The southern express:  
Winter storm of 28-30 January 2010  
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1. **INTRODUCTION**

A storm system of Pacific origin tracked across the southern United States from 27-31 January 2010 (Fig. 1). This storm system produced a wide range of weather to include freezing rain and snow in from the Texas Panhandle eastward across Oklahoma to the Mississippi Valley, the Ohio Valley and the Mid-Atlantic region. This was a high impact storm in Texas and Oklahoma where ice dominated the event. There were about 14 reports of severe convective weather with storm system over Texas on the 28th of January.

The precipitation shield associated with the storm is shown in Figure 2. The precipitation is valid for the 24 hour periods from 1200 UTC 27 January through 1200 UTC 31 January. These data show the initial precipitation on the 27th over southwest Texas with more widespread precipitation on the 28th over Texas and Oklahoma (Fig. 2b) and then the precipitation shield moved eastward reaching the Mid-Atlantic region on the 29th and 30th. Figure 3 shows the snowfall over the eastern United States with the storm. Heavy snow was observed over the southern Ohio Valley eastward into Virginia. Several locations in Virginia received in excess of 12 inches of snowfall.

This storm was one of several southern stream storms which are often quite typical of an El Nino winter. Unlike recent El Nino winters, the winter of 2009-2010 has had the El Nino episode in the Pacific during a time of frequent high latitude blocking at high latitudes and a negative Arctic Oscillation (AO) and a negative North Atlantic Oscillation. The active southern stream combined with the negative AO and NAO typically helps produces winter storms containing snow and wintry precipitation (Hirsch et al 2000).

The data in Figure 1 suggest that there were large positive pressure anomalies associated with the surface anticyclone. Previous studies on ice storms and ice storms in the southern United States showed the importance of low-level cold air and anticyclones (Gyakum and Roebber 2001 and Baker 1960). The value of anomalies in predicting winter storms was shown by Stuart and Grumm (2006) and more recently for significant weather events in the western United States by Graham and Grumm (2010). Using the methods described by Hart and Grumm (2001) this event will be presented using climatic anomalies to define areas of potentially significant winter weather.

This paper will provide an overview of the winter storm of 28-30 January 2010. The focus is on the larger scale setting and ensemble forecasts of the event.

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:

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

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.
Model and ensemble data shown here were primarily limited to the GFS and GEFS. 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 31/0000 UTC signifies 31 January 2010 at 0000 UTC.

3. RESULTS

i. Synoptic scale pattern

The evolution of the surface pattern for the event was shown in Figure 1. These data showed the cyclone along the coast of California move inland on the 27th (Fig. 1a) and across the Rocky Mountains by 29/0000 UTC (Fig. 1e). Then, the storm system moved eastward along the Gulf Coast and then up the East Coast (Figs. 1f-1i).

The 500 hPa heights with the system are shown in Figure 4. Similar to the surface data, these
data show a relatively strong upper-level wave with 1-2SD below normal height anomalies move onshore, cross the southern Rocky Mountains and then weaken as it moved into a relatively persistent trough in the eastern United States. Thus, from the perspective of a strong surface cyclone, this was not an impressive system.

Closer inspection of the data in Figure 1 reveal that there was a strong continental anticyclone with 1 to 3SD above normal mean sea-level pressure anomalies associated with it. The strong anticyclone and the weak cyclone to the south produced a strong gradient and implied a strong low-level easterly jet over the southern United States. This pattern is consistent with the pattern of several historic southern United States ice storms to include the northern Alabama ice storm of 1960 (Baker 1960).

**ii. Regional pattern and anomalies**

The surface evolution in 6-hour periods from 28/1800 UTC through 30/1800 UTC is shown in Figure 5. These data a focused along the southern portion of the United States to show the details associated with the storm. The corresponding 850 hPa winds and u-wind anomalies are shown in Figure 6.

The 850 hPa winds and u-wind anomalies (Figure 6) show that were strong negative u-wind anomalies north of the 850 hPa cyclone and surface cyclone (Figs. 5a & 6a). The u-wind anomalies were there lowest at 28/1800 UTC when there were -5SD anomalies over the Texas Panhandle. As the cyclone lifted out to the east, the u-wind anomalies tracked over Oklahoma and into southern Kansas. The heaviest precipitation fell south of this strong 850 hPa wind anomaly associated with an anomalous low-level jet (LLJ). This strong LLJ redeveloped over Missouri and moved over the Ohio Valley (Figs. 6f-h). The strong LLJ redeveloped along the Mid-Atlantic coastal zone and was clearly visible by 30/1800 UTC. The heavy snow areas were relatively well aligned with the strong LLJ falling near and south of the u-wind anomaly regions.

Though not shown, but implied from Figure 4, there was a strong 250 hPa jet with a strong jet entrance region north and east of the evolving surface cyclone.

The 850 hPa temperatures are shown in Figure 7. These data reveal a warm layer at 850 hPa over central and eastern Oklahoma at the onset of precipitation (Figs. 7a-c). Despite the low-level cold air, 850 hPa temperatures were 2-6°C over the region, thus the initial freezing rain over that region. By 29/1200 UTC, the 850 hPa temperatures dropped 0 to -4°C over the region.

Some of the precipitation for the period ending at 29/1200 UTC (Fig. 2) fell as snow over eastern Oklahoma and all the precipitation after 29/1200 UTC, 4-8mm fell as snow. The 850 hPa temperature field showed that temperatures of 0 to -6°C dominated the Ohio Valley and most of the Mid-Atlantic region as the precipitation shield moved eastward. Thus another southern snow storm with 3-6 inches of snowfall in and around Louisville, Kentucky and 6-13 inches of snow in and about Richmond Virginia (Fig. 3).

**iii. GEFS forecasts**

Figures 8-11 show the GEFS forecasts from 9 forecast cycles for the event. The MSLP forecasts (Fig. 8) all showed the surface wave with similar anomalies but varying locations and degrees of intensity. All these forecasts showed the critical anticyclone with pressure anomalies to the north of the surface wave. The anticyclone was relatively consistently predicted though it had a more banana shape in later forecasts.

Figure 9 is valid at 1200 UTC 29 January and shows the low-level jet over Oklahoma and Texas. Earlier forecasts had a stronger jet than latter forecasts suggesting good agreement amongst the members of the ensemble. Some of the differences related to timing of the period of stronger winds.

Figure 10 shows the 850 hPa winds a valid at 30/1200 UTC. This time was chose as it was
close to when the snow had moved into the Ohio Valley. In this case, later forecasts showed a stronger low level jet and larger u-wind anomalies. The track of the 850 hPa cyclone was similar in the forecasts but the details of the LLJ varied considerably.

Figure 11 shows the total QPF forecast by each GEF run. The overall pattern of QPF is quite similar to between runs with differences in the details of where (and when) the heaviest QPF would fall. However the larger scale pattern of the QPF shield reflected the similarities in the evolution of the broader cyclone and the attendant circulations about the cyclone center. The persistent tight gradient in the QPF along its northern edge is quite remarkable as is the run-to-run variability in where the heaviest precipitation would fall.

The verifying QPE in Figure 12 shows that the pattern was well predicted but the details of where the heaviest QPF would fall were of limited value. The heavy rains, over 64 mm in Texas is difficult to compare to all forecasts due to the GEFS initialization being after the time in Figure 12. However, forecasts that overlapped that time were showing over 32 mm of QPF in that same region. The heavier QPE over Alabama and Georgia (Fig. 12) was not so well anticipated by the GEFS, the convection that developed was poorly predicted in this course EFS. The northward surge of the 8 and 16mm contours in the QPE relative to the QPF played significant role in the heavy snowfall forecast issues in the Richmond to Baltimore corridor.

4. CONCLUSIONS

A Pacific storm system moved across the southwestern United States, and then off the Mid-Atlantic coast producing a winter storm from New Mexico eastward to Delaware. A strong anticyclone to the north provided cold air and an enhanced baroclinic zone from Oklahoma to Maryland. To the south, the system produced heavy rains and along the northern edge the system produced snow. In the transition zone, freezing and ice pellets provide for a significant icing event from the Texas Panhandle, across Oklahoma and into Arkansas. Overall, the anticyclone and weak cyclone were relatively well predicted by the NCEP GEFS.

The strong anticyclone in Figure 1 is a consistent feature found in many historic ices storms (Gyakum and Roebber 2001). In this instance, a strong anticyclone pushing low-level cold air similar to the pattern of several historic southern United States ice storms to include the northern Alabama ice storm of 1960 (Baker 1960). The strong LLJ (Fig. 6) south of the anticyclone was a good indicator for the regions receiving snow, freezing rain, and ice pellets. Stuart and Grumm (2006) noted the proximity of the anomalous LLJ and heavy snow in winter storms. The strong LLJ and anomalous easterly winds and the strong anticyclone were relatively well predicted by the NCEP GEFS (Figs 8, 9, 10). Thus a good synoptic signal was present supporting precipitation in the cold air.

Tracking the 850 hPa low center (Figs 6, 9, & 10) clearly showed that the old Younkin rule (Younkin 1968) worked well for the snow associated with this event. Clearly the heavy snow was just a few degrees of latitude north of the 850 hPa low tracks, in close proximity to the most significant 850 hPa u-wind anomalies. This event was another good example of the value of easterly wind anomalies in defining areas of heavy precipitation and possible snowfall north of the 850 hPa low track.

The GEFS QPFs showed some problems with the areas to received heavy rainfall and QPF relative to where the precipitation was observed. Figures 11 and 12 clearly illustrate this point. Ultimately, the QPF was under predicted in the Texas, Alabama, and Georgia. No probabilities or SREF data were shown so it is unclear if some EFS members predicted significantly higher amounts. Farther north, in Virginia to New Jersey, the GEFS did not bring the axis of the 8 and 16mm contours far enough north and since this QPE fell as snow there were forecast issue associated with snow and snow amounts in this region.

The sharp northern edge of the QPF was a problem. In the Louisville area, forecasts varied considerably. At times the GEFS suggested the
potential for heavy snowfall and then backed off. Portions of the region, mainly south of the City itself saw heavy snow. Thus the uncertainty in tight gradient situations was considerable forecast issue.

Three plume diagrams for Louisville, KY from the GEFS are shown in Figure 13. The data show that earlier runs of the GEF threatened to produce 0.30 to 1.38 inches of liquid and most members showed snow from the 27/0000 UTC forecast cycle. The mean was around 0.61 inches. A good 3 to 10 inch range with high probability of 4-8 inches was probably a good first guess. But 24 hours, (28/0000 UTC) later the GEFS backed off the forecast and the PDF suggested about 0.40 inches in the median and a 0.15 to 0.75 range. As the event drew nearer, the QPF and snow amounts continued to drop suggesting a 0.20 inch event with perhaps 4 inches of snowfall using a 10:1 ratio.

Overall, on a synoptic scale this was a well predicted event. However, the details, especially near regions of tight gradients remained elusive, event at relatively short ranges. Uncertainty in weather forecasting is an unrelenting challenge to those issuing forecasts to the public. Examining the sharp edge to the snowfall (Fig. 14) one can see how gradients can be difficult areas to distinguish between snow and no snow, let alone heavy snow.

5. Acknowledgements

Thanks to John LaCorte for snow fall maps. Mark Jarvis (LMK) for snowfall data in the Ohio Valley. Mike Dangelo retrieved MODIS images to examine for the case.

6. REFERENCES


Figure 2. As in Figure 3 except accumulated 24 hour precipitation for the periods ending at 1200 UTC a) 18 January, b) 19 January, c) 20 January and d) 21 January 2010.


Figure 3. Snowfall in inches for the event of 29-30 January 2010. Upper image shows the snow over the eastern United States and the lower panels show the snowfall in the Louisville and Washington DC areas. No West Virginia snowfall data was easily accessible thus the hole. The MODIS images show the eastern snowfall quite well.
Figure 4. GFS 00-hour forecasts of the 500 hPa heights (m) and height anomalies (standard deviations) from GFS initialized at a) 0000 UTC 27 January, b) 1200 UTC 27 January, c) 0000 UTC 28 January, d) 1200 UTC 28 January, e) 0000 UTC 29 January, f) 1200 UTC 29 January, g) 0000 UTC 30 January, h) 1200 UTC 30 January, and i) 0000 UTC 31 January 2010. Return to text.
Figure 5. As in Figure 1 except showing mean sea level pressure from the GFS every 6-hours from a) 1800 UTC 28 January through i) 1800 30 January 2010. Return to text.
Figure 6. As in Figure 5 except for 850 hPa winds (kts) and u-wind anomalies. Return to text.
Figure 7. As in Figure 5 except 850 hPa temperatures and temperature anomalies for the period a)-i) of 1800 UTC 28 January through 1800 UTC 30 January 2010. Return to text.
Figure 8. GEFS forecasts of mean sea level pressure and anomalies valid at 0000 UTC 30 January 2010 from forecasts initialized at a) 1800 UTC 26 January, b) 0600 UTC 27 January, C) 1800 UTC 27 January, d) 0000 UTC 28 January, e) 0600 UTC 28 January, f) 12Z 28 January, g) 1800 UTC 28 January, h) 0000 UTC 29 January and i) 0600 UTC 29 January 2010. Return to text.
Figure 8. GEFS forecasts of mean sea level pressure and anomalies valid at 0000 UTC 30 January 2010 from forecasts initialized at a) 1800 UTC 26 January, b) 0600 UTC 27 January, C) 1800 UTC 27 January, d) 0000 UTC 28 January, e) 0600 UTC 28 January, f) 12Z 28 January, g) 1800 UTC 28 January, h) 0000 UTC 29 January and i) 0600 UTC 29 January 2010. Return to text.
Figure 9. As in Figure 8 except 850 hPa winds and u-wind anomalies valid at 1200 UTC 29 January 2010. Return to text.
Figure 10. As in Figure 8 except 850 hPa winds and u-wind anomalies valid at 1200 UTC 30 January 2010. Return to text.
Figure 11. As in Figure 8 except total QPF (mm) for the period ending at 0000 UTC 31 January 2010. Return to text.
Figure 12. As in Figure 2 except showing total precipitation from 12Z28JAN2010 to 12Z31JAN2010.
Figure 13. GEFS parallel plumes of precipitation type for a point near Louisville, KY from forecast issued, from top to bottom, at 0000 UTC 27, 28, and 29 January 2010. Gray lines show the 6-hour instantaneous precipitation. Colored lines show the accumulated precipitation by dominant precipitation type as per the color code to the left of the images which show the mean, and range of precipitation by type. Return to text.
Figure 14. MODIS images showing sharp snow line and northern edge of the eastern US portion of the snowfall on 29-30 January 2010. Return to text.