The Deep South snowfall of 11-13 February 2010

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1. INTRODUCTION

A surface cyclone tracked across Mexico and the Gulf of Mexico (Fig. 1) producing snowfall from Texas to Florida as it tracked eastward (Fig. 2). Several locations, including Dallas/Fort Worth set a record snowfall for the month and for a single 24 hour event on 11 February 2010. The 11.2 inches at DFW beat the old record of 7.8 inches set on 14 January 1917 and 15 January 1964.

This was one of the largest snowfall events in Texas since the historic Christmas 2004 storm (Morales 2009 and Morales 2007) which produced as much as 13 inches of snow along the Gulf Coast on 24-25 December 2004. This storm produced 1.5 inches of snow in Brownsville, which was the first snowfall since 1899. Deep southern snows, though rare do occur. During December 1989 there was another deep southern storm which brought a White Christmas to many of the Gulf and southeastern States.

This snow event occurred during a time of unseasonably low values of the Arctic Oscillation (Table 1) and a period of high latitude blocking (Rex 1950a&b). This general pattern has dominated the northern hemispheric winter of 2009-2010. This tends to push cold air and the storm track to the south. Combined with a an El Nino episode, which favors Pacific Storms moving into North America farther south is a good combination for cold and wetter conditions in the southern United States. The right combination of cold and precipitation occurred 11-13 February 2010.

This deep southern storm produced measureable snow in all the southern States. On the morning of 13 February 2010 snow was reported in 49 of 50 States. The lack of snow on Mona Lao left Hawaii out of the snow party.

This paper will document the historic Deep South snow event of 11-13 February 2010. The focus will be on the pattern and the anomalies of key fields associated with potential winter storms.

2. METHODS AND DATA

Rainfall data used here were obtained from the unified precipitation dataset (UPD) and the Stage-VI rainfall data (Seo 1998). Both are gridded datasets and were displayed using GrADS (Doty and Kinter 1995). Snowfall data was retrieved from the National Snow site and from National Weather Service Public information statements.

The 500 hPa heights, 850 hPa temperatures, 850 hPa winds, and other standard level fields were derived from the NCEP NAM and GFS data using the NCEP/NCAR (Kalnay et al. 1996) data as the climatological comparison. 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:

3. $SD = (F - M)/\sigma$ (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.

NCEP determinist model and ensemble data shown here were primarily limited to the GFS and NAM and the ensembles systems shown are the NCEP GEFS and SREF. Displays will focus on the forecasts of the pattern conducive for precipitation and snowfall and products showing the amount and gradients of the QPF used to produce snowfall forecasts.

For brevity, times will be displayed in day and hour format such at 12/0000 UTC signifies 12 February 2010 at 0000 UTC.

4. RESULTS

i. Large scale overview

Figure 3 shows the large scale pattern over North America from 11/0000 through 13/0000 UTC. The high latitude block over Canada is quickly identified by the 2 to 3 SD above normal height anomalies over northeastern Canada. The block persisted through the event.

Farther south, the southern stream shortwave is visible at 11/0000 UTC (Fig. 3a) crossing northern Mexico and the southwestern United States. Height anomalies were -1 to -2SDs below normal in the trough. This wave slowly moved eastward and was over the eastern Gulf States by 13/0000 UTC (Fig. 3i).

Figure 4 shows the precipitable water (PW) and PW anomalies. These data show that there was dry air over much of the central and eastern United States. The storm system was able to tap deep moisture and PW anomalies of 2 to 4 SDs above normal were ingested into the warm sector of the evolving cyclone.

In addition to the surge of moisture into the shortwave, there was unseasonably cold air over the region. The 850 hPa temperatures (Fig. 5) showed -2SD below temperature anomalies with most locations at or below 0C at 850 hPa.

ii. Regional view

The NAM 850 hPa winds and u-wind anomalies over the Gulf States are shown in Figure 6. These data show that the 850 hPa low was not a coherent system until around and after 11/1800 UTC (Fig. 6d). The strong southeast winds and u-wind anomalies aid in finding the circulation which then moved eastward across the coast. There was a hint of a second circulation, farther north over Texas near the Red River Valley at 12/0000 UTC. A second u-wind anomaly and perhaps cold conveyor like circulation clearly developed between 11/1200 and 12/0000 UTC. This feature with -1SD u-wind anomalies lined up fairly well with the snowfall areas in Figures 2a&b.

The NAM 850 hPa temperatures show the cold air with -1 to some -2SD anomalies over the Gulf Coast. The 850 hPa 0C line pushed south of the coast as the surface cyclone moved to the east. Most inland areas were -1 to -2C during the event. Near Dallas, the 850 hPa temperatures were -4 to near 0C during most of the event. Wet bulb temperatures may have been more instructive in this case.

iii. Ensemble forecasts

For brevity the SREF forecasts from 11/0900 UTC are presented with a focus on the precipitation type forecasts over the course of the event (Figs 8-11). The overall pattern was well predicted and thus will not be covered here. The precipitation shield

and precipitation types reflect the relatively well predicted pattern.

It should be noted precipitation rates varied between cycles and thus early SREF cycles had less QPF and thus lower snow probabilities. The colder GEFS, not shown, had snow probabilities in the affected earlier too.

The images show that near the northern edge of the Gulf Storm, the SREF predicted snow to be the dominant precipitation type. One cycle is tracked from Texas to Georgia to provide sense of how well the northern precipitation shield was predicted and how the higher probability snow shields moved across the Gulf States from Texas to Georgia as it did in the observations shown in Figures 2a&b.

iv. Precipitation and snow fall

Figure 12 shows the total QPE for the period of 11/1200 through 13/0000 UTC. Data were derived from the 6-hourly Stage-IV precipitation data. The precipitation pattern shows areas of discrete propagation. The heaviest precipitation was over the Gulf and along the coastal zone.

Figure 13 compliments Figures 8-12 and Figures 2a&b by showing the observed QPE over discrete 12 hour intervals. The event began in Texas producing most of the precipitation between 11/1200 and 12/0000 UTC. The moved east affecting the region of eastern Texas to Florida between 12/0000 and 12/1200 UTC. Then the system moved farther east with heaviest QPE from Florida into South Carolina. The snow along the northern edge of the precipitation shield was maximized near the times of maximum QPE shown in these 3 images.

5. CONCLUSIONS

A surface cyclone moving across the Gulf of Mexico helped to produce a snowfall across the Deep South from 11 to 13 February 2010. The snow fell well north of the surface cyclone in a focused cold conveyor belt depicted by the 850 hPa winds and modest 850 hPa u-wind anomalies.

For many locations this snow was a record event for the date and in some cases the month as measurable snow is an infrequent visitor to the Deep South. The maximum snowfall record in Florida, 4 inches was unscathed as the maximum snowfall in Florida was 3 inches Dallas set a new single storm record.

This record snowfall was associated with a period of strongly negative AO. The winter of 2009-2010 is also an El Nino year when the storm track in the southern United States is often quite active. This combination produced the following conditions conducive to Texas (Ryan and Hanes 2009) and deep Southern storms including:

- A strong anticyclone to the north to keep cold dry air on the north side of the storm,
- abnormally cold air with sub-freezing conditions at 850 hPa
- easterly winds north of the surface and primary 850 hPa cyclones (Brown and Younkin 1970, Goree and Younkin 1966, Younkin, 1968).
- Deep moisture south of the warm front.

These conditions were relatively well predicted by the NCEP models and ensemble forecast systems. As shown in Figures 8-11 the SREF did relatively well predicted the general area of snowfall from Texas to Georgia.

The impact of the negative AO and the ENSO pattern is of interesting. It would be interesting to compare previous Deep South snow storms to determine if an AO/ENSO signal (Higgins et al 2001) exists in the these data. A terse examination of the Deep South Storms of December 2004 (Fig. 14) and

December 1989 (Fig. 15) showed no signal as the AO mostly positive during those events. Common meteorological characteristics included below normal 850 hPa temperatures, cold air to the north, and anchoring anticyclone and negative u-wind anomalies north of the surface cyclone. Both December systems had very strong and anomalous mid-level cyclones (Figs. 14a & 15a) which were not present in the February 2010 case. The anticyclone in the December 1989 was extremely strong and the pressure anomalies to the north were over 3SDs above normal with near 5SD anomalies in Texas.

6. Acknowledgements

Snowfall records were summarized by multiple National Weather Service Offices.

7. REFERENCES

Brown, R.F. and R.J. Younkin, 1970: Some Relationships between 850-mb Lows and Heavy Snow Occurrence over the Central and Eastern United States. *Monthly Weather Review*, 98, 5, 399-401.

Doty, B. E., and J. L. Kinter III, 1995: Geophysical data and visualization using GrADS. Visualization Techniques Space and Atmospheric Sciences, E. P. Szuszczewicz and Bredekamp, Eds., NASA, 209–219.

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Goree, P.A., and R.J. Younkin, 1966: Synoptic Climatology of Heavy Snowfall over the Central and Eastern United States. *Monthly Weather Review*, 94, 11, 663-668.

Grumm, R.H. and R. Hart. 2001: **Standardized** Anomalies Applied to Significant Cold Season Weather Events: Preliminary Findings. *Wea. and Fore.*, **16,736**–754.

Hart, R. E., and R. H. Grumm, 2001: Using normalized climatological anomalies to rank synoptic scale events objectively. *Mon. Wea. Rev.*, **129,** 2426–2442.

Higgins, R.W., Y. Zhou and H.-K. Kim, 2001: Relationships between El Niño-Southern Oscillation and the Arctic Oscillation: A Climate-Weather Link. NCEP/Climate Prediction Center ATLAS 8. (Link to Atlas)

Hirsh, M.E, A.T.DeGaetano, S.J. Colucci,2000: An East Coast Winter Storm Climatology.J.Climate,14,882-899.

Junker, N.W, M.J.Brennan, F. Pereira, M.J.Bodner,and R.H. Grumm, 2009:Assessing the Potential for Rare Precipitation Events with Standardized Anomalies and Ensemble Guidance at the Hydrometeorological Prediction Center. Bulletin of the American Meteorological Society,4 Article: pp. 445–453.

Junker, N. W., R. H. Grumm, R. Hart, L. F. Bosart, K. M. Bell, and F. J. Pereira, 2008: Use of standardized anomaly fields to anticipate extreme rainfall in the mountains of

northern California. *Wea. Forecasting,***23,** 336–356.

Neiman, P.J., F.M. Ralph, G.A. Wick, J. D. Lundquist, and M. D. Dettinger, 2008: Meteorological characteristics and overland precipitation impacts of atmospheric rivers affecting the west coast of North Amercia based on eight years of SSMI/satellite observations. *J. Hydrometeor*., 9, 22-47.

Pelly,J.L, and B.J. Hoskins, 2003: A new perspective on blocking. JAS,60,743-755.

Ralph, F. M., P. J. Neiman, and G. A. Wick, 2004: Satellite and CALJET aircraft observations of atmospheric rivers over the eastern north Pacifc Ocean during the winter of 1997/98. Mon. Wea. Rev., 132, 1721-1745.

Rex, D. F., 1950a: Blocking action in the middle troposphere and its effect upon regional climate. I. An aerological study of blocking action. *Tellus,* **2,** 196–211.

——, 1950b: Blocking action in the middle troposphere and its effect upon regional climate. II. The climatology of blocking action. *Tellus,* **2,** 275–301.

Ryan, T and S Hanes,2009 A Synoptic Climatology of Texas Winter Storms. NWA Digest,33,37-56.

Younkin, R.J., 1968: Circulation Patterns Associated with Heavy Snowfall over the Western United States. *Monthly Weather Review*, 96, 12, 851-853.

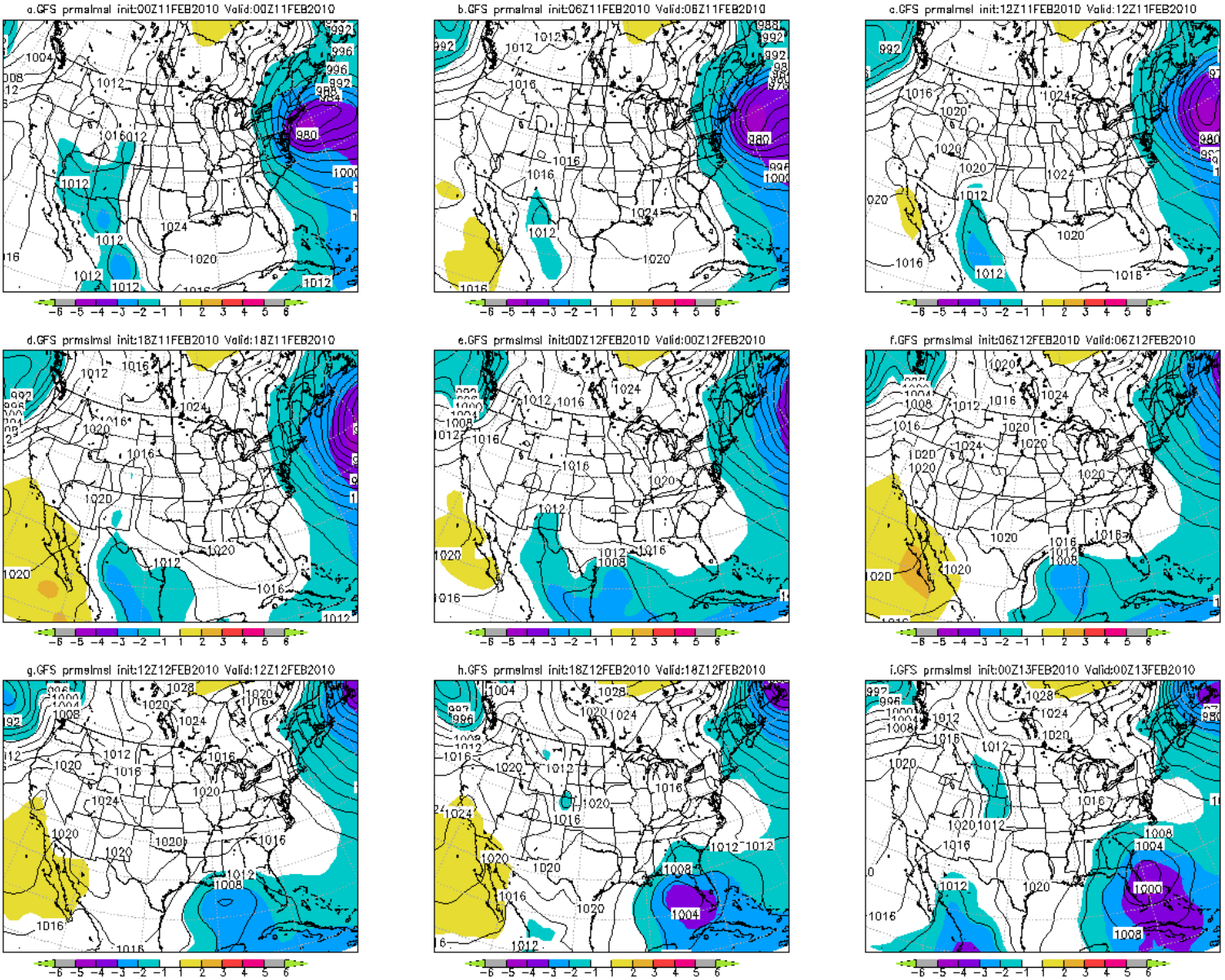
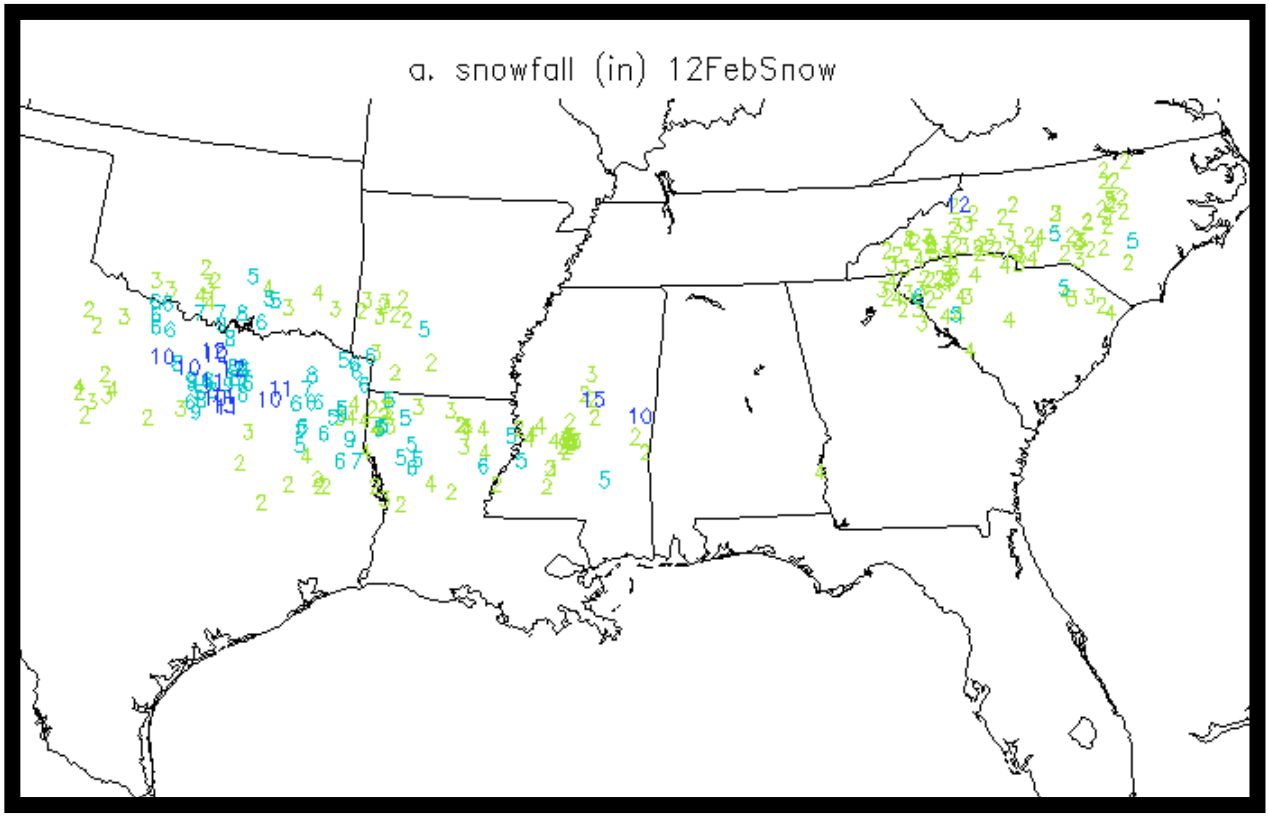


Figure 1. GFS 00-hour analysis of mean sea level pressure (hPa) and pressure anomalies (standard deviations) from GFS analysis valid at a) 0000 UTC 11 February, b) 0600 UTC 11 February, c) 1200 UTC 11 February, d) 1800 UTC 11 February, e) 0000 UTC 12 February, f) 0600 UTC 12 February, g) 1200 UTC 12 February, h) 1800 UTC 12 February, and i) 0000 UTC 12 February 2010.



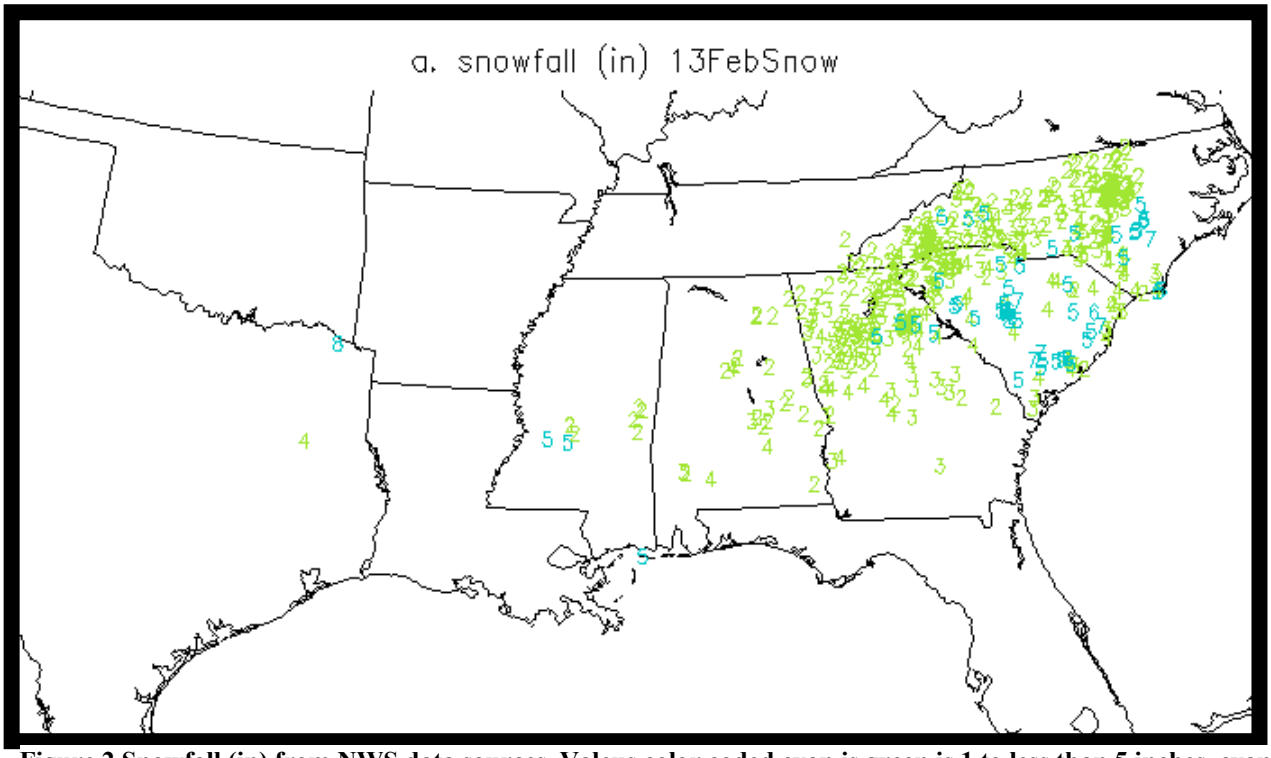


Figure 2 Snowfall (in) from NWS data sources. Valeus color coded cyan is green is 1 to less than 5 inches, cyan is 5 to less than 10 inches and blue is 10 to less than 20 inches.

Year	Month	Day	AO	NAO	PNA
2010	2	1	-2.774	-0.116	0.566
2010	2	2	-2.286	-0.353	0.383
2010	2	3	-2.417	-0.367	0.268
2010	2	4	-3.379	-0.355	0.276
2010	2	5	-4.398	-0.620	0.484
2010	2	6	-5.0788	-0.936	0.946
2010	2	7	-5.1058	-1.051	1.298
2010	2	8	-4.825	-1.240	1.100
2010	2	9	-4.601	-1.282	0.827
2010	2	10	-4.117	-1.146	0.639
2010	2	11	-4.4	-1.04	0.7012
2010	2	12	-4.7	-1.040	0.690
2010	2	13	-4.64	-1.260	0.684
2010	2	14	-5.04	-1.370	0.755
2010	2	15	-4.88	-1.390	0.896

Table 1. Daily values of the Arctic Oscillation (AO), North Atlantic Oscillatin (NAO) and the Pacific North American (PNA) index for the first 15 days of February 2010. Data from the Climate Prediction Center.

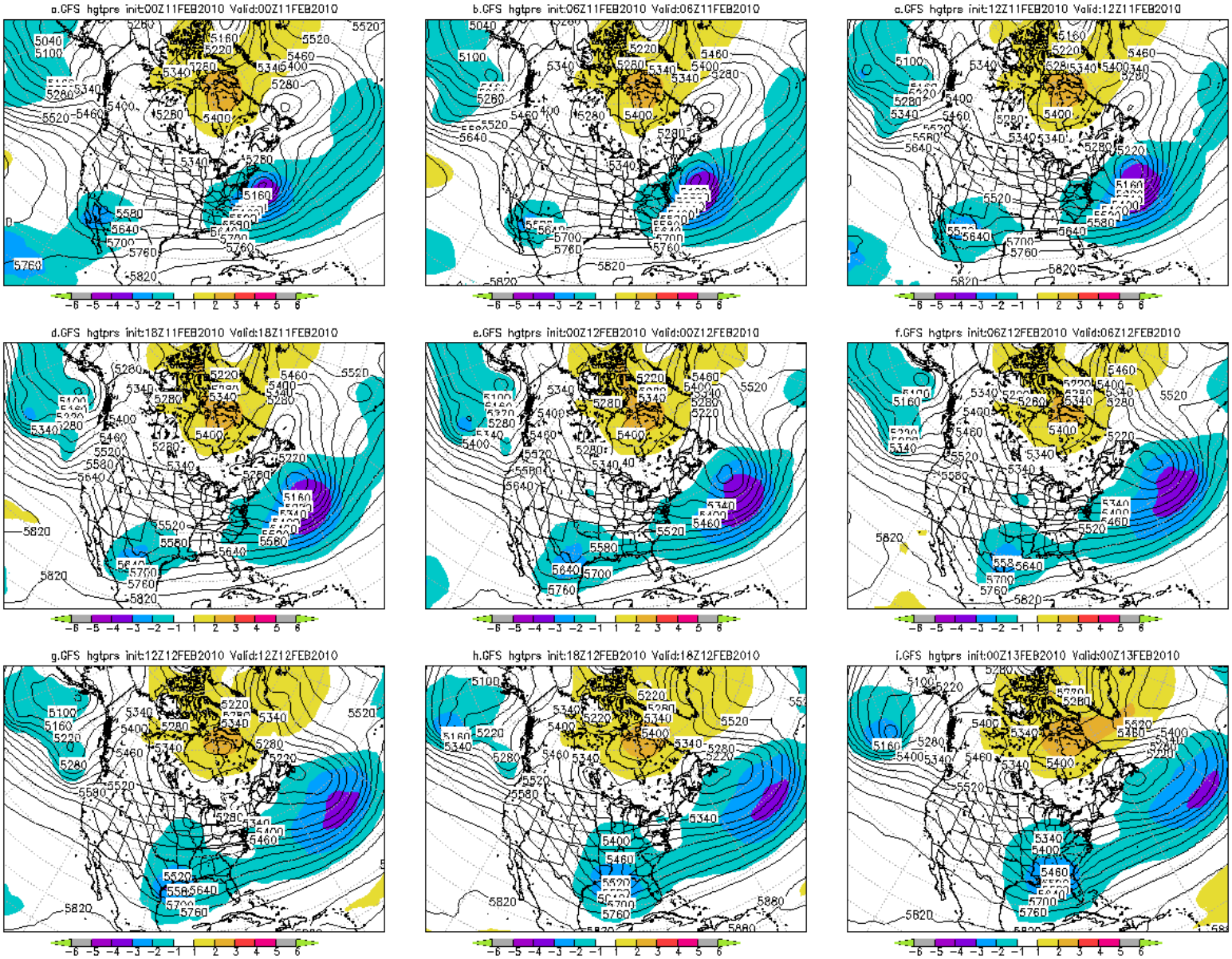


Figure 3 As in Figure 1 except showing 500 hPa heights (m) and anomalies.

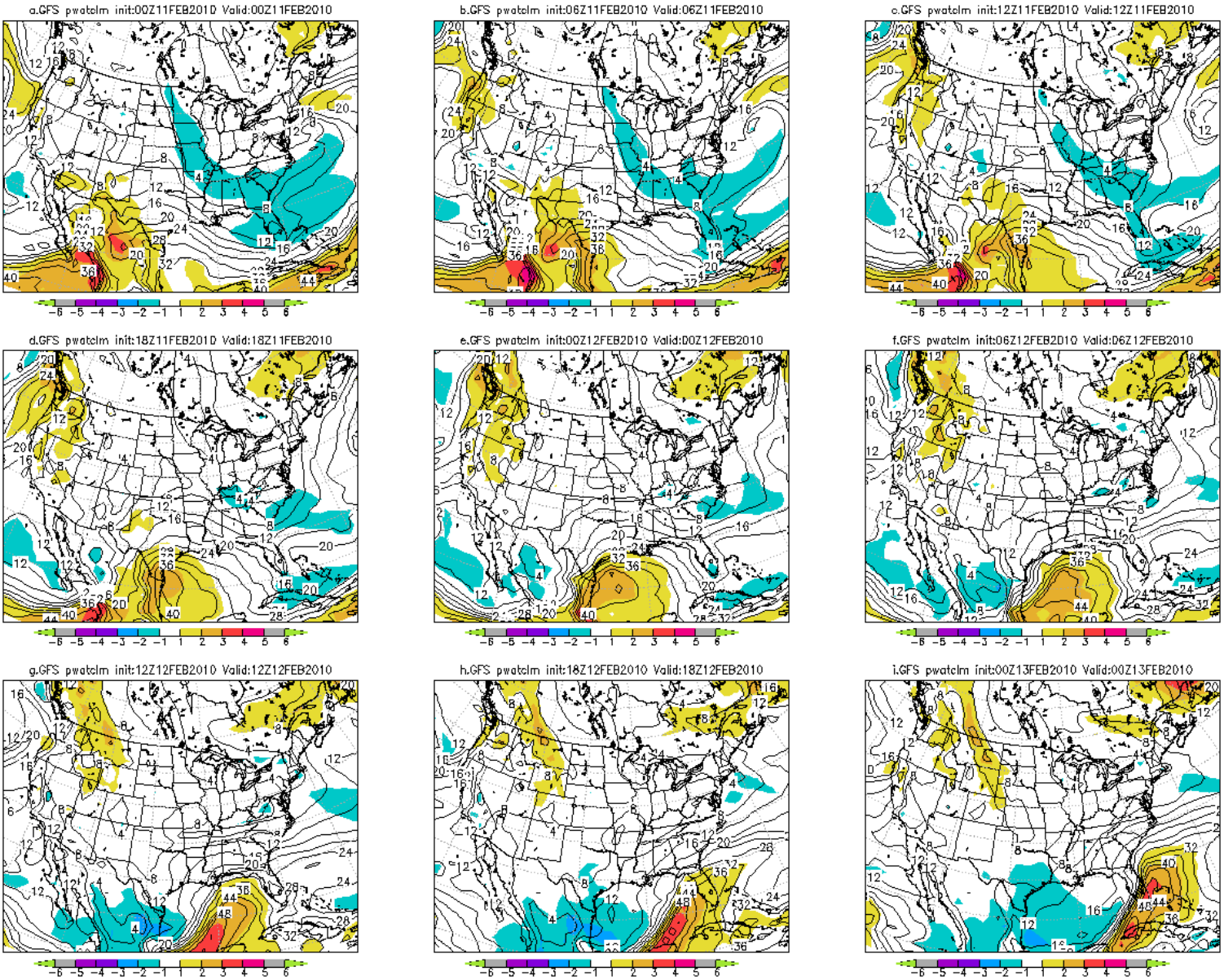


Figure 4. As in Figure 1 except showing GFS PW and PW anomalies.

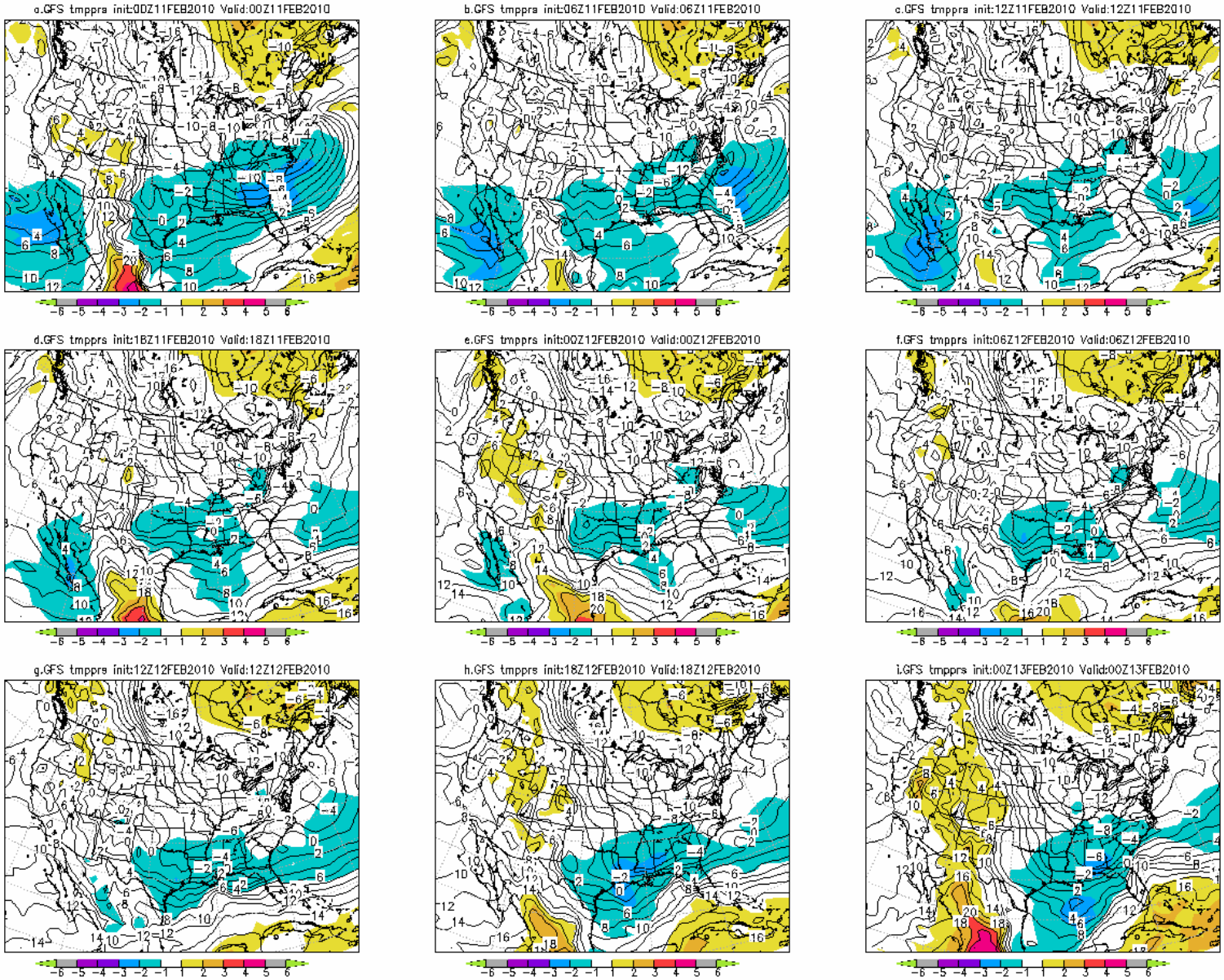


Figure 5. As in Figure 1 except showing GFS 850 hPa temperatures and temperature anomalies.

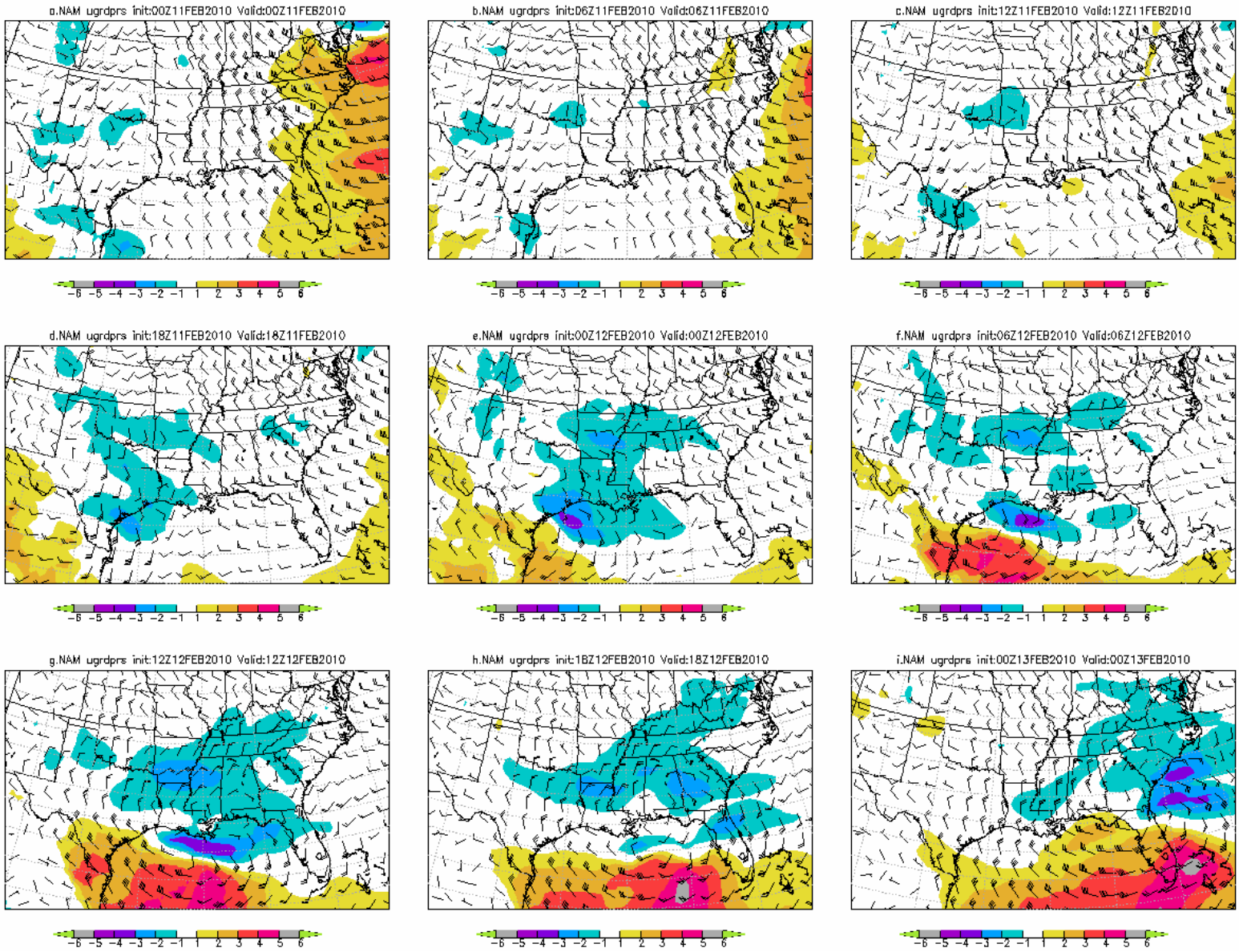


Figure 6. As in Figure 1 except NAM 0-hour forecasts of 850 hPa winds and u-wind anomalies.

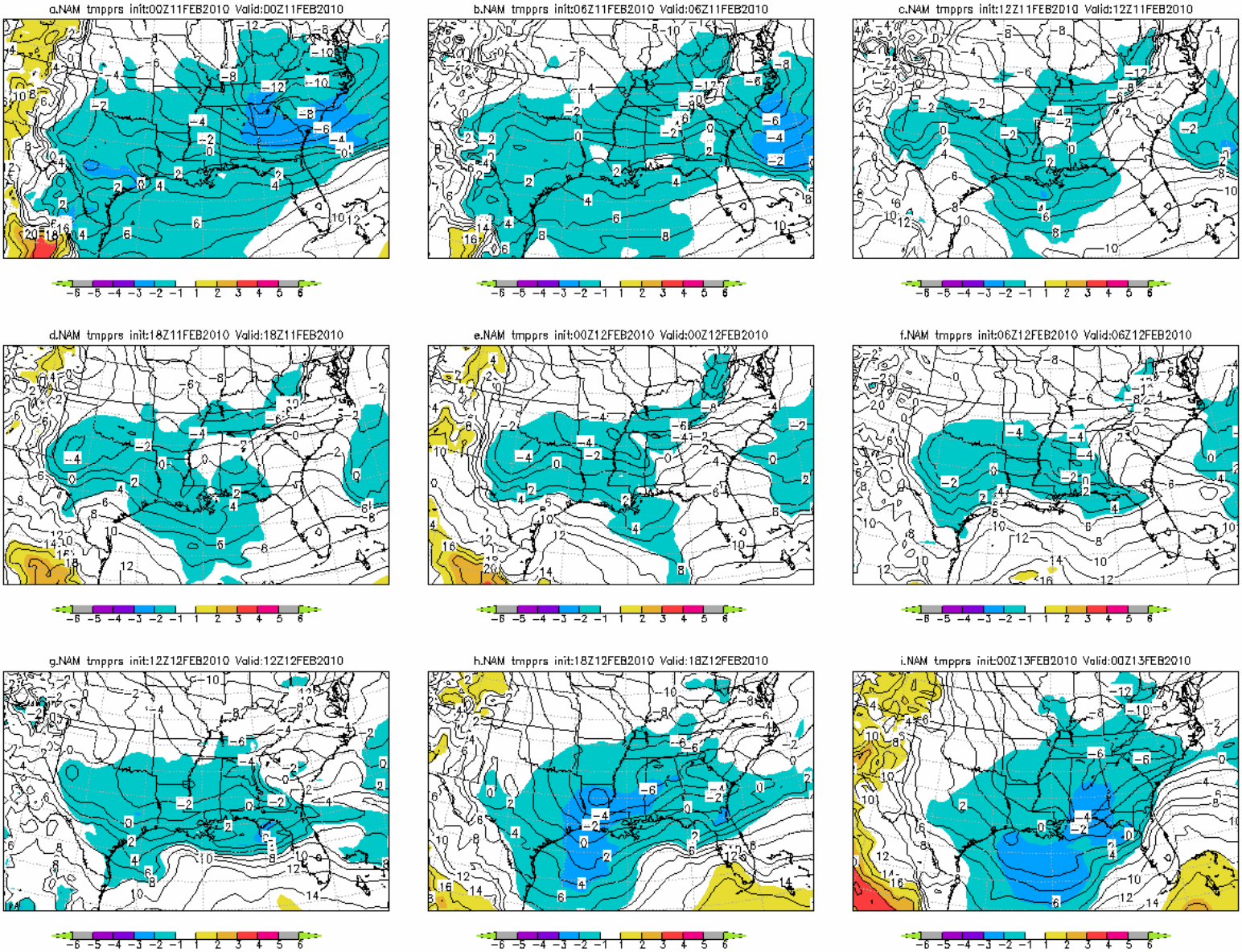


Figure 7. As in Figure 6 except NAM 00-hour 850 hPa temperatures and anomalies.

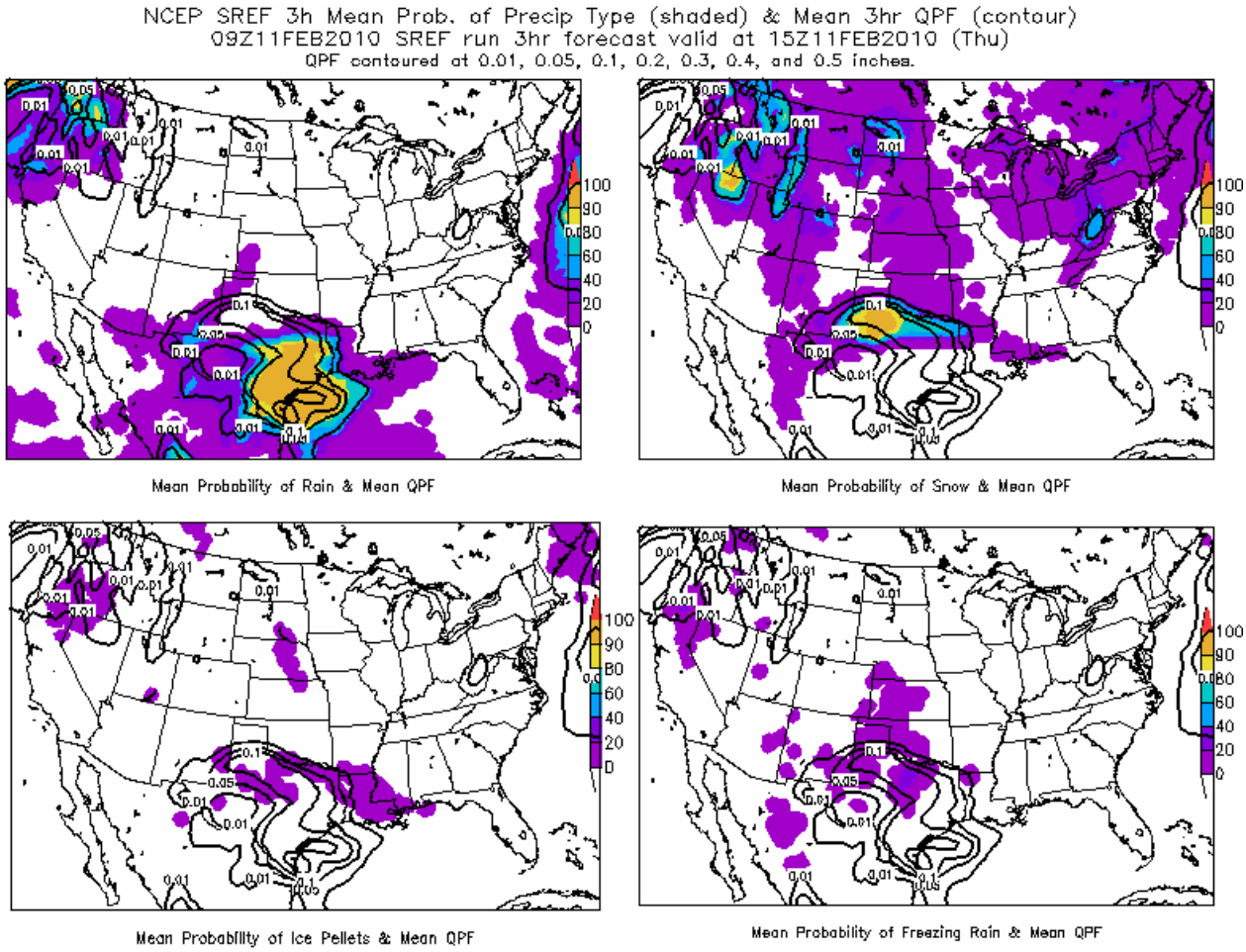


Figure 8. SREF precipitation type and 3-hour QPF (in) forecasts initialized at 0900 UTC 11 February 2010 valid at 1500 UTC 11 February showing clockwise from upper left the probability for rain, probability of snow, probability freezing rain and the probability of ice pellets.

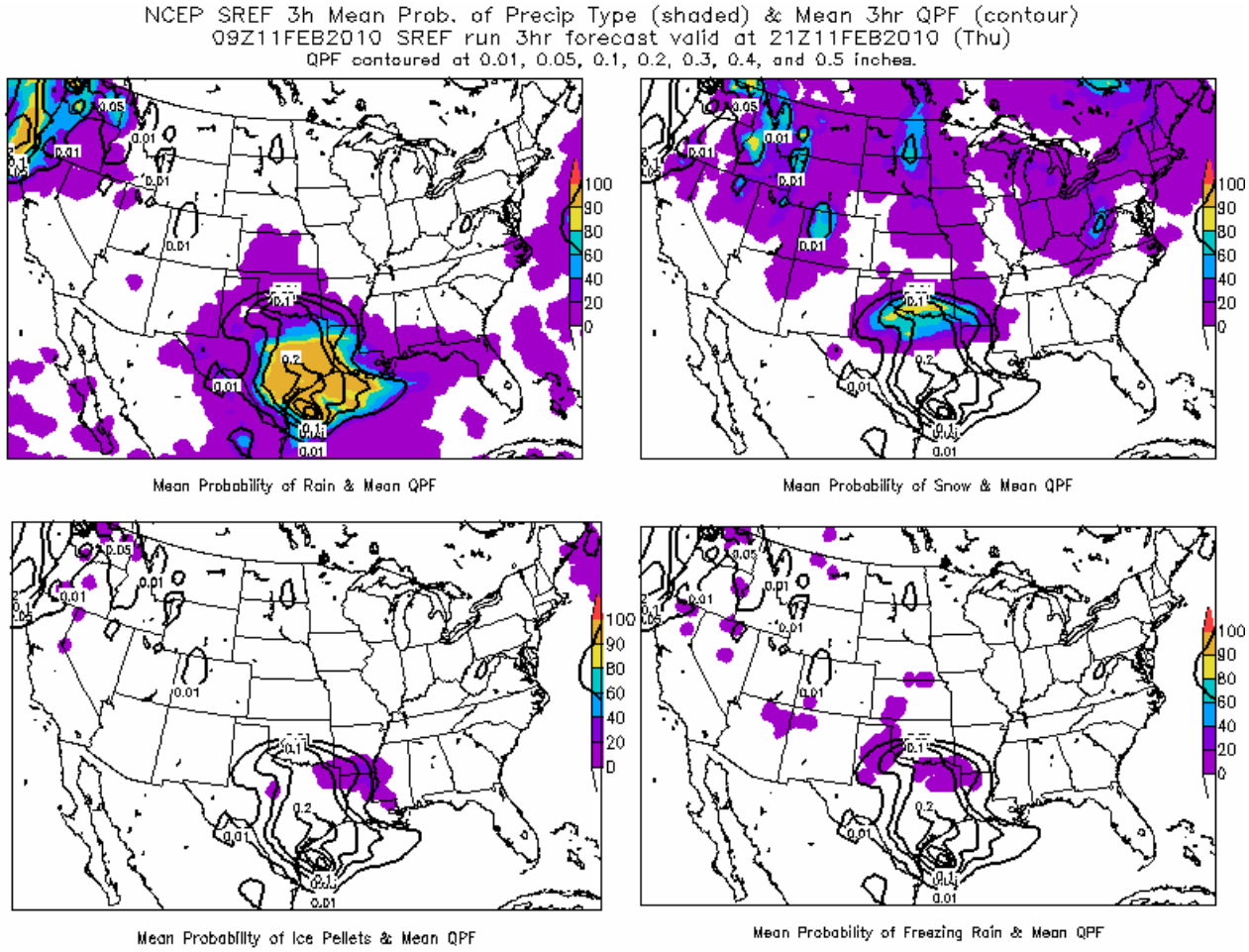


Figure 9. As in Figure 8 except valid at 2100 UTC 11 February 2010.

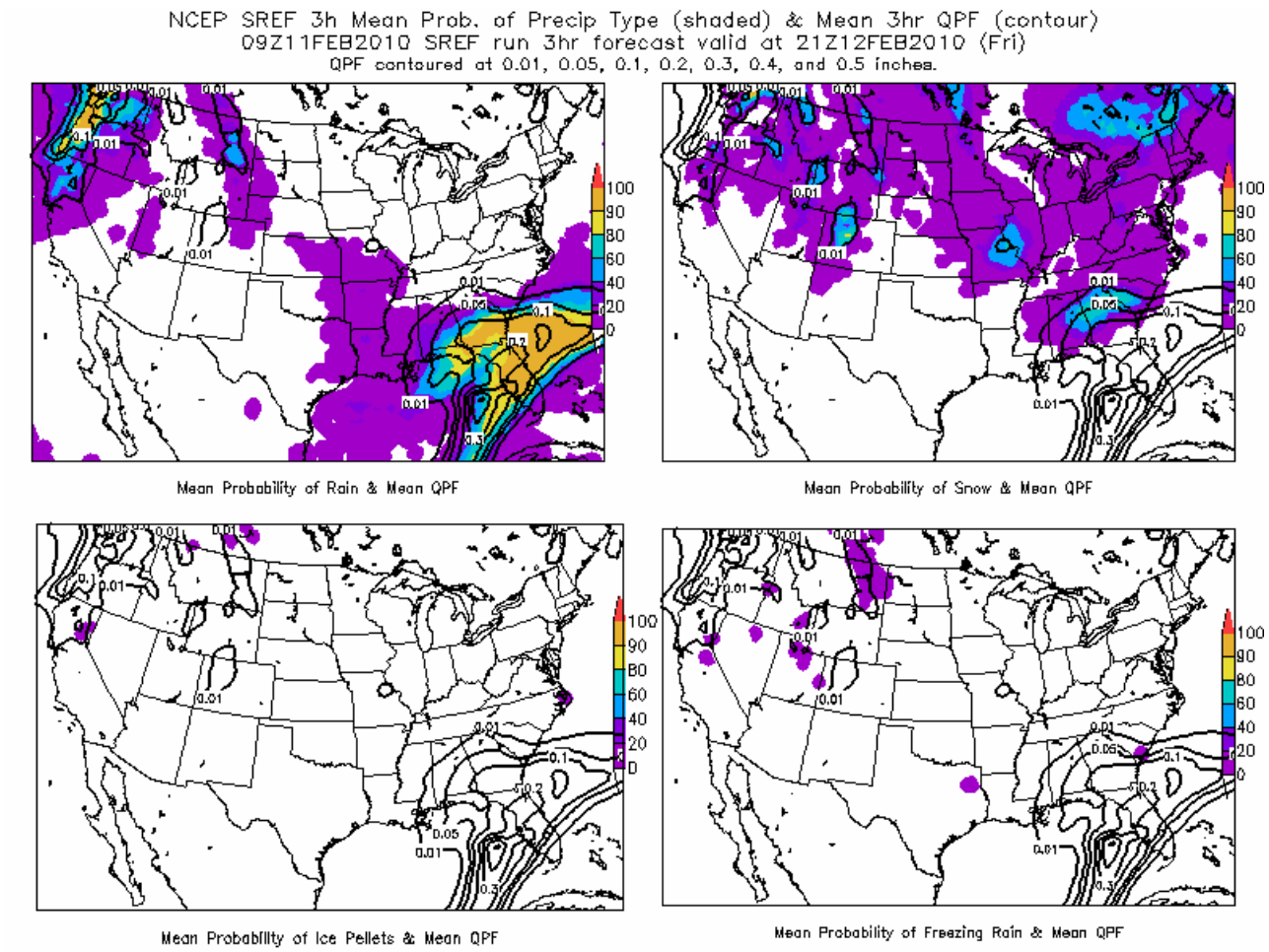


Figure 10. As in Figure 8 except valid at 2100 UTC 12 February.

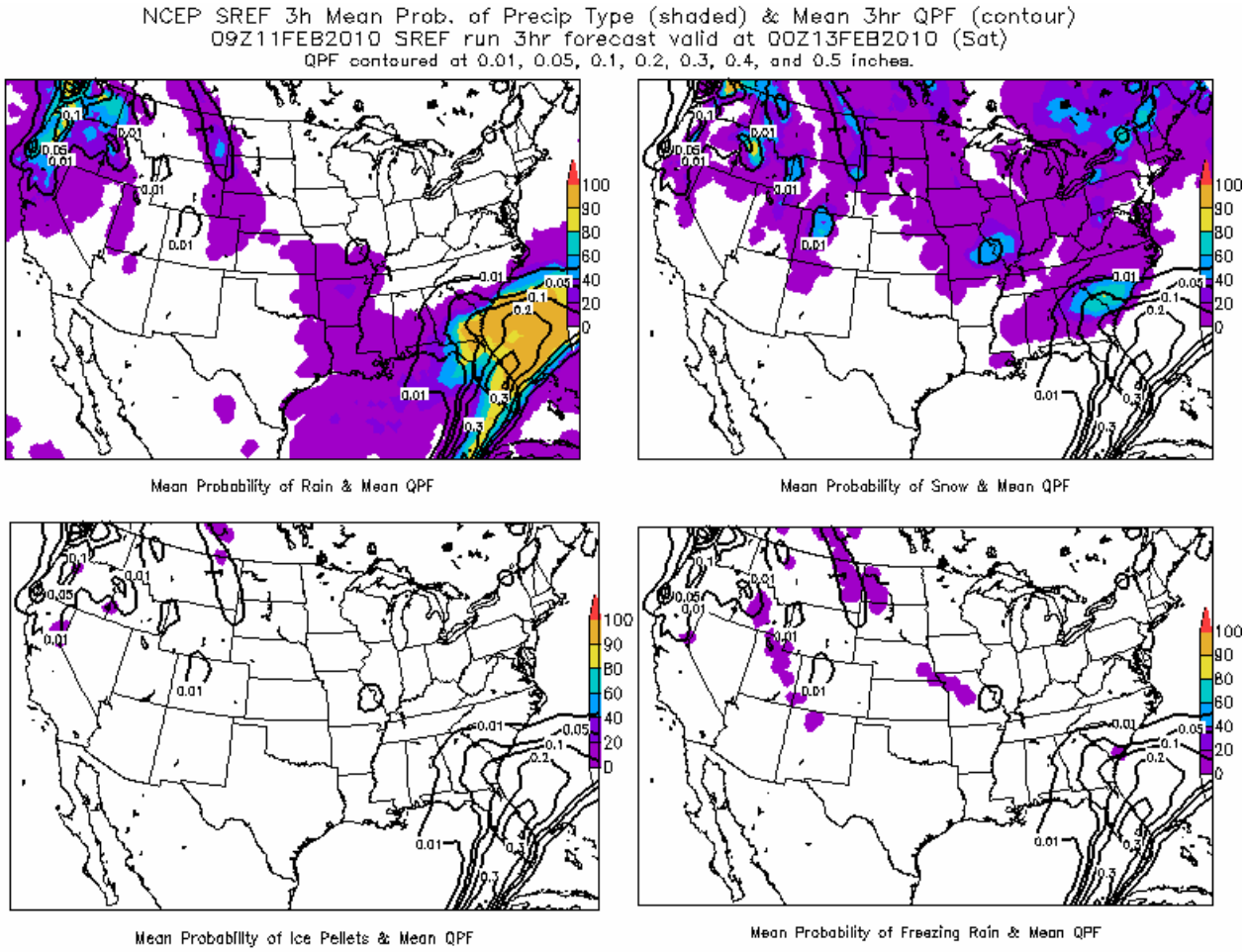


Figure 11. As in Figure 8 except valid at 0000 UTC 13 February 2010.

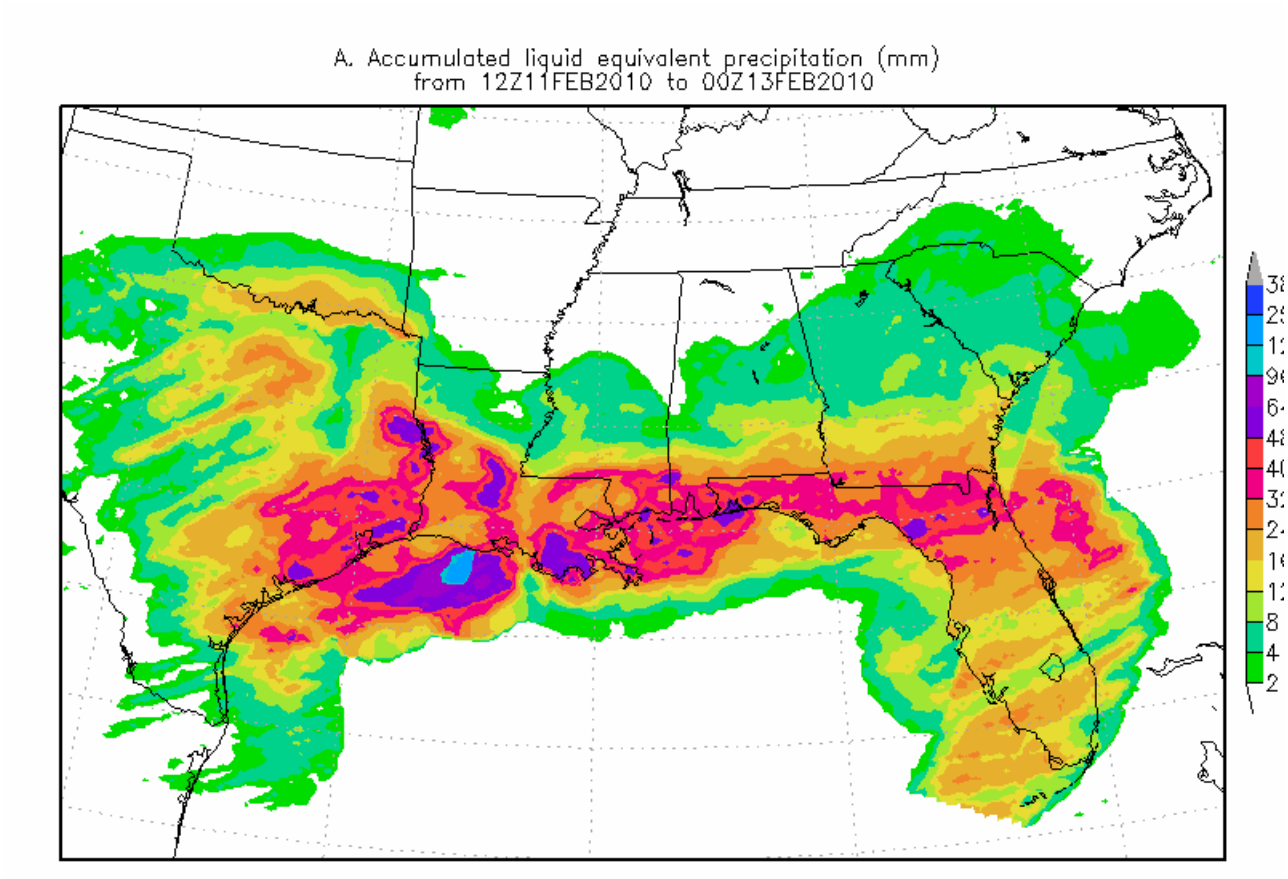


Figure 12. Total QPE (mm) from the 4km Stage-IV data summed over 6-hour intervals.

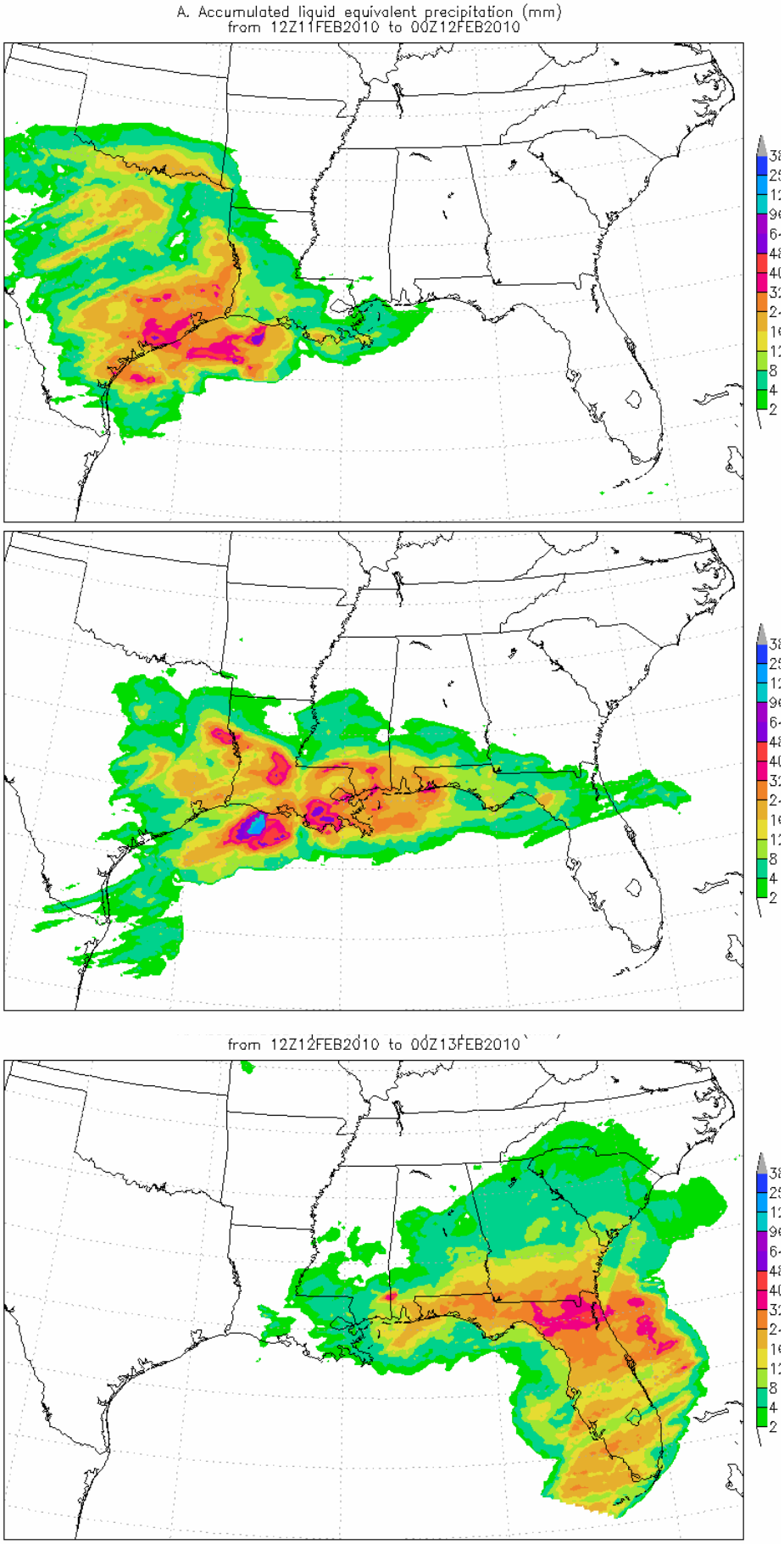


Figure 13. As in Figure 12 except QPE over 12 hour intervals, from top to bottom, the 12 hour period ending at 0000 UTC 12 February, 1200 UTC 12 February and 0000 UTC 13 February 2010.

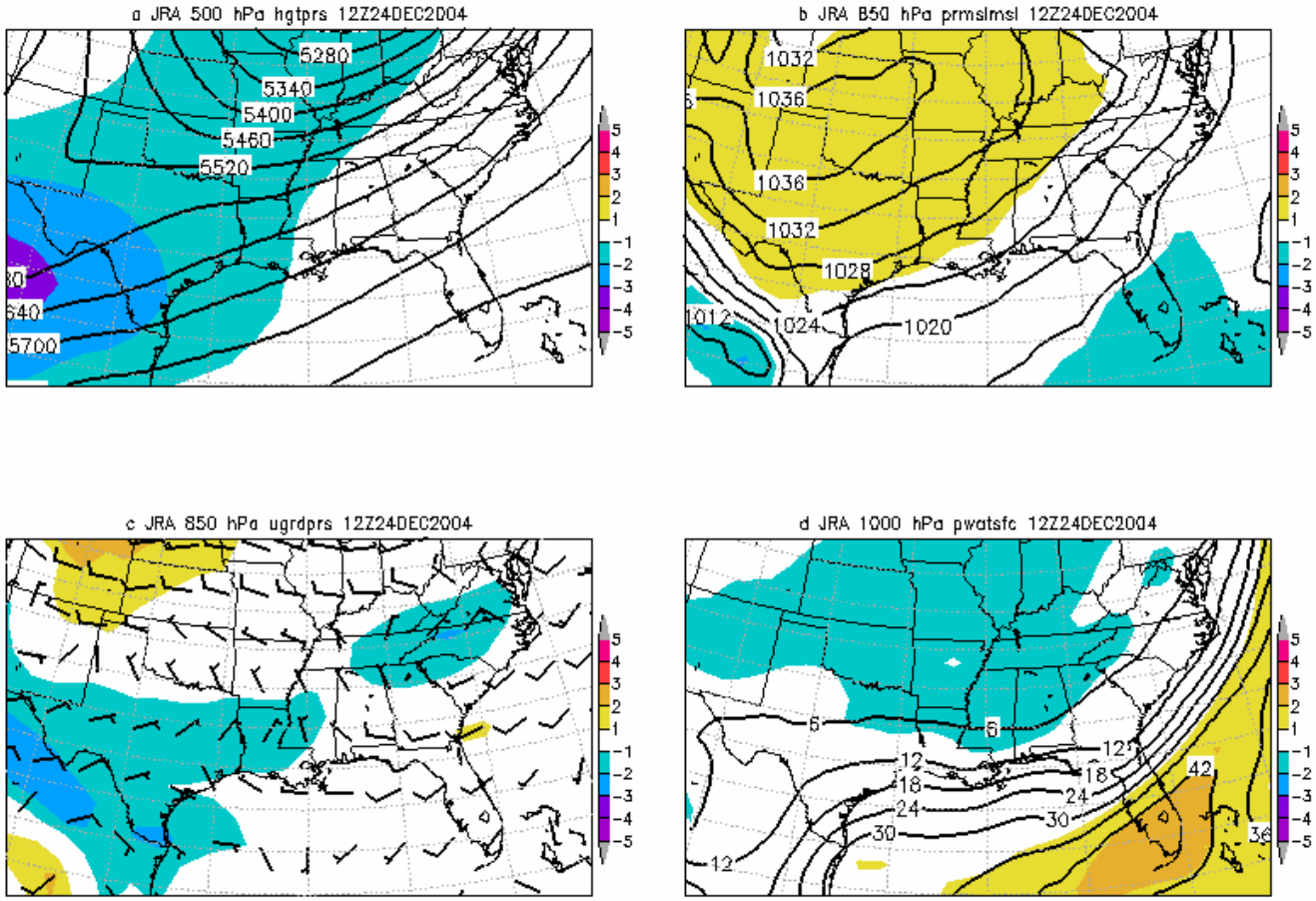


Figure 14. JRA reanalysis data showing conditions at 1200 UTC 24 December 2004 including a) 500 hPa heights (m) and height anomalies, b) mean sea level pressure (hPa) and anomalies, c) 850 hPa winds and u wind anomalies, and d) precipitable water and anomalies.

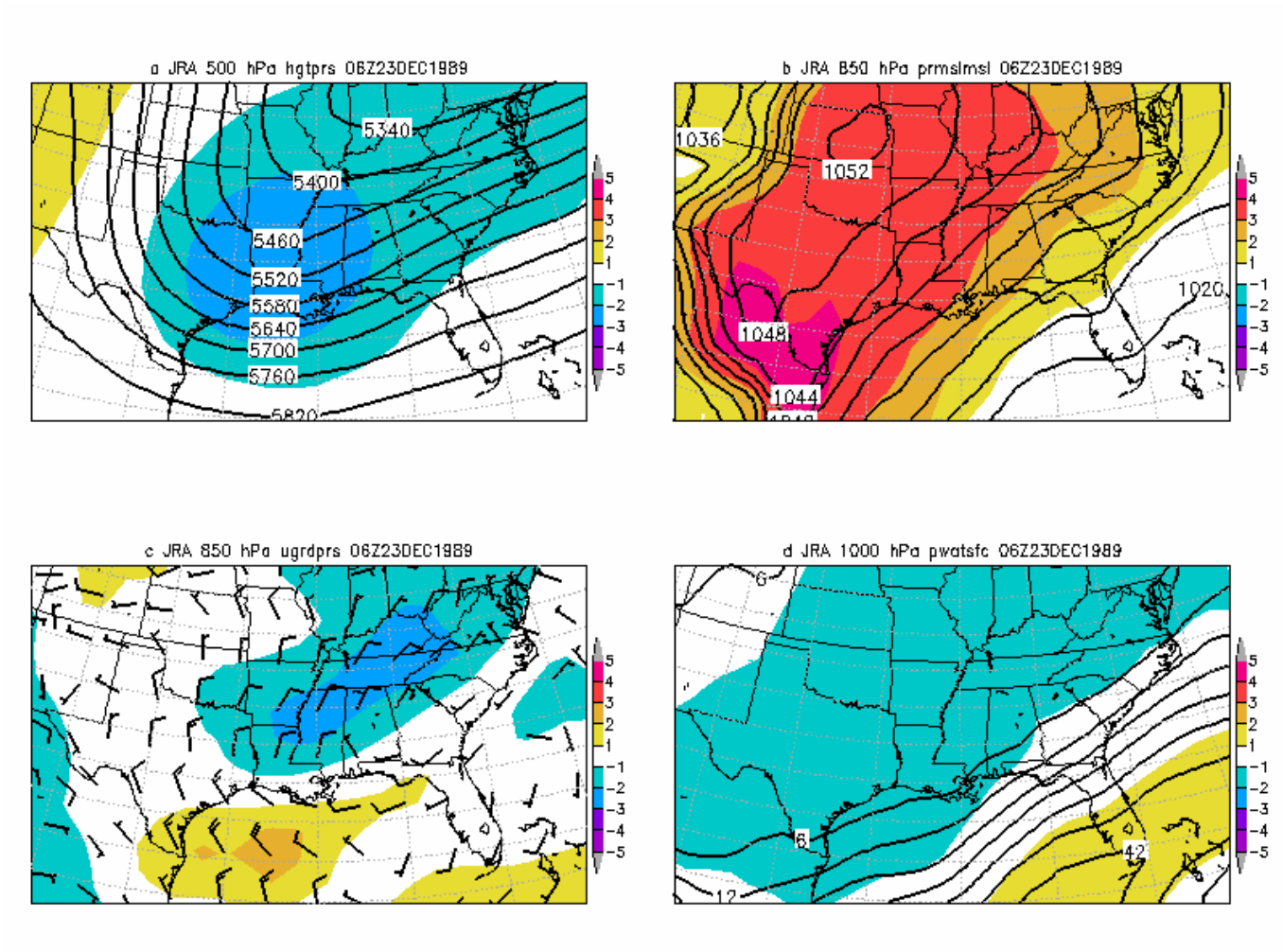


Figure 15. As in Figure 14 except valid at 0600 UTC 23 December 1989.