Heavy rainfall associated with Hurricane Gustav
August-September 2008

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1. INTRODUCTION

Hurricane Gustav came ashore in Louisiana on 1 September 2008 approximately 72 miles southwest of New Orleans. The storm was rated a 2 on the Saffir-Simpson scale of hurricanes which puts winds in the 83 to 95kts range and central pressure in the 965-979 hPa range.

The storm produced considerable damage from winds, severe, weather and heavy rainfall. The rainfall centered over Louisiana from 0000 UTC 31 UTC August to 1200 UTC 2 September 2008 is shown in Figure 1. These data show the banded structure to the rainfall and that the heavy rainfall was focused to the east of the track of the surface circulation center. Maximum rainfall in these data was on the order of 200 to 250 mm, locally heavier amounts from point data were likely observed.

In addition to the heavy rainfall, the storm produced severe weather from embedded thunderstorms (Fig. 2). Similar to the heavy rainfall, the severe weather and tornado activity were generally confined to the feeder bands on the east side of the storm. It should be noted that this slow moving storm produced tornadoes in Louisiana on the 1, 2 and 3rd of September. But Figure 2 only display Storm Prediction Center reports from the 1st and 2nd of September.

This paper will document the pattern associated with the rainfall associated with hurricane Gustav along the Gulf Coast. This event will likely be studied extensively by others. Thus, the focus here is an overview of the rainfall, the pattern, to include associated anomalies, which produced the rainfall.

2. METHOD

Data for this study include re-analysis climatological data from the NCEP/NCAR global re-analysis project (GR: Kalnay et al 1996). The means and standard deviations were used to compute standardized anomalies, displayed in standard deviations from normal (SDs).

The 00-hour forecasts from the NCEP North American Meso-model (NAM) is used to provide an overview of the large scale pattern and the evolution of the rain event.

Ensemble data shown here were primarily limited to the NCEP GEFS and SREF. Displays
will focus on the forecasts of the pattern conducive for heavy rain the EPS probabilities of heavy rainfall.

The climatological data used to compute anomalies was restricted to those produced by the NCEP/NCAR GR data set (Hart and Grumm 2001). They will be presented in relation to both NAM and GEFS output.

All data was displayed using GrADS (Doty, et al 1995). Anomalies were computed as described Hart and Grumm (2001) and Grumm and Hart (2001). Shaded values show the standardized anomalies computed as:

\[ SD = \frac{F - M}{\sigma} \]  

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 \( \sigma \) is the value of 1 standard deviation at each grid point.

For brevity times are presented in the format of 01/1200 UTC which signifies 1 September 2008 at 1200 UTC. Forecasts from both model and EPS initial and valid times are presented in this format.

The 4km precipitation data was obtained from the multi-sensor State-IV data (Seo 1998 and Seo et al. 1999). The summed data was shown in Figure 1, zoomed over the Louisiana.

3. Results

i. large scale pattern

Figures 3-6 show the NAM 00-hour analysis of hurricane Gustav (hereafter HG) as it approached coastal Louisiana on 1 September 2008. At 01/0000 UTC (Fig. 3) the deep cyclone was analyzed south of Louisiana with central pressure under 970 hPa. The 850 hPa winds showed that the outer bands at 850 hPa were already affecting the Gulf Coast. Though not shown, 925 hPa winds showed a similarly strong low-level jet.

By 01/0600 UTC (Fig. 4), HG was still to the south in the NAM 00-hour analysis with the largest 850 hPa u-wind anomalies over southern Louisiana. The precipitable water (PW) fields showed a band like structure along the coast, the NAM data used here are not on the native grid and likely were unable to resolve the narrow bands on the north side of HG.

HG was close to land fall in the NAM 00-hour forecasts valid at 01/1200 UTC (Fig. 5) and was over southern Louisiana by 01/1800 UTC (Fig. 6). At both times, strong easterly winds and southeasterly winds were present over Louisiana with extreme low-level wind anomalies in both.
fields, exceeding -6SDs from normal. These high winds likely depict the coarse representation of bands about the storm and they line up closely to the severe weather reports and precipitation axis shown in Figures 2 & 1 respectively. The PW anomalies over the Gulf coast were extremely high, not unexpectedly, with the arrival of HG.

By 02/0000 UTC (Fig. 7) the surface pressure field indicated that HG had weakened after landfall and was likely a tropical storm. The storm still had large wind anomalies and PW anomalies on the north and east side of the storm. The NAM 850 hPa winds appeared to detect a band independent of the main circulation, in western Alabama and eastern Louisiana. There are hints of a second rainfall maximum in Figure 1 in this region and this band like feature may be related to some of the more northerly reports of tornadoes in a similar region in Figure 2 (upper panel).

By 02/0600 UTC the remains of HG were still in Louisiana (Fig. 8). The NAM showed a strong south-southeasterly wind on the east side of the storm with PW values over 60 mm and anomalies in the 4 to 5SD above normal range. The v-winds were still over 5.5 SDs above normal over Louisiana. The feeder band circulation appeared to dominate the wind field relative to the winds about the circulation center at this time. The winds also suggest a compact storm with a broad feeder band on the east side of the circulation center.

By 02/1200 UTC, the slow moving storm was still in Louisiana. The easterly jet was north of area the data were displayed in. However, strong southerly winds with large v-wind and PW anomalies were still present over Louisiana and adjacent Alabama. These data fields indicate a close parallel to the total rainfall ending at this time shown in Figure 1.

The remnants of HG were entering Texas by 02/1800 UTC (Fig. 9). Rain and strong inflow

Figure 3. NAM 00-hour forecasts valid at 0000 UTC 01 September 2008 showing a) 850 hPa winds and v-wind anomalies, b) 850 hPa winds and u-wind anomalies, c) mean sea-level pressure (hPa) and pressure anomalies, and d) precipitable water (mm) and precipitable water anomalies.
were still affecting most of Louisiana and though not shown, the entire southern Mississippi Valley.

By 03/0000 UTC the remnants of HG were over southwestern most Arkansas (Fig. 10). The easterly winds on the north side of the storm and wind anomalies were penetrating as far north as southern Missouri. The PW field suggested that a frontal boundary was located over Iowa with +1 to +2 SD anomalies associated with this feature. The higher PW anomalies with HG were still independent of the front system.

The independent circulation of the remnants of Hurricane Gustav, were clearly resolved by the NAM at 03/1200 UTC (Fig. 11). The storm showed a plume of high PW air over the central Mississippi valley and strong wind couplets with strong anomalies about the circulation center.

The SREF forecasts of the cyclone track were quite consistent over the 3 days and 4 forecast periods shown (Fig. 12). Other forecast cycles were quite similar (not

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"Figure 4. As in Figure 3 except valid at 0600 UTC 1 September 2008.

The easterly wind anomalies were maximized over Iowa and the southerly anomalies were maximized over Arkansas and Missouri. This storm had a long life span.

ii. Forecasts

The SREF forecasts are shown in Figure 12. The forecast show the mean sea-level pressure from select SREF forecast cycles from 0900 UTC 30 August through 0900 UTC 1 September. All the runs focused the track of the cyclone into Louisiana and the QPF. The SREF timing varied from landfall around 01/1200 to about 01/1800 UTC on 1 September 2008 (Fig. 12). In this case the SREF was consistent and the track proved to be quite good.

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1 NHC issued the last bulletin on Tropical Depression Gustav at 5 AM Tuesday 2 September 2008. It was down graded to a tropical storm in an advisory issued at 11 PM Monday 1 September 2008.
shown). It is unclear why these forecasts were so consistent and relatively accurate. Suffice to say that in this case the SREF, and other NCEP models for that fact (not shown) were quite consistent with the forecasts of Gustav.

The QPF’s (Fig. 13) provide by the SREF showed a high potential for over 4 inches of rainfall in Louisiana. These forecast show timing and location issues with each run. Note at shorter ranges and lower uncertainty the higher probability of 100 mm or more of QPF. A mean QPF of over 100 mm is quite high and forecasters knew that amounts would be considerably higher than forecast by the SREF. The overall pattern of the QPF was quite well matched to the pattern in the observations (Fig.1 and Fig. 14). Thus this was quite useful guidance in reference to the area to be affected by the heavy rainfall. Single model forecasts showed more details (not shown).

Figure 15 shows SREF forecasts initialized at 31/2100 UTC of Gustav valid at 01/1800 UTC and a 24 hour QPF showing the probability of 50 mm or more QPF. These data show that the SREF did a reasonable job approximating the strong winds, moisture surge, and cyclone location, relative to the verifying NAM analysis.

4. Conclusions

Hurricane Gustav came ashore in Louisiana on 1 September 2008 approximately 72 miles southwest of New Orleans during the morning hours of 1 September 2008. The category 2 storm on the Saffir-Simpson scale produced power outage and a wide range of severe weather over the Gulf Coast States. The storm, as analyzed by the NAM 00-hour forecasts, lingered over Louisiana for over 2 days as it slowly weakened.

The storm produced considerable damage from winds, severe, weather and heavy rainfall. Rainfall in portions of Louisiana exceeded 250 mm. The heavy rains were clearly focused in the strong southeasterly flow on the north and east side of the storm. The NAM analysis appeared to capture some sense of the bands on the northeast side of the storm. Both the rainfall data (Fig. 1) and the severe weather patterns (Fig. 2) imply the bands on the northeast side of the storm.

The SREF forecasts shown here indicated that the SREF reasonably forecast the landfall timing and location of Gustav. The SREF did a reasonable job approximating the winds and sure of high PW air into the Gulf States. The QPF, though under done by the ensemble mean, showed a reasonable pattern relative to observations. Clearly, at 32 to 45 km resolution, the SREF did an excellent job. In future SREF version, the model resolution will be improved and this could lead to improve forecasts of similar systems in the coming months and years.

5. Acknowledgements

6. REFERENCES


Figure 5. As in Figure 3 except valid at 1200 UTC 1 September 2008.
Figure 6. As in Figure 3 except valid at 1800 UTC 1 September 2008
Figure 7. As in Figure 3 except valid at 0000 UTC 2 September 2008.
Figure 8. As in Figure 3 except valid at 0600 UTC 2 September 2008.
Figure 9. As in Figure 3 except valid at 1800 UTC 2 September 2008.

Figure 10. As in Figure 3 except valid at 0000 UTC 3 September 2008 and projection changed to the Midwest from the Gulf Coast.
Figure 11. As in Figure 10 except valid at 1200 UTC 4 September 2008. Return to text.
Figure 14. As in Figure 1 except total rainfall over Louisiana and the central US for the time period from 0000 UTC 1 September 2008 to 1200 UTC 3 September 2008. Return to text.
Figure 12. SREF forecasts initialized at (top left) 0900 UTC 30 August 2008, (top right) 0900 UTC 31 August 2008, (bottom left) 2100 UTC 31 August 2008 and (bottom right) 0900 UTC 1 September 2008. Each image shows the time where members were indicating the potential landfall of Gustav. Upper panels show each member's 1016, 1008, 1000, and 992 hPa contour and the spread about the mean. Lower panels show the ensemble mean and the departure of this field in standard deviations from normal. Return to text.
Figure 13. SREF forecasts initialized at (top left) 0900 UTC 30 August 2008, (top right) 0900 UTC 31 August 2008, (bottom left) 2100 UTC 31 August 2008 and (bottom right) 0900 UTC 1 September 2008. Each image shows the accumulation and probability of 100 mm (4 inches) of QPF and the mean QPF with each member 100 mm and the ensemble mean 100 mm contour (mm) in the 24 hour ending period specified in each image. The 30 August forecasts were not long enough to end at 1200 UTC 3 September 2008. Return to text.
Figure 15. SREF forecasts initialized at 2100 UTC 31 August 2008 showing MSLP, 925 hPa winds, PWAT valid at 1800 UTC 1 September. The QPF is for the 24 hour period ending at 0900 UTC 2 September 2008.

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Figure 16. Summarized rainfall totals from Gustav based on station reports. Plotted by John LaCorte.