# Mid-Mississippi Heavy rainfall and flooding

*Double whammy rain events late April and early May*

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## 1. Overview

In the mean, a strong ridge over the western Atlantic and a deep trough over the central United States (Fig. 1a) persisted during the period of 26 April through 5 May 2017. This produced persistent low pressure over the Mid-Mississippi Valley (MMV: Fig. 1c) and above normal temperatures (Fig. 1b) and moisture (Fig. c) over portions of the eastern United States.

The mean pattern in Figure 1, including the deep trough to the west and the ridge to the east is a common pattern associated with heavy rainfall event. This general pattern was found to be critical for heavy rains in the mountains of California (Junker et al. 2008). Junker et al. (1999) showed the importance of deep southerly flow and high PW air in the Great Midwest floods of 1993. The pattern during this event was similar to the pattern and composites which accompanied the Mid-Mississippi Valley floods of April 2011 (Fig.4: Grumm 2011).

The semi-persistent pattern produced a broad area of heavy rain across the MMV with many areas receiving in excess of 200 mm (8 inches) of rainfall and over 300 to 400 mm of rainfall in southeastern Missouri (Fig. 2). There were actually two significant rainfall events spanning 1200 UTC 29 April to 1800 UTC 30 April and 0000 UTC 4-5 May (Fig. 3). The first event produced a large swath of over 100 mm mover much of southeastern Missouri into Illinois with an embedded area of 150 to 200 mm of QPE in southeastern Missouri and Illinois. AN impressive rainfall event. The second event produced lower QPF amounts but did produced 50 to 75 mm of QPE over portions of Missouri and Illinois.

The first event lead to record and near record flooding in Missouri (MO State Government; Washington Post; CNN; TWC). The flooding in late April and early May killed at least 5 people, closed about 272 roads, and flooded hundreds of homes. Interestingly many of the reports of flooding occurred southwest of St Louis affecting towns such as Eureka and Pacific, MO and along the Meramec River. Most of these areas saw 100 to 125 mm of rainfall. Farther south, where over 150 mm of rain fell from 1200 UTC 29 April to 1800 UTC 30 April flooding reports were not as frequent in the reports. Most of the flooding in the area of heaviest rainfall was based on river gage data where gages surpassed records set in the past 100 years. Patterson, MO set a record reading along the St. Francis River. This and several other locations were in the region where over 150 to 200 mm of QPE was shown (Fig. 3a). There was additional flooding on 5 May in Missouri and Illinois. The high flows and wet soils form the earlier event likely contributed to the flooding issues on 4-5 May 2017.

This will summarize the period of heavy rainfall from 26 April to 5 May 2017. The focus is on the pattern and rainfall associated with the two significant periods of heavy rainfall. The NCEP GEF is used to show how well the NCEP GEFS forecast the potential for heavy rainfall.

## 2. Methods and Data

The NCEP GEFS was used to show the potential forecasts of heavy rainfall. Probabilities guidance and the ensemble mean are examined.

The climate forecast system reanalysis version II (CFSR) were used to diagnose and reconstruct the meteorological setting for the event. The data were available in 6-hour increments. For the composites of the pattern, all intervening 6-hour data times were averaged to get the mean pattern and the mean anomalies within that pattern.

The rainfall was retrieved using the NCEP Stage-IV QPE analysis.

## 3. Pattern

### *i. 29-30 April*

The 500 hPa pattern during the event of 29-30 April (Fig. 4) showed the nearly classic pattern with a deep 500 hPa low to the west and the ridge to the east implying deep southerly flow from the Gulf of Mexico into the MMV. The PW pattern over the MMV (Fig. 5) initially showed a quasi-east-west boundary with +3s PW anomalies. This pattern evolved to a more north-south boundary as a developing cyclone moved through the region (Fig. 6).

As the surface low moved through the region strong easterly flow was observed north of the low (not shown with anomalies) and strong southerly flow developed to the south and in the plume of high PW air (Fig. 5). The 850 hPa low-level jet (LLJ) with over 3s v-wind anomalies moved over southeastern Missouri around 1800 UTC 29 April. Strong southerly winds were present in Arkansas and Missouri through 1200 UTC 30 April. The v-wind anomalies peaked at +6s above normal at 1200 UTC 30 April 2017 (Fig. 7e).

This event had a near classic look from a heavy rainfall pattern and standardized anomaly pattern. The trough ridge pattern, plume of high PW air and strong southerly flow are all common characteristics of many heavy rainfall events. On the north side of this storm, GOES-16 showed an impressive swath of snow from the Texas Panhandle across western Kansas and Nebraska (GOES-16 blog[1]; Animated Loop). The snow on the cold side of this boundary and the swath of 100 to 200 mm of QPE in Missouri and Arkansas (Fig. 2a) reinforce how unseasonable this event was for late May.

This strong system actually moved into the eastern United States producing a significant severe weather event from North Carolina to New York (SPC) with over 364 reports of severe weather in the eastern United States on 1 May 2017.

### *ii. 4-5 May*

The 500 hPa pattern for the event of 4-5 May (Fig. 8) was similar to that which produced the heavy rainfall on 29-30 April. However, the eastern ridge was not nearly as strong as during the previous event. Thus the PW values during the event were only slightly above normal (Fig. 9) and were considerably lower than those present during the previous event.

As in the previous event, a surface cyclone moved through the region (Fig. 10). The cyclone deepened as it moved over the MMV and into the Appalachian mountains. North of the low there was strong easterly/northeasterly flow (Fig. 11). Most of the heavy rainfall in Illinois and Missouri fell in the deep east-northeasterly flow. The u-wind anomalies peaked at about -3s at 0600 UTC 5 May 2017 (Fig. 11f) over southern Indiana. Though not shown, there was strong southerly flow on the order of +2s in the deep southerly flow ahead of the surface cyclone.

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[1] Full GOES-16 Blog site link with chronological events link is here.

The pattern in the second event was not as anomalous as that in the first event. Thus, not surprisingly was the large difference in the maximum QPE between the two events (Fig. 2). The more anomalous event produced the more significant QPE event. The flooding on 4 and 5 May in Missouri, Illinois and Indiana likely was the result of the wet antecedent conditions and the heavy rainfall.

## 4. Forecast data

The NCEP guidance has become quite effective at predicting the patterns in which rain and heavy rain will occur. Thus the focus here is on the GEFS QPFs rather than the pattern which was quite similar to those diagnosed by the CFSR.

### *i. 29-30 April event*

Six GEFS forecasts of the QPF meeting or exceeding 75 mm is shown in Figure 12. With at least 5 days of lead-time, the GEFS forecast a high probability of 75 mm or more QPF in the MMV. Clearly, the probability increased as the forecast length decreased. It is clear that the GEFS members had to reasonably approximate the pattern in order to forecast such high QPF amounts.

The ensemble mean forecast and each member 100 mm contour (Fig. 13) show a similar pattern. There was a strong signal for 50 to 100 mm of QPF in the MMV. All six GEFS forecast cycles shown forecast at least some area to receive 100 mm or more QPF. Four of the 6 cycles shown also had a close 100 mm contour in the mean.

From an extreme forecast example, this was a highly successful forecast of a synoptic scale extreme rainfall event. However, from a spatial perspective, the GEFS had the highest QPF amounts displaced east of the verifying location and the GEFS under forecast the extreme amounts of in excess of 150 to 200 mm of QPE observed.

### *ii. 4-5 May event*

The GEFS probability of 50 mm or more QPF is shown in Figure 14. These data show a focus for 50 mm or more QPF from all six forecast cycles focused over eastern Missouri and into north-central Indiana. Based on the QPE in Figure 3b these forecasts got the approximate location relatively well. Clearly, the shorter range forecasts were better than the longer range forecasts.

The ensemble mean QPF (Fig. 15) and each member 75 mm QPF show that forecasts much over 50 mm were relatively low probability forecasts.

This case was relatively well forecast by the GEFS and the maximum QPF was not too much higher than the values estimated using the Stage-IV data.

## 5. Summary

A persistent ridge over the western Atlantic and a deep trough over the central United States (Fig. 1a) during the period of 26 April through 5 May 2017 produced two heavy rain events in the MMV. The trough and ridge were stronger during the first event which led to more rainfall and more extensive flooding than the second event. The western Atlantic ridge was considerably weaker during the second event and the rainfall totals were significantly lower in the MMV.

Despite this there was still significant flooding, likely the result of high flows produced by the previous heavy rainfall event.

Both events occurred in a well-known pattern for heavy rainfall, including a deep trough to the west and the ridge to the east... This general pattern was found to be critical for heavy rains in the mountains of California (Junker et al. 2008); Junker et al. (1999) showed the importance of deep southerly flow and high PW air in the Great Midwest floods of 1993. The pattern during this event was similar to the pattern and composites which accompanied the Mid-Mississippi Valley floods of April 2011 (Fig.4: Grumm 2011).

The heavy rainfall of 29-30 April was a highly successful forecast of a synoptic scale extreme rainfall event.  However, from a spatial perspective, the GEFS had the highest QPF amounts displaced east of the verifying location and the GEFS under forecast the extreme amounts of in excess of 150 to 200 mm of QPE observed. Relative to the event of 4-5 May 2017 the stronger trough ridge pattern and the more anomalous plume of high PW led to more rainfall in the earlier event. The GEFS was able to produce higher QPFs which reflected the stronger signal in the first event. Thus, the QPFs indicated that the GEFS can distinguish significant from extreme rainfall events.

The second event had a weaker signal in the pattern and the GEFS produced less QPF compared GEFS forecasts during the second event. They key point here is that the GEFS could discriminate between a heavy rainfall and a potentially extreme heavy rainfall event. Getting the exact area affect and the maximum QPF remains elusive but if properly used these data can provided extremely useful data to forecast extreme rainfall events.

## 6. Acknowledgements

## 7. References

Junker, N. W., R. S. Schneider and S. L. Fauver, 1999: Study of heavy rainfall events during the Great Midwest Flood of 1993. Wea. Forecasting, 14, 701-712.

Junker, N.W., R.H. Grumm, R.H. Hart, L.F Bosart, K.M. Bell, and F.J. Pereira, 2008: Use of normalized anomaly fields to anticipate extreme rainfall in the mountains of northern California. Wea. Forecasting, 23,336-356.

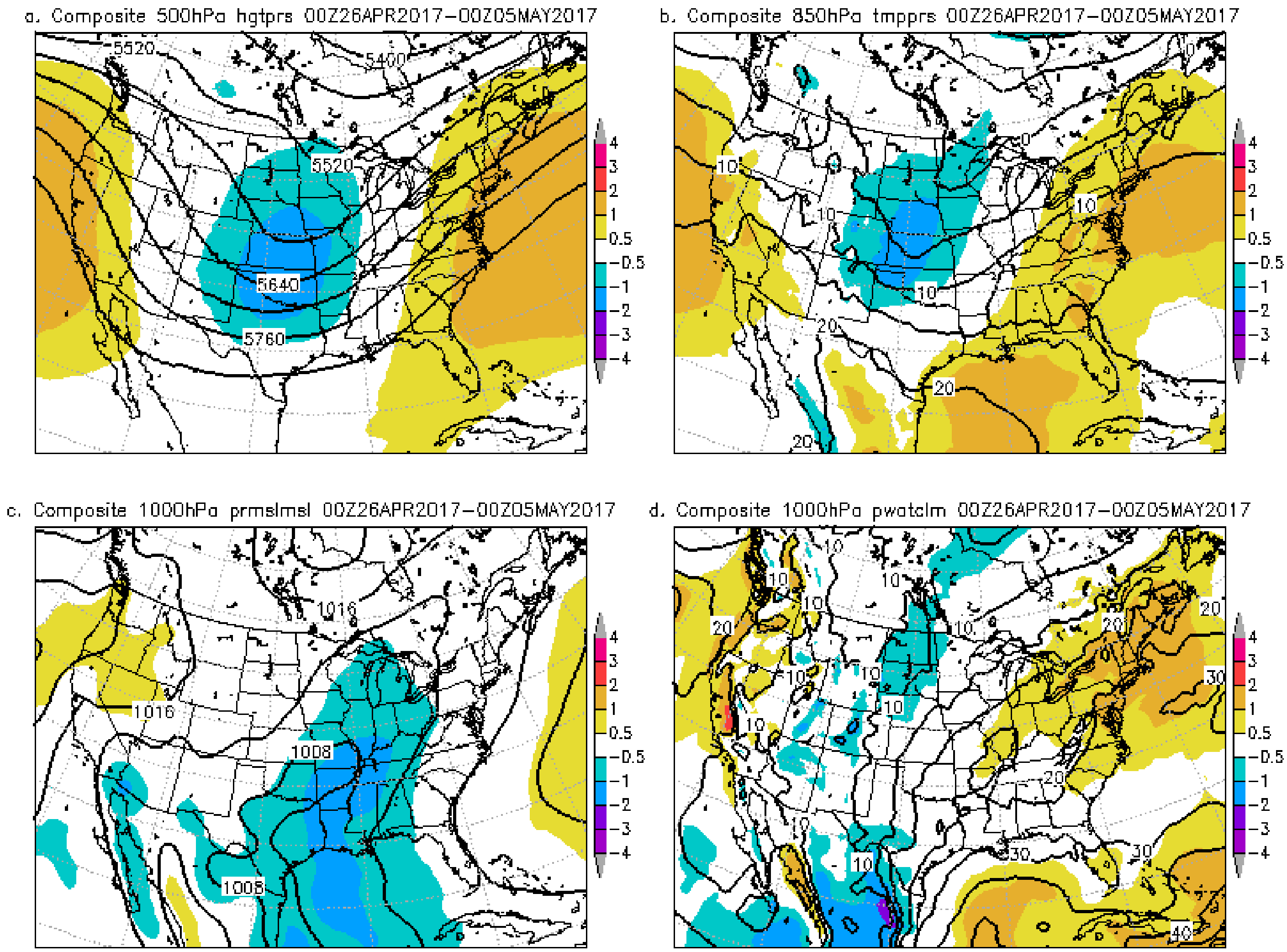


**Figure 1. The mean CFSR pattern over the United States from 0000 UTC 26 April through 0000 UTC 5 May 2017. Data include the mean and standardize anomaly over the period. Data include a) 500 hPa heights, b) 850 hPa temperatures, c) mean sea level pressure, and d) precipitable water.** [**Return to text.**](#)

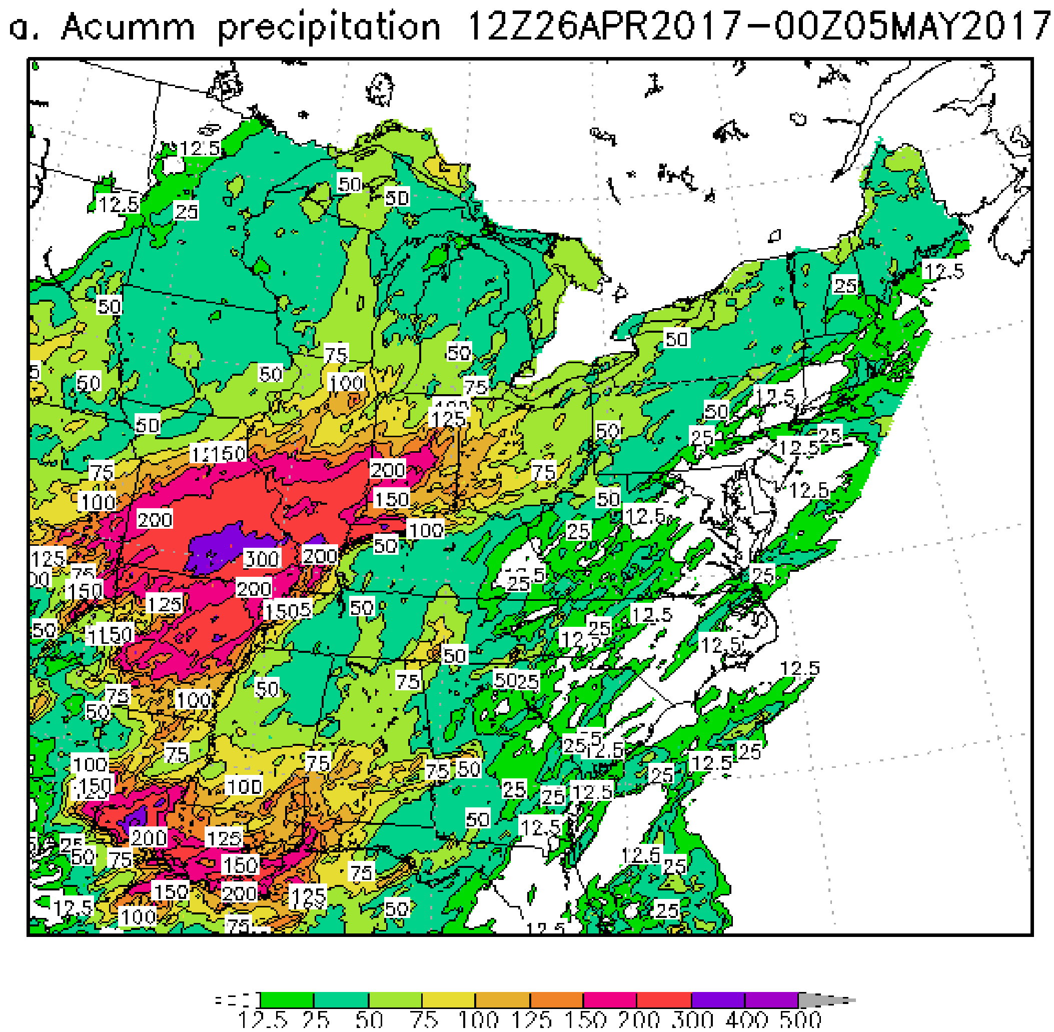


**Figure 2. Stage-IV estimated QPE for the period of 1200 UTC 26 April through 0000 UTC 5 May 2017. Data were derived using the 6-hour QPE estimates and are plotted in mm as in the color bar at the bottom of the image. Note values of fewer than 12.5 mm are not shown. Return text.**

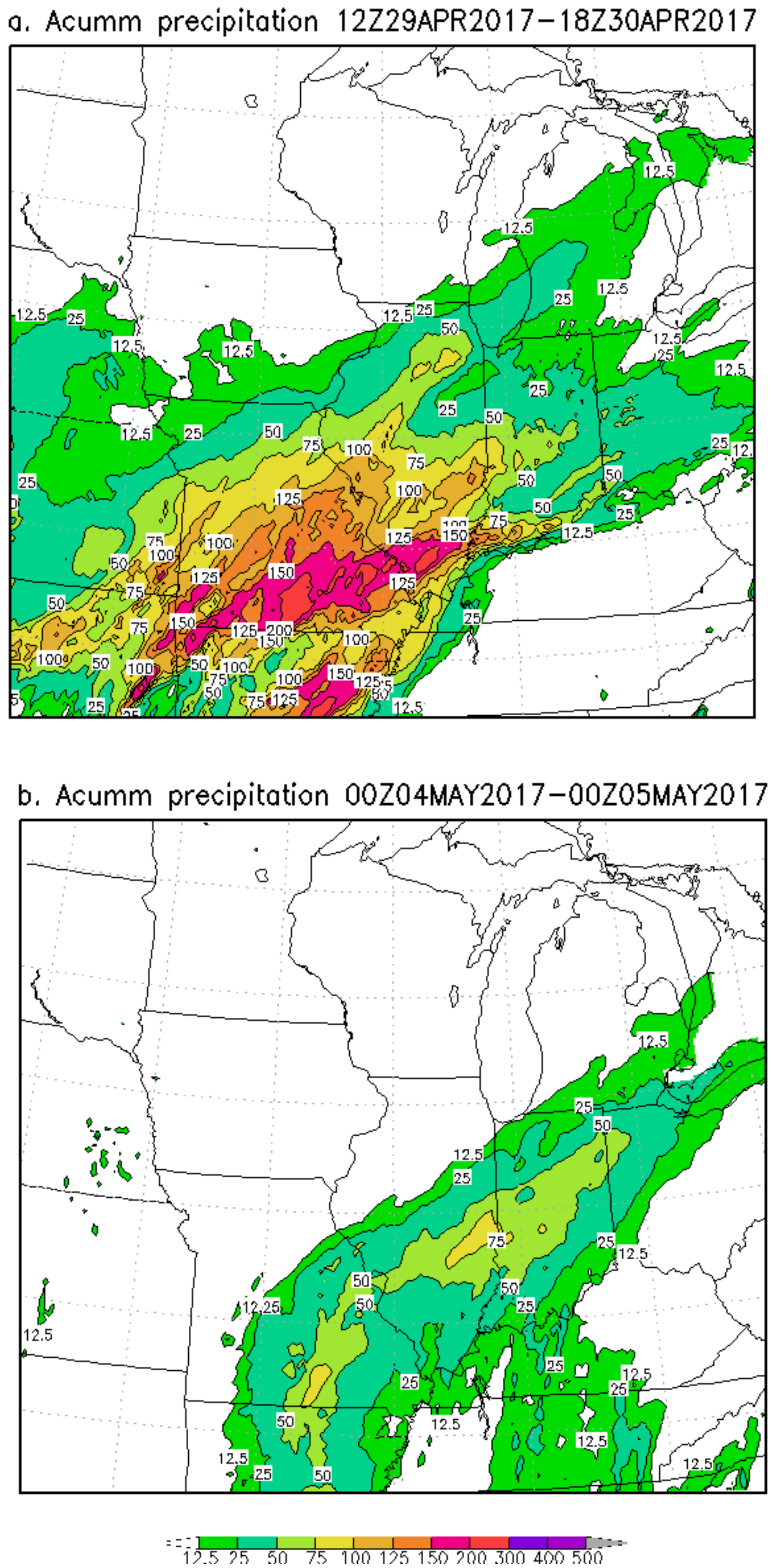


**Figure 3. As in Figure 2 except showing the two significant rainfall events in the MMV from a) 12Z 29 April to 18Z 30 April and b) 00Z 4 May through 00Z 5 May 2017. Values in mm.** [Return to text.](#)

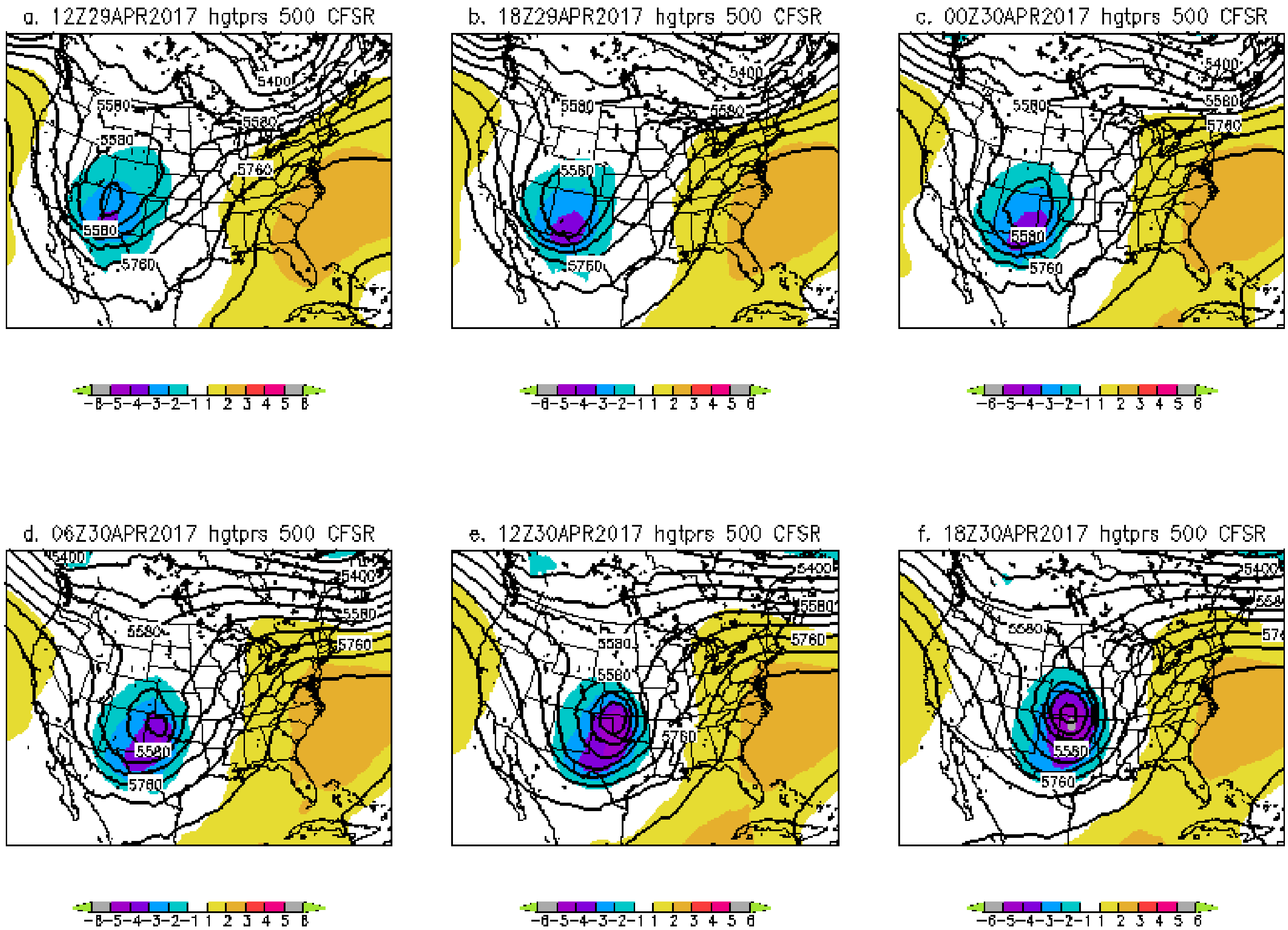


**Figure 4. CFSR 500 hPa heights and height anomalies every 6 hours from a) 1200 UTC 29 April through f) 1800 UTC 30 April 2017. Return to text.**

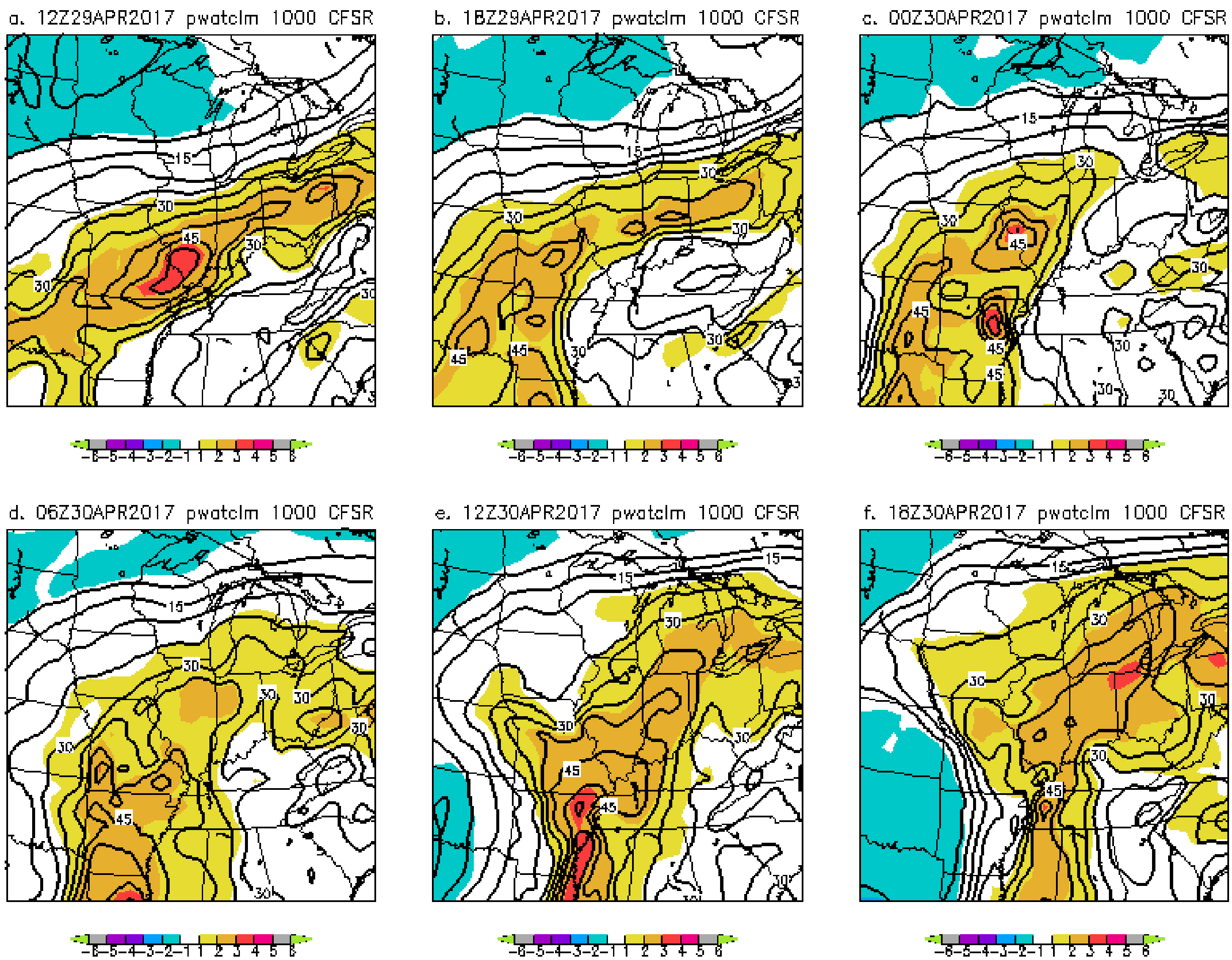


**Figure 5. As in Figure 4 except for CFSR precipitable water and precipitable water anomalies. Return to text.**

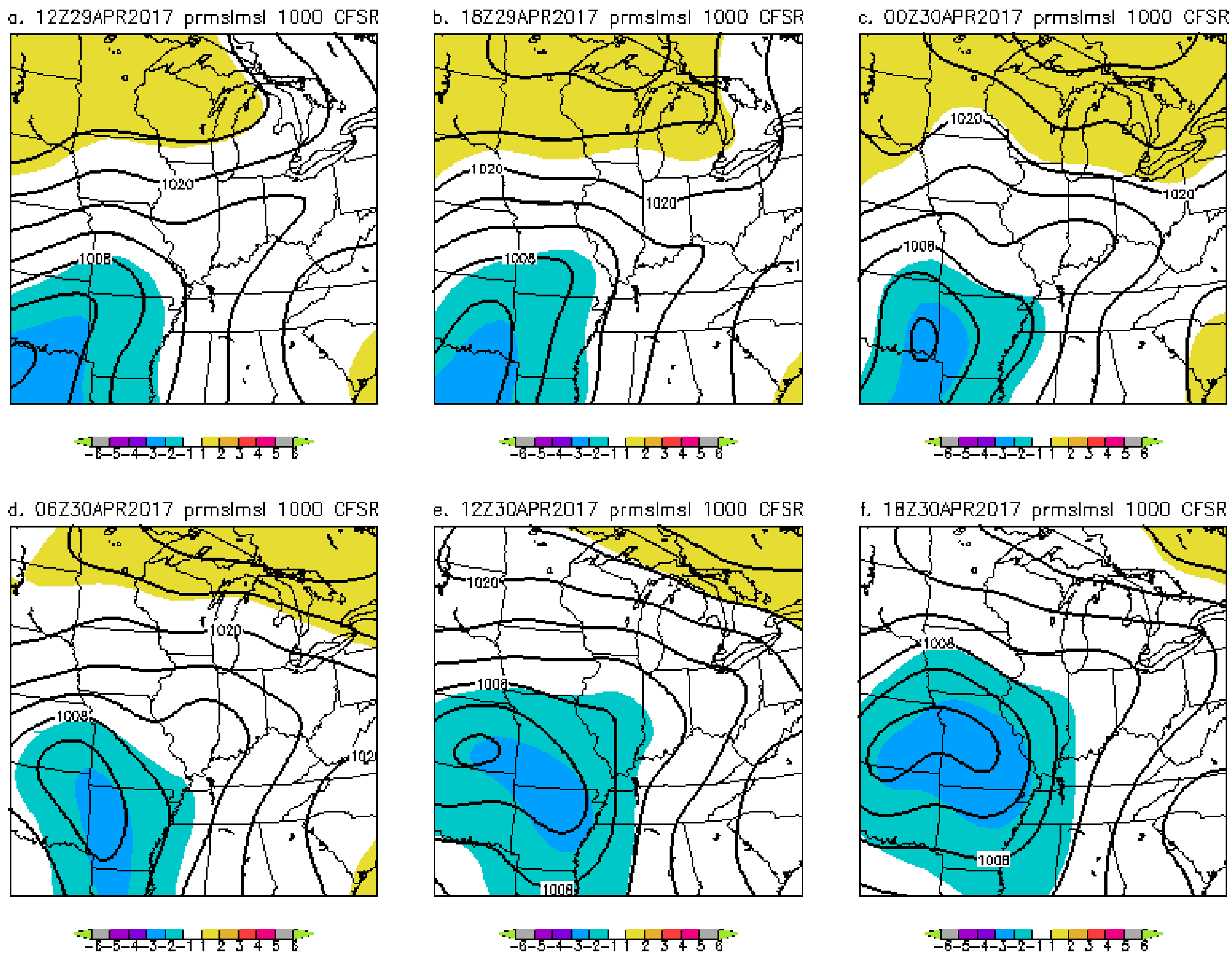


**Figure 6. As in Figure 5 except for CFSR mean sea-level pressure and standardized anomalies.** **Return to text**

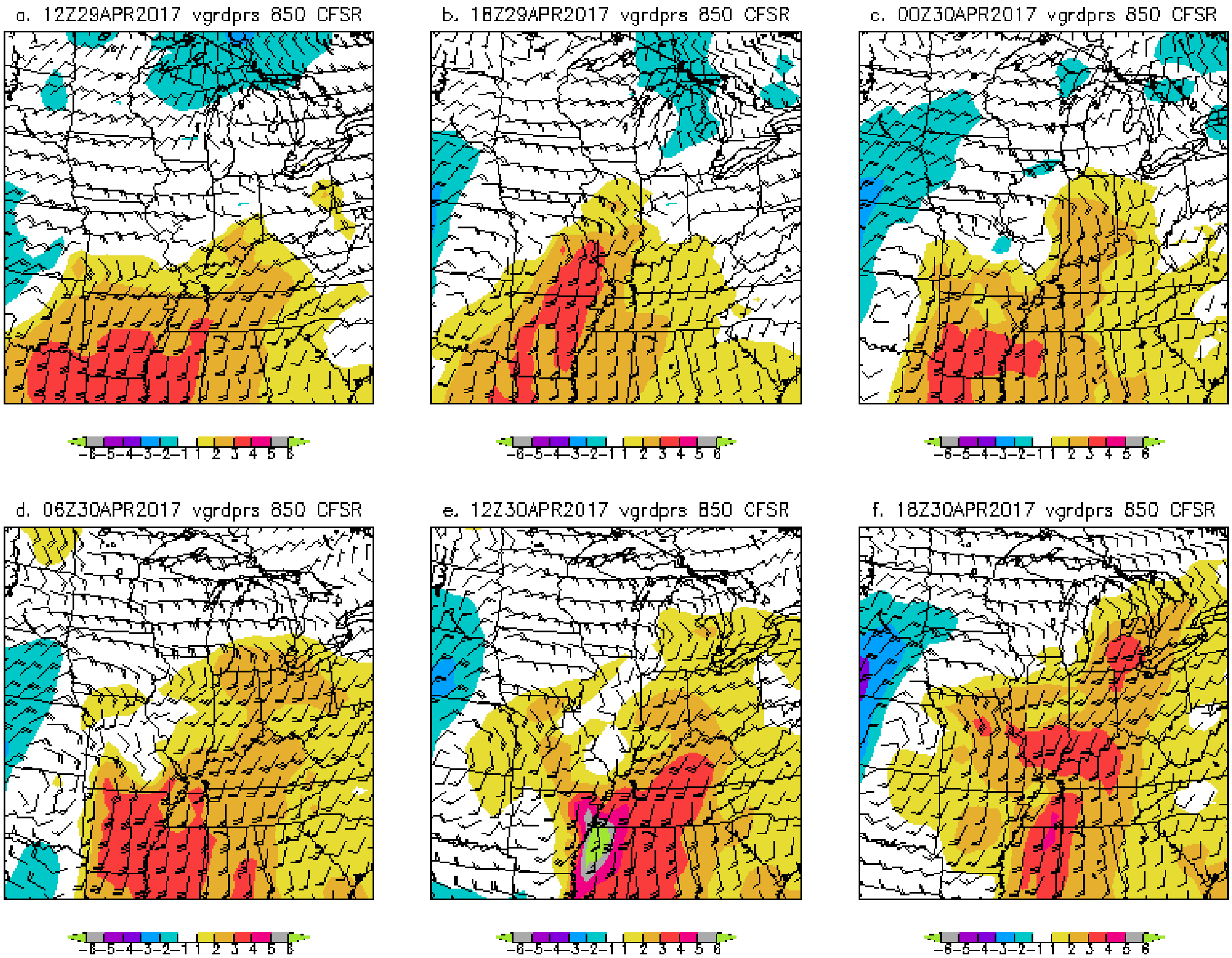


**Figure 7. As in Figure 6 except for CFSR 850 hPa wind (ms1-) and v-wind anomalies.** **Return to text**

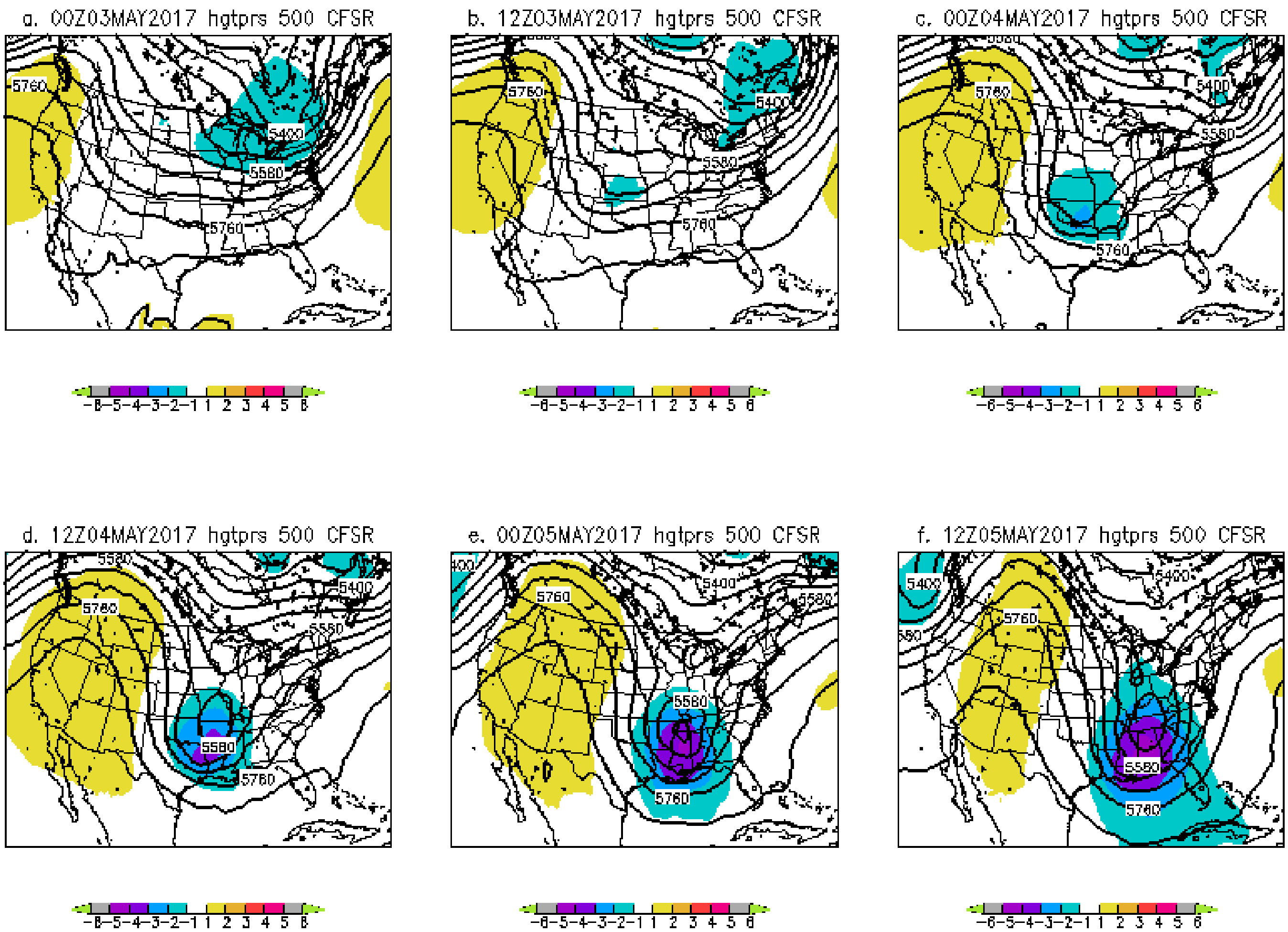


**Figure 8. As in Figure 4 except for the 12 hour periods of a) 000 UTC 3 May through f) 1200 UTC 5 May 2017.** **Return to text.**

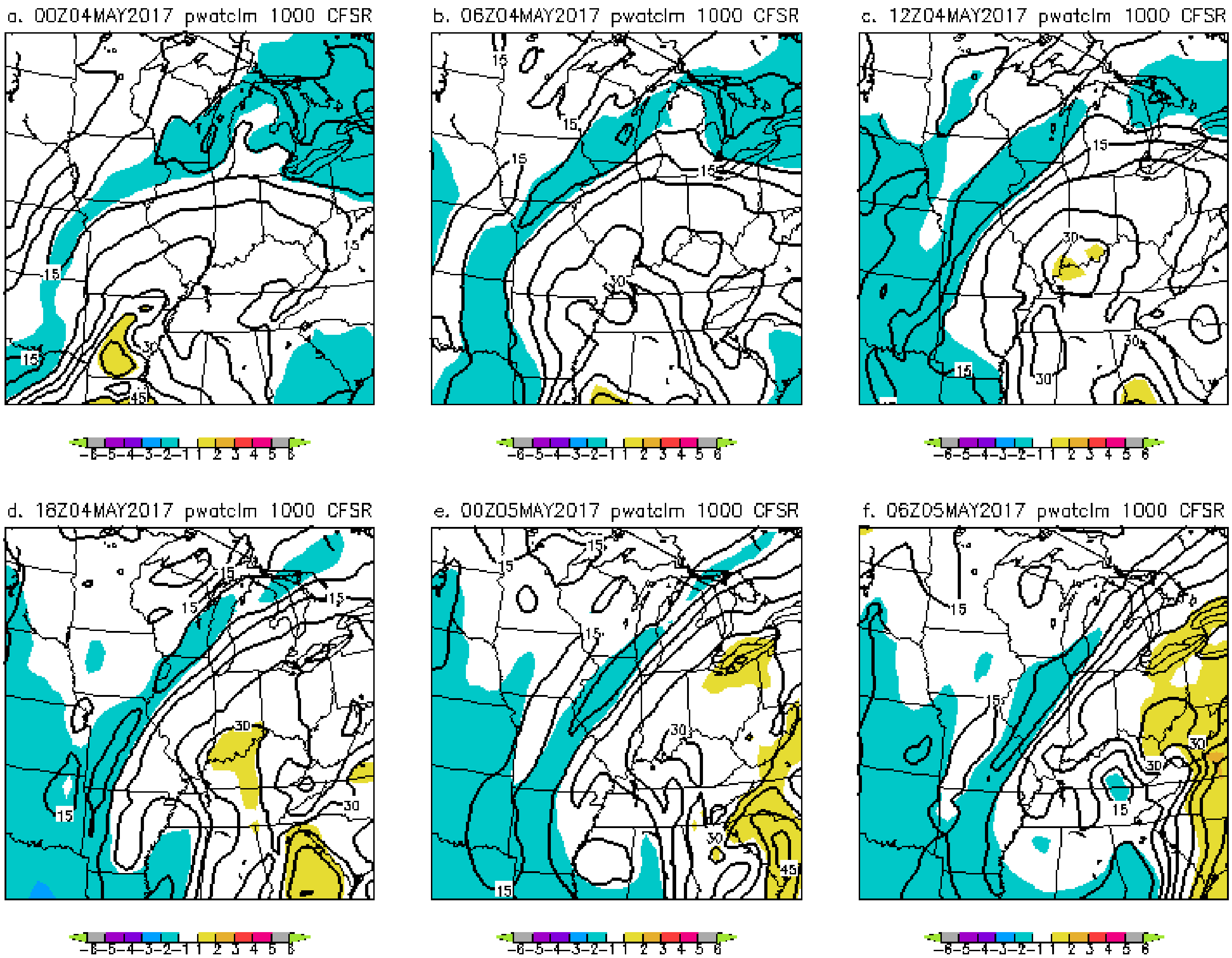


**Figure 9. As in Figure 8 except for precipitable water and precipitable water anomalies and for the 6 hour periods from a) 0000 UTC 4 May through f) 0600 UTC 5 May 2017.** [**Return to text.**]

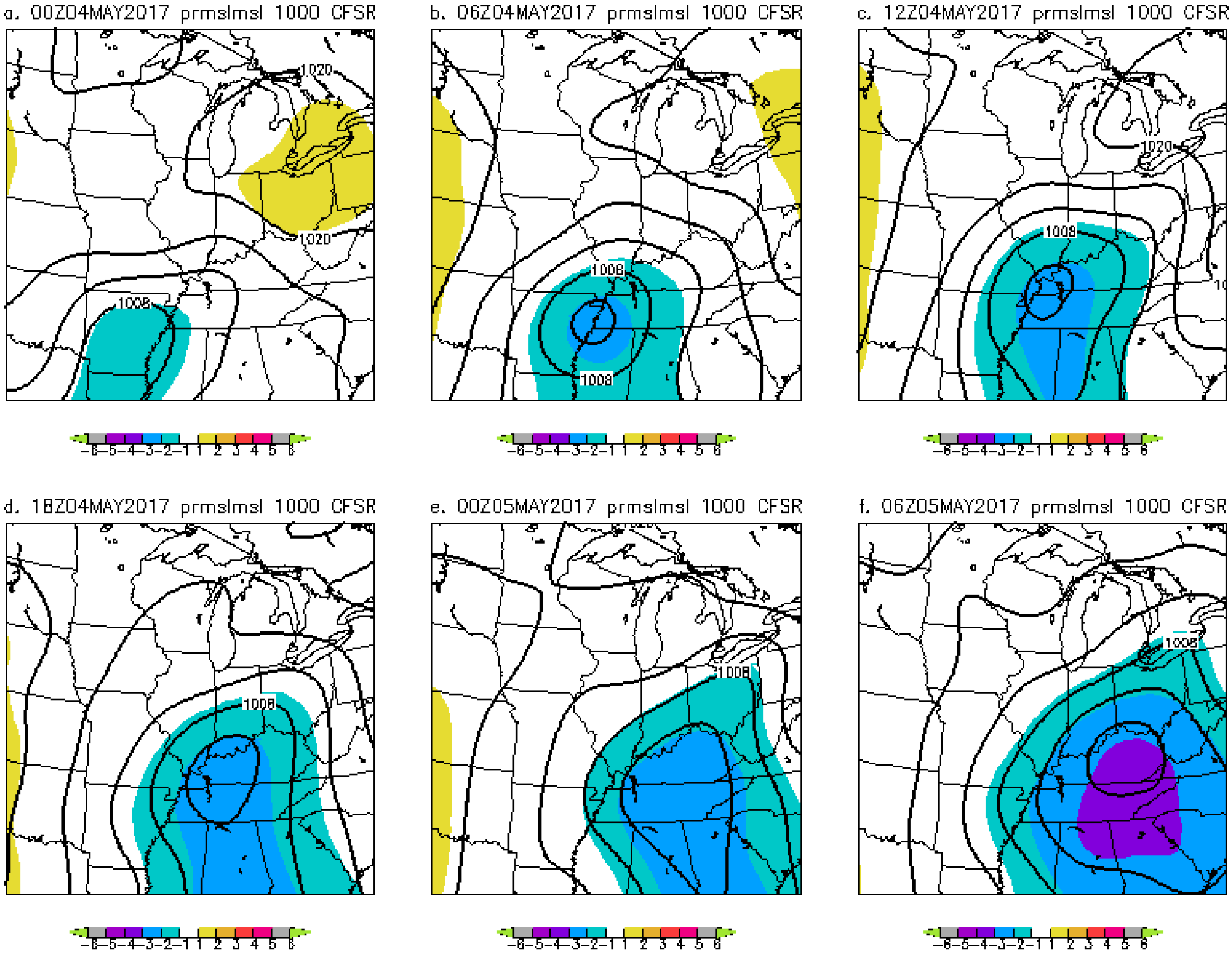


**Figure 10. As in Figure 9 except for mean sea-level pressure and pressure anomalies.** [Return to text.]

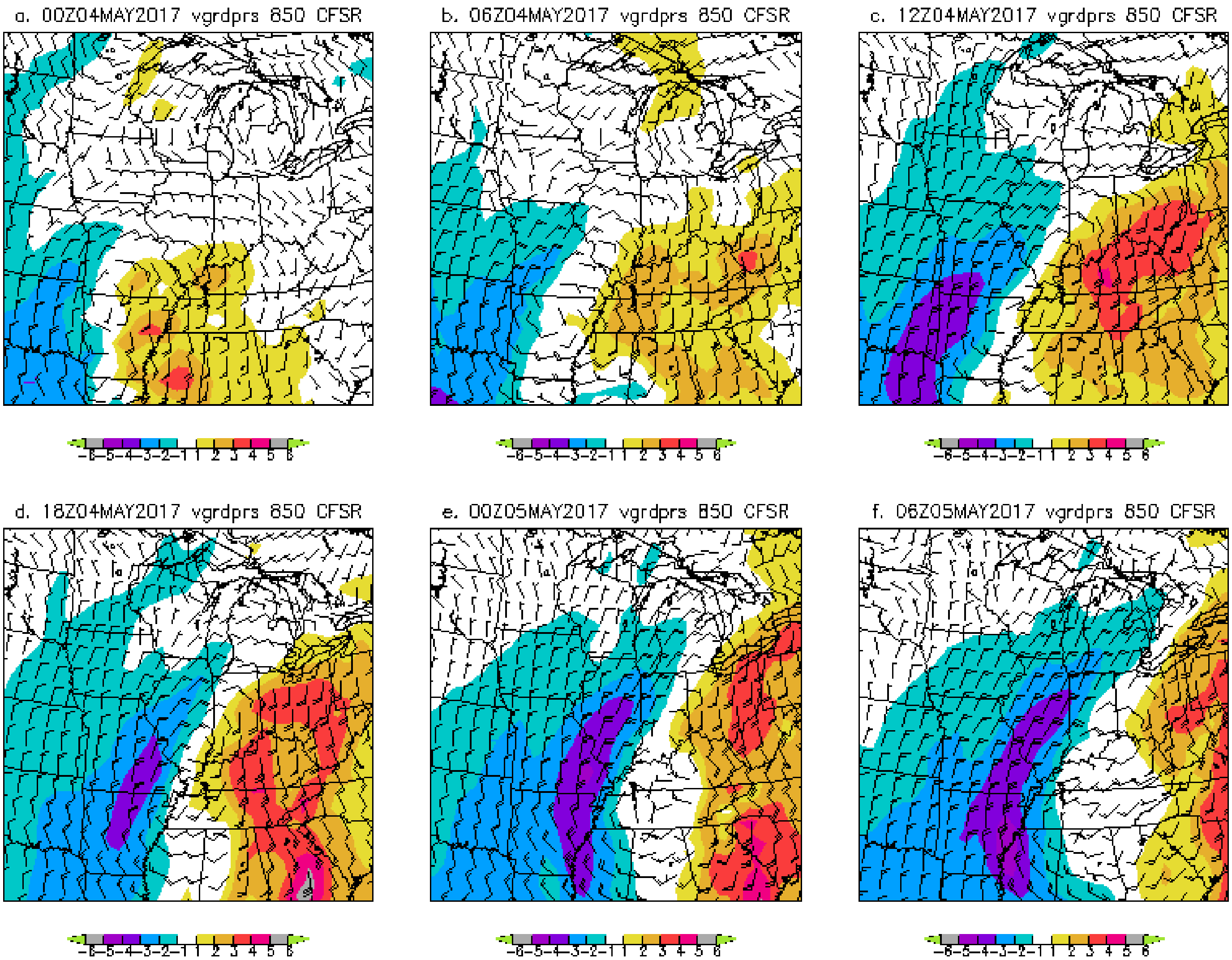


**Figure 11. As in Figure 7 except for the period of a) 0000 UTC 4 May through f) 0600 UTC 5 May 2017.** **Return to text.**

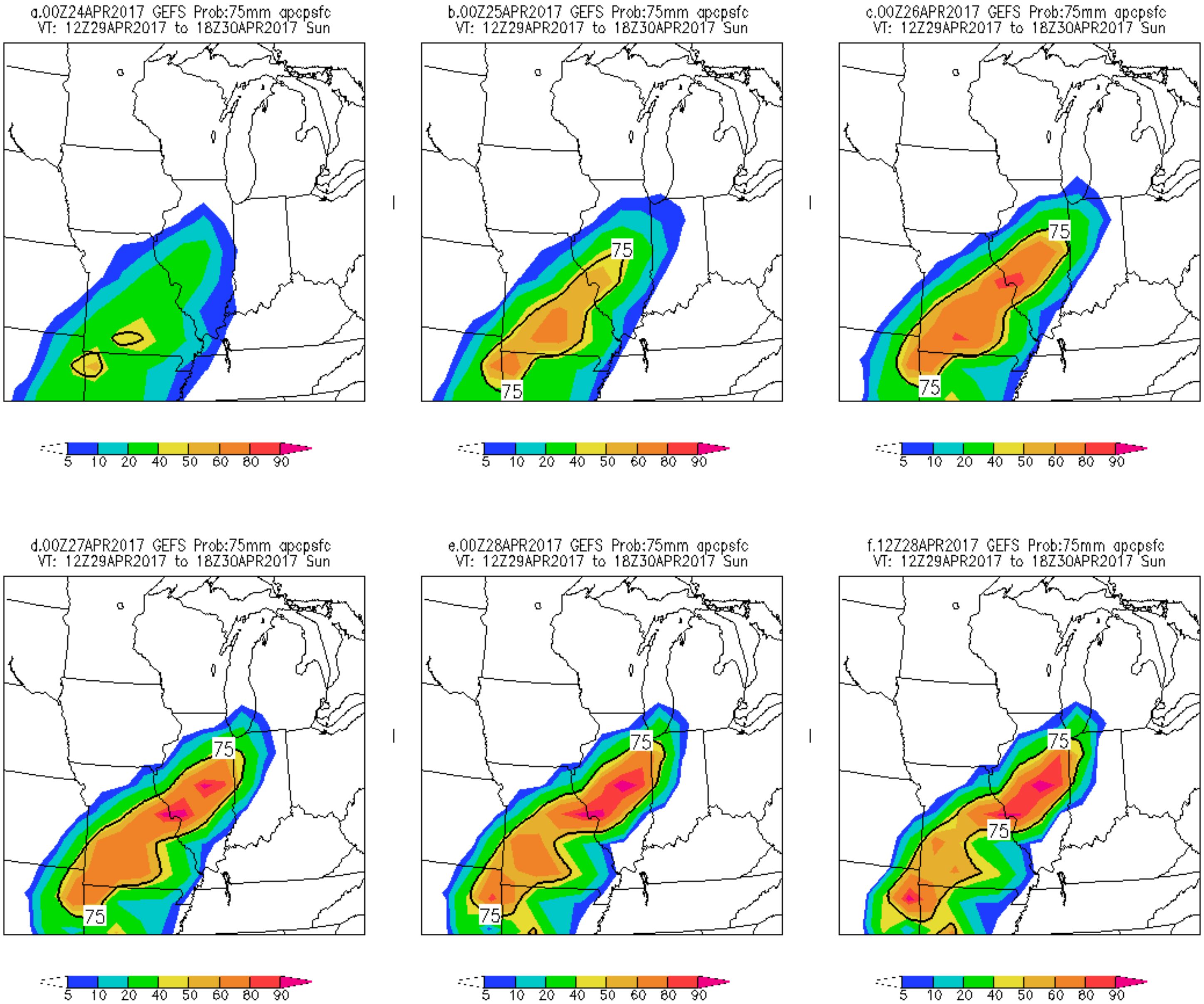


**Figure 12. NCEP GEFS forecasts for 75 mm or more QPF for the 30 hour period ending at 1800 UTC 30 April 2017. Data are from GEFS cycles from 0000 UTC a) 24 April, b) 25 April, c) 26 April, d) 27 April, e) 28 April and 1200 UTC 28 April 2017. Shading as in the color bar shows the percentage and the mean position of the 75 mm contour.** [Return to text.](#)

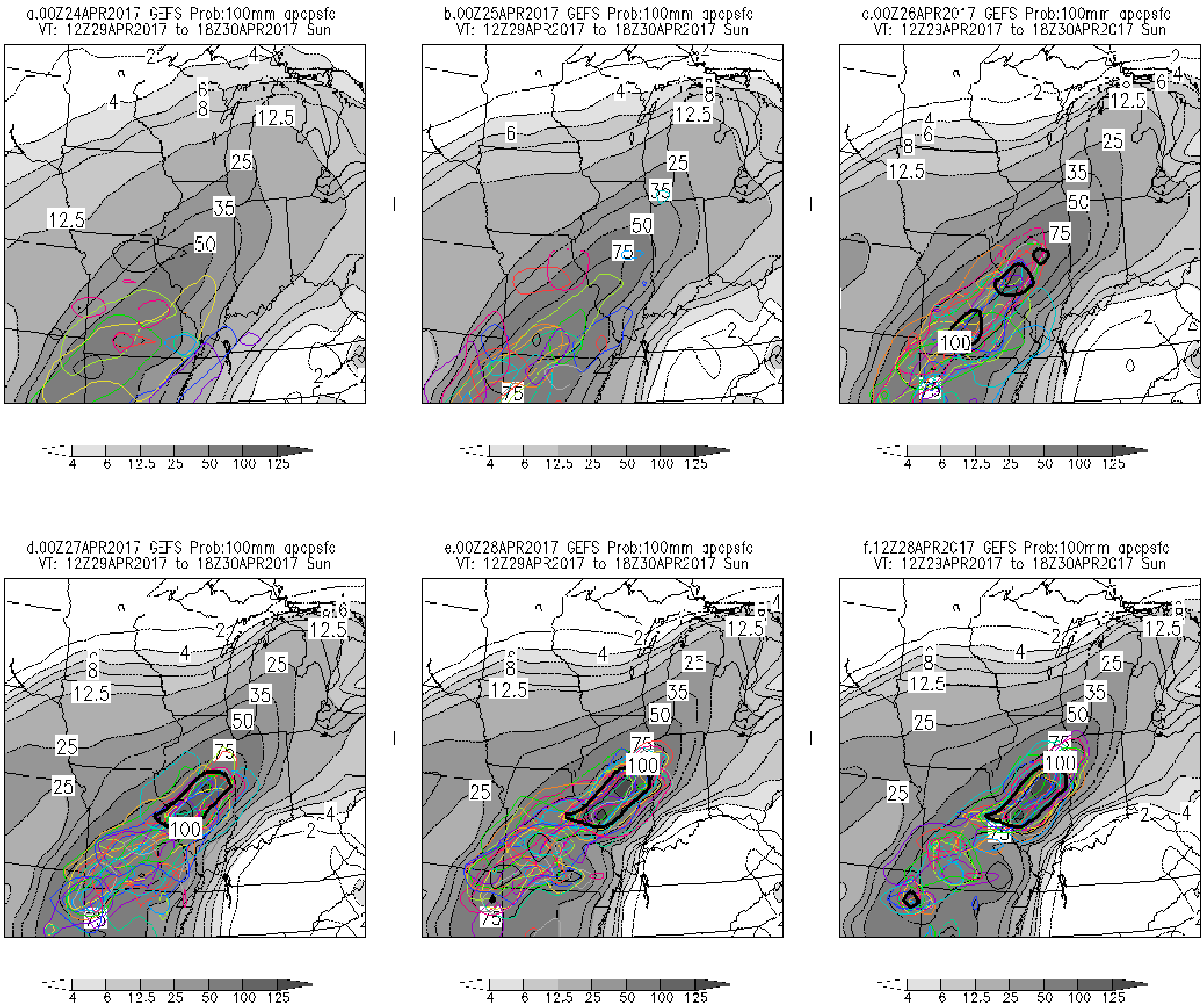


**Figure 13. As in Figure 12 except for the GEFS mean QPF from all 21 member and each members 100 mm contour of forecast. The thick black line is the ensemble mean 100 mm contour of present.** [**Return to text.**]

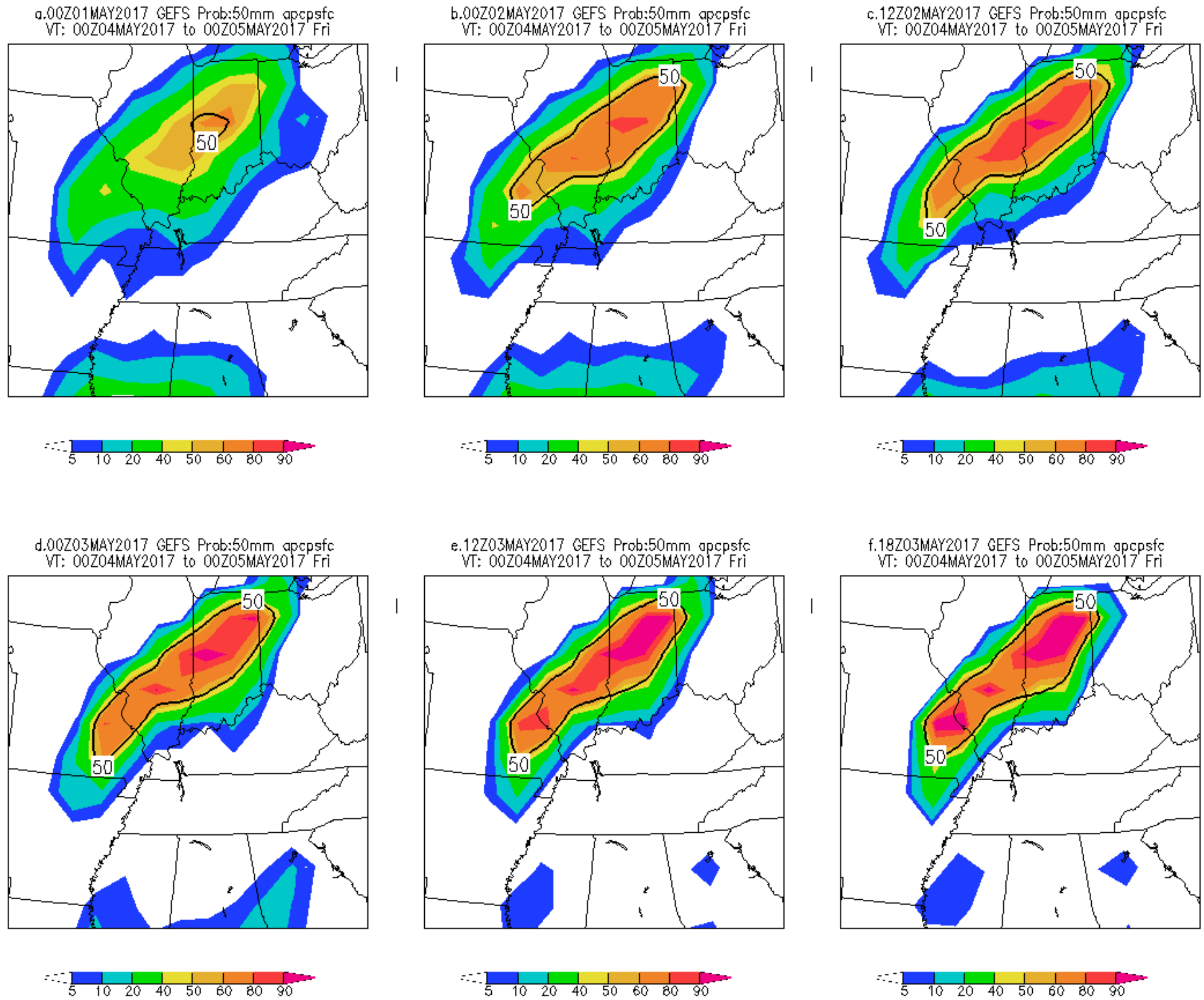


**Figure 14. As in Figure 12 except for the probability of 50 mm or more QPF from GEFS cycles initialized at 0000 UTC a) 1 May, b) 2 May, c) 3 May, and e) 1200 UTC 3 May, and f) 1800 UTC 3 May 2017.** **Return to text.**

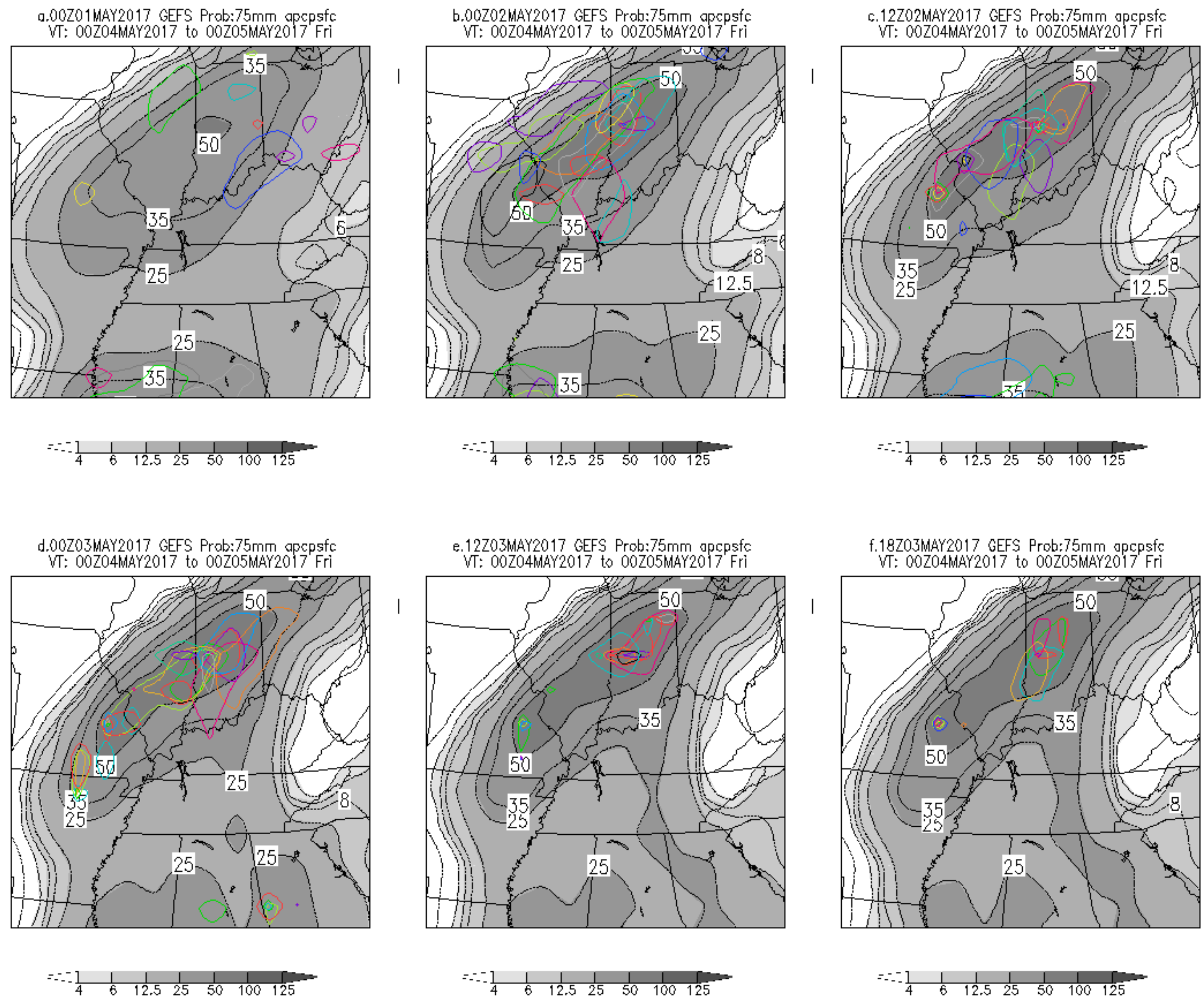


**Figure 15. As in Figure 14 except for the ensemble mean QPF and each members 75 mm contour of present.** **Return to text.**