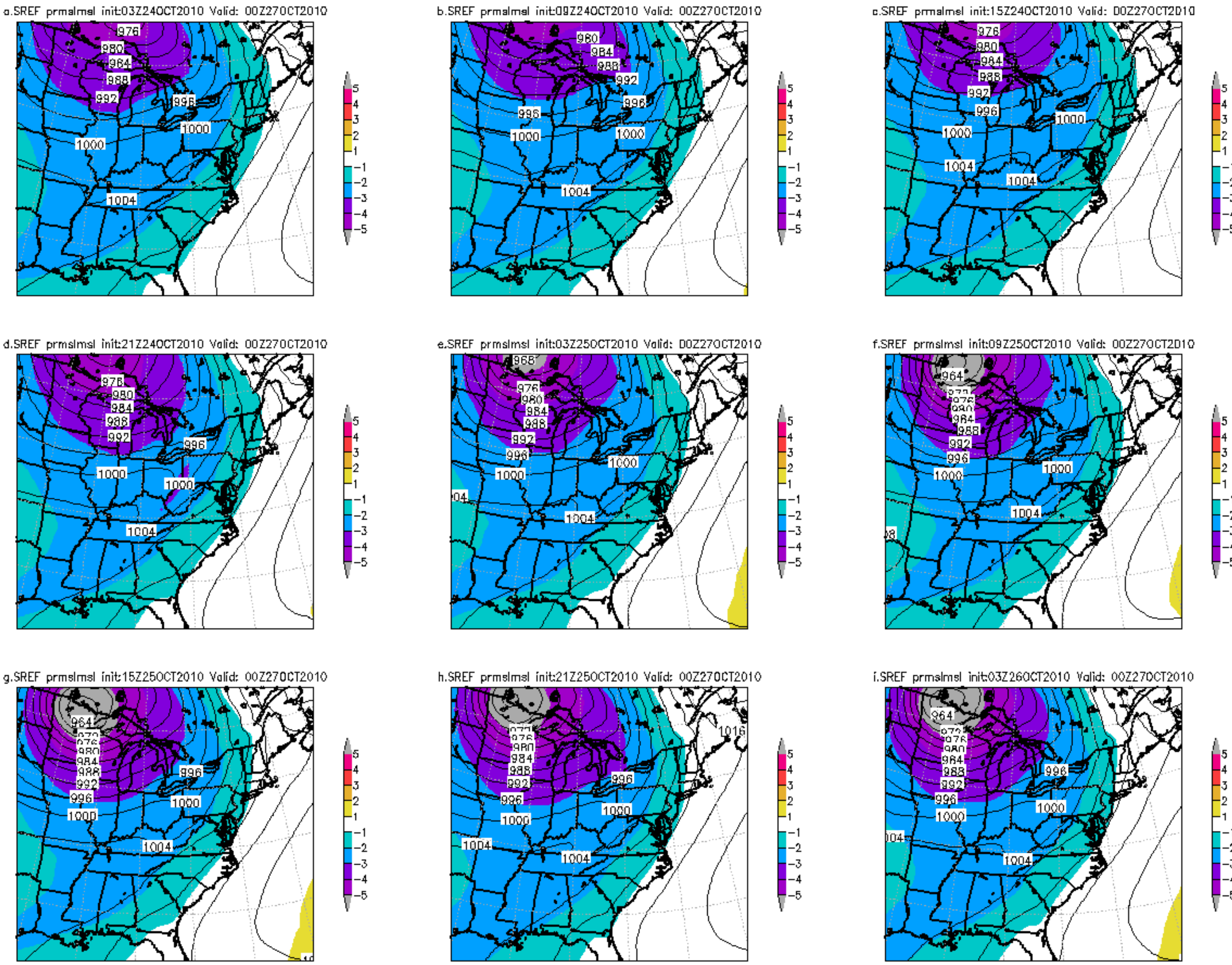

Figure 16. SREF forecasts valid at 0000 UTC 27 October 2010 showing mean sea level pressure and pressure anomalies from forecasts initialized at a) 0300 UTC 24 October, b) 0900 UTC 24 October, c) 1500 UTC 24 October, d) 2100 UTC 24 October, e) 0300 UTC 25 October, f) 0900 UTC 25 October, g) 1500 UTC 25 October, h) 2100 UTC 25 October and i) 0300 UTC 26 October 2010. Return to text.

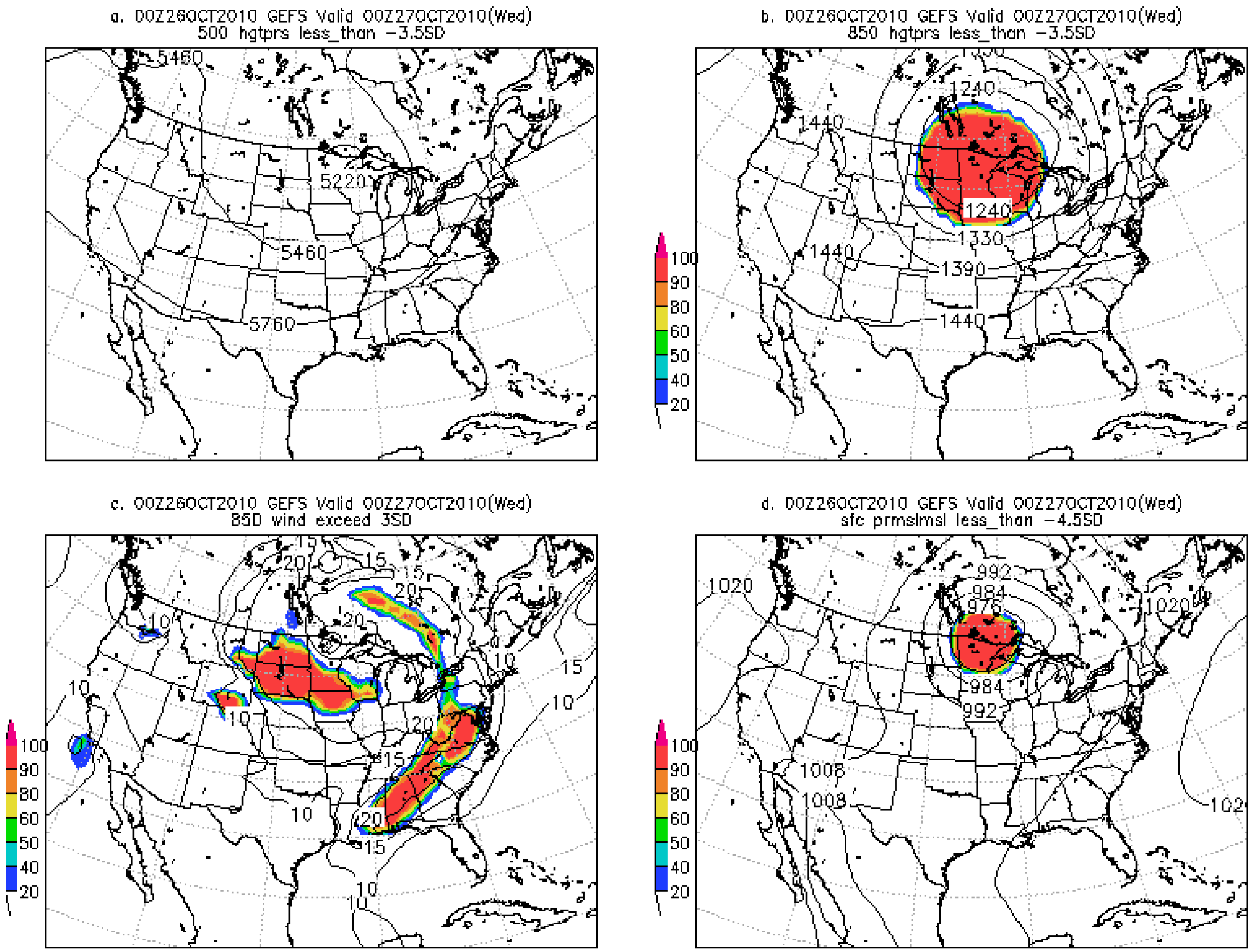

Figure 17. GEFS forecasts initialized at 0000 UTC 26 October 2010 valid at 0000 UTC 27 October 2010 showing a) mean 500 hPa heights and the probability of height anomalies less than -3.5SD below normal, b) 850 hPa heights and probability of heights below -3.5SDs, c) 850 hPa winds (ms-1) and wind anomailesl more than 3SDs above normal and d) mean-sea level pressure and probability of pressure anomalies less than -4.5SDs below normal. **Return to text.**

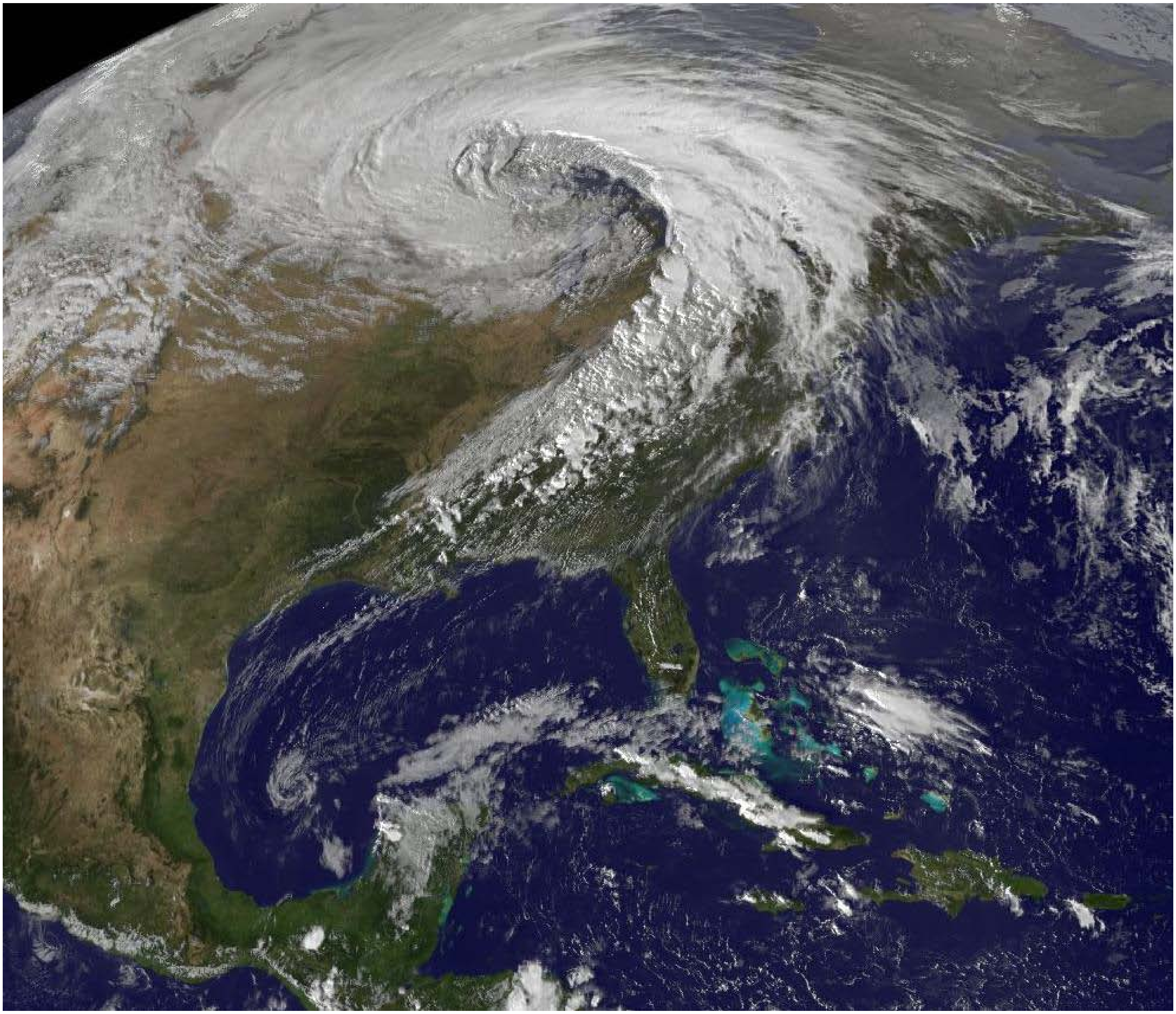

Figure 18. Visible satellite image of the "October Bomb" or the "Superstorm of October 2010" from 26 October 2010. [Return to text.](#)