13B.2 14 SEPTEMBER 2008 OHIO VALLEY HIGH WIND EVENT ASSOCIATED WITH THE REMNANTS OF HURRICANE IKE

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1. Overview

On 13 September 2008, Hurricane Ike slammed into the Gulf Coast of Texas near Galveston Island. The hurricane brought destruction to the coast with an immense storm surge and wind speeds near 97 kts. Ike quickly moved inland across eastern Texas and then into Arkansas and southeast Missouri by the early morning hours of 14 September 2008. As the system turned extratropical, it interacted with a mid-latitude trough and surface cold front as it headed into the Ohio Valley. Destruction was once again wrought as hurricane force wind gusts blasted Kentucky, Indiana, and Ohio.

In the following sections, the synoptic setup, model and operational forecasts, verification, and impact will be discussed. Furthermore, suggestions for improving forecasts and services will also be talked about.

2. Synoptic Setup and Model Forecasts

During the early morning hours of 14 September 2008, Tropical Storm Ike was moving through eastern Texas and beginning to weaken. Ike became extratropical around 12 UTC 14 September as the system raced northeast across Arkansas and into southeast Missouri (Berg 2009). The remnants of Ike began interacting with a trough and accompanying surface cold front in the mid-Mississippi Valley.

The remnants of Ike were forecast to ride northeastward along this front across southern Illinois, central Indiana, northern Ohio and Pennsylvania before merging with another system across southern Canada. Both the NAM12 and the GFS40 operational models forecast Ike to fill or hold steady with a minimum surface pressure around 995 mb as the low moved across the Ohio Valley. Both models forecast a band of prefrontal precipitation across central Kentucky between 18 UTC 14 September and 00 UTC 15 September (Fig. 1).

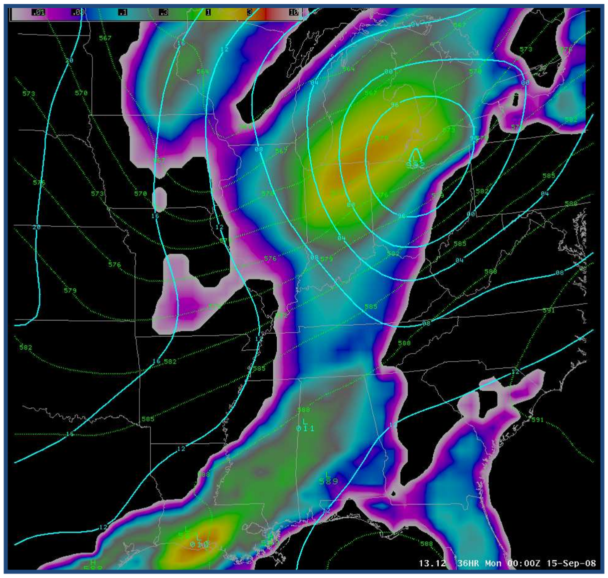

Figure 1. The operational GFS precipitation (shaded), MSLP (blue) and 500 mb heights (green) at 00 UTC 15 September 2008 show a convective line across the Ohio and Tennessee Valleys.

The 925 mb to 850 mb wind forecasts for the 00 UTC 14 September model runs showed a wind speed maximum of 50 to 60 kts across southeast Missouri and western Kentucky at 12 UTC 14 September. The maximum was forecast to move northeast across central Indiana and clip the Ohio River Valley by 18 UTC 14 September before rapidly moving into the eastern Great Lakes by 00 UTC 15 September. The GFS appeared to be the more aggressive model with a larger bullseye of 50 to 60 kt winds extending into north-central Kentucky, while the NAM had a bullseye north of the Ohio River across south-central

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Indiana. Forecast soundings also showed the possibility of the boundary layer mixing to around 850 mb with maximum mixed layer wind gusts near 60 kts, as shown in Fig. 2. The NAM and GFS soundings showed a peak surface wind gust of 59 kts and 58 kts, respectively, with sustained surface winds around 40 kts.

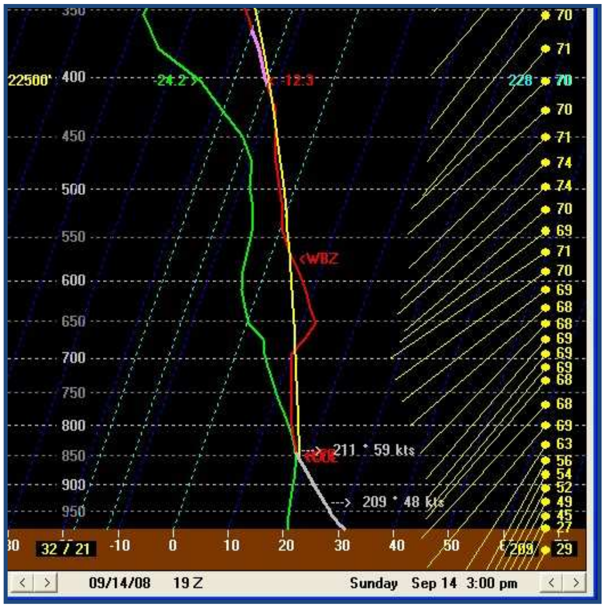

Figure 2. The NAM12 BUFKIT sounding from 06 UTC 14 September 2008 showed a mixed layer extending from the surface to 850 mb, translating maximum gusts of around 60 kts to the surface.

3. Operational Forecast

Operational forecasts around the region followed model forecasts fairly closely. The expectation was that the low associated with Ike would remain steady or fill as it traveled to the northeast. Thunderstorms were also initially forecast and the Storm Prediction Center had a slight risk of severe weather in its Day 1 Convective Outlook from Tennessee through central Kentucky and into the Great Lakes and western New England (Fig. 3). Wind Advisories were issued by National Weather Service offices in the region, including Paducah, KY; Louisville, KY; Indianapolis, IN; and Wilmington, OH. These advisories were either issued in the afternoon the day before the event or during the midnight shift leading up to the event. The advisories were then upgraded to High Wind Warnings, but not until the high wind event was already underway.

4. What Really Happened

a. Observed Weather

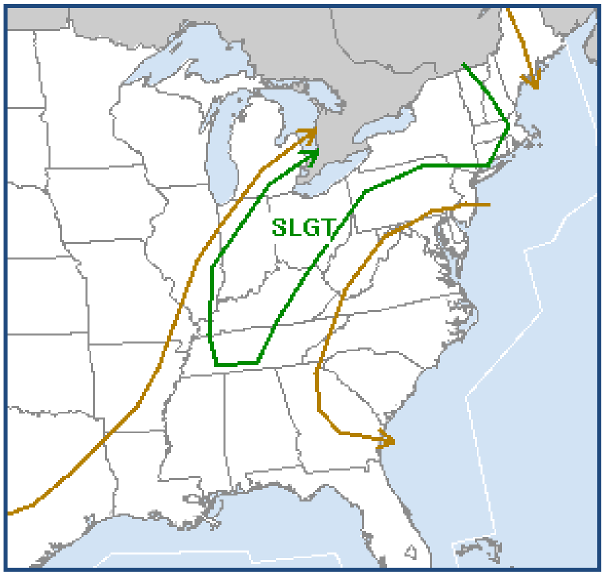

Figure 3. The Day 1 SPC Convective Outlook issued 13 UTC 14 September 2008. Convection with the possibility of severe thunderstorms was expected ahead of and along the surface cold front as the low-level jet associated with Ike increased.

While the models were correct in forecasting the surface low associated with Ike remaining at a near constant pressure, they were incorrect in their assessment of the strength of that low. The models consistently forecast a low pressure near 996 mb. However, on average, the minimum surface pressure of Ike as the system moved through the Ohio Valley was closer to 989 mb. Therefore, as the low tracked across the region, locations saw pressure falls of around eight to ten millibars over three hours.

By 11 UTC 14 September, upstream observations were already showing wind gusts up to 43 kts across northeast Arkansas and southeast Missouri when the atmosphere had not yet reached full mixing potential. On the KLVX radar located at Fort Knox, KY, the vertical wind profiler (VWP) was showing a low-level jet of 60 to 70 kts at three to four thousand feet by late morning. However, United Parcel Service (UPS) AMDAR, also known as ACARS, soundings showed a substantial capping inversion from around 925 mb to 850 mb, which hence kept the higher winds several thousand feet off the ground. It should be noted that several studies have found AMDAR data to be reliable and comparable to National Weather Service radiosonde data (Benjamin and Schwartz 1999). By 17 UTC 14 September, the low-level jet was lowering and measured 60 kts at two thousand feet on the KLVX VWP.

It should also be noted that very little, if any, precipitation fell across Tennessee and Kentucky, with the bulk of the precipitation falling across central and northern Indiana near the actual surface low. Therefore, the model forecasts of prefrontal precipitation were not realized for much of the slight risk area as the capping inversion shown by the AMDAR soundings suppressed convective development.

Visible satellite imagery showed that breaks in cloud cover were developing just ahead of the surface cold front (Fig. 4). Given that the expected precipitation did not fall, the potential for mixing out the inversion shown by earlier AMDAR soundings was increasing. The partial clearing, in conjunction with the cold front and the increased low-level jet due to the surface low and associated pressure rise/fall couplet (Fig. 5), proved critical in producing maximum wind gusts of 65 kts at Louisville, KY, 73 kts just north of Cincinnati, OH, and 55 kts at Indianapolis, IN. Many other locations in the Ohio Valley reported wind speeds in excess of 50 kts, which met high wind warning criteria. Most of these wind gusts occurred just ahead of the cold front in areas of partial clearing where surface heating was maximized.

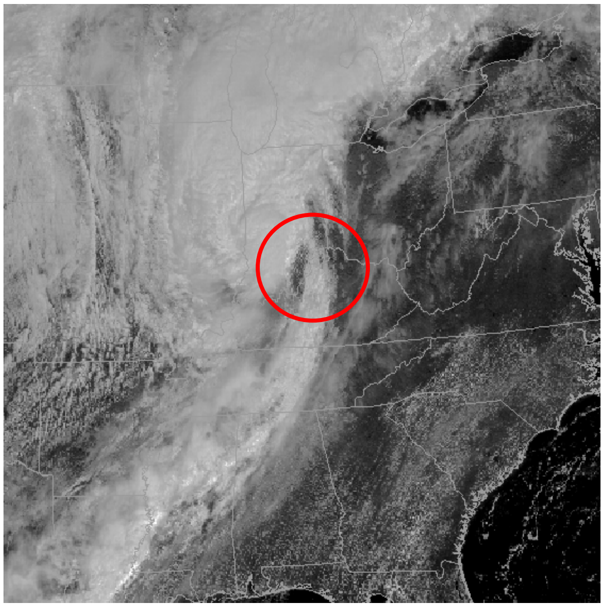

Figure 4. Partial clearing from Louisville to Cincinnati is indicated by the circle. Surface observations showed a 65 kt maximum wind gust as the clearing passed over the Louisville airport, and then over 70 kts an hour later near Cincinnati.

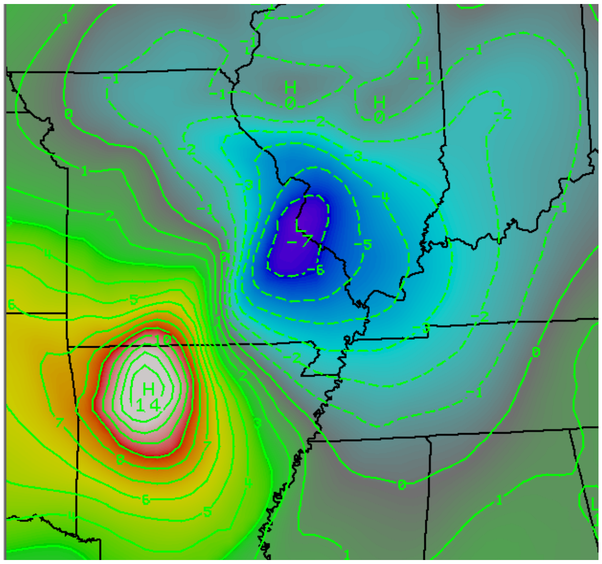

Figure 5. This 3-hour pressure change chart from the MSAS based on NWS observations shows a strong rise/fall pressure couplet with a maximum pressure fall of around 7mb just ahead of Ike.

b. Societal Impacts

This high wind event proved to be not only rare, but one of the most costly and devastating events the Ohio Valley has ever experienced. Not since the April 3-4, 1974 tornado outbreak had this region seen this magnitude of damage and power outages.

Regional damage estimates were nearly one and a half billion dollars, with Indiana suffering \$60 million in damages, Kentucky incurring nearly \$200 million in damage, and Ohio seeing damage estimates of nearly one billion dollars alone. This was Ohio's second most expensive storm, outdone only by the 1974 Xenia, OH tornado (Berg 2009).

Power outages were widespread and for some customers, lasted up to two weeks. Nearly one million customers lost power in Kentucky, making it the largest power outage in state history (only recently outdone by the January 27-28, 2009 ice storm), representing nearly 75% of Louisville Gas and Electric's customer base. At one point during the event, Interstate 65 near Louisville was shut down in both directions due to fallen trees and debris on the roadway. The Louisville International Airport was also shut down and the air traffic control tower was evacuated for a time when wind speeds over 85 kts were measured at the tower, just 220 feet off the ground.

The damage was worse in Ohio where nearly two million customers lost power, the most ever for the Cincinnati, Columbus, and Dayton metro areas and the second largest outage ever statewide. Two-thirds of Duke Energy's customers were without power, the most in their history. In Indiana, nearly 100,000 customers lost power.

Sadly, 12 fatalities were attributed to the storm. Most of these were from falling tree branches either during the storm or from clean-up efforts soon after the storm. One fatality was reported in Kentucky along with 46 injuries (as noted by the Louisville, KY *Courier-Journal*), five fatalities occurred in Indiana with seven injuries, and six fatalities and eight injuries were reported in Ohio (*Storm Data September 2008)*.

6. Why Was Ike Under-forecast?

The remnants of Hurricane Ike caused arguably some of the worst damage ever experienced across the Ohio Valley. So why did such an extreme event occur, and why was it perceived as being so largely under-forecast? There are three main reasons that may explain why this destructive event was so under-forecast.

a. Rarity and timing of event

Perhaps most of the blame, from a public perspective, could be attributed to the rarity and timing of this event. The remnants of Ike, as stated previously, were responsible for the most downed trees and power lines ever experienced in two major metro areas in the Ohio Valley: Louisville and Cincinnati. Thus, this exceptional 100-year wind event was extremely difficult if not nearly impossible to forecast accurately.

Furthermore, the wind event occurred on a Sunday, beginning in the late morning hours. Many families at this time may have been involved in church activities or outdoor events, as there were many festivals occurring that day. Either way, it is speculated that less people watch television on weekend mornings than on weekday mornings. Since the majority of the public receives their weather information via television, many people may have been completely unaware of the imminent high wind event.

b. Models under-forecast the strength of Ike

From a forecast perspective, this event may have been under-forecast because the short-range computer models under-forecast the strength of the central pressure of the system. The NAM, GFS, and locally-run WRF model all indicated that the central pressure of the low associated with Ike would remain unchanged around 996 mb as it tracked northeast. While the pressure remained fairly stable, it was actually measured to be closer to 989 mb, dropping eight to ten millibars in ten hours at any given location as the low tracked over an area. This pressure fall center led not only to a tighter pressure gradient and but also to a significant isallobaric wind that was approximately lined up with the low-level jet, thus producing higher gradient winds and wind gusts.

c. Convection did not materialize

Another main reason this system was so tricky to forecast was that little if any of the expected convection actually developed. This allowed low-level lapse rates to become dry adiabatic, permitting surface winds aloft to mix down. The only rain showers that did develop were located close to the actual surface low in central and northern Indiana, and along the cold front in south-central Kentucky and middle Tennessee (Fig. 6). The convection was inhibited because of a strong capping inversion around 5,000 feet in the UPS ACARS soundings from Indianapolis and Louisville (not shown). The lack of convection over areas surrounding the Ohio River was key in allowing breaks in cloud cover.

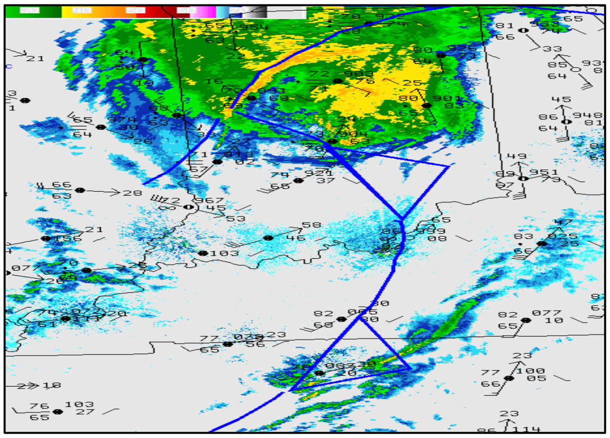

Figure 6. Surface observation plot, regional reflectivity, and cold frontal location valid 18 UTC 14 September 2008. Note the lack of precipitation over south-central Indiana, north-central Kentucky and southwest Ohio.

These areas of partial clearing allowed the maximum gusts suggested by BUFKIT and ACARS soundings to be realized.

7. Lessons Learned and Public Preparedness

a. Operational lessons learned

Several clues from this devastating high wind event could have, and arguably should have, been identified in order for forecasters to have properly prepared for the potential and resultant severity of the event. From a forecasting perspective, the GFS and NAM BUFKIT soundings for four consecutive model runs showed that at least 40 kt wind gusts were possible (supporting Wind Advisory criteria), as well as maximum mixed-layer winds of 50 to 59 kts (supporting High Wind Warning criteria). Knowing this and observing Sunday morning soundings that displayed a large cap in place and a well-mixed layer below it, forecasters may have been able to issue a High Wind Warning sooner than while the event was unfolding.

Secondly, during the early morning hours of the high wind event, there were several wind gusts observed over Missouri and Arkansas over 40 kts, already verifying Wind Advisory criteria. This is significant in that the sun had not yet risen and, therefore, full mixing potential was not yet met and winds were still meeting Advisory criteria. This should have been a clue that if partial sunshine and thus some mixing could occur, then higher wind gusts were inevitable.

In reference to the aforementioned large cap in place, the resultant lack of convection contributed to breaks in the clouds. This should have alerted forecasters to the likelihood of higher wind gusts since the mixing down of strong winds would have been (and was) realized, thus providing another reason to issue a High Wind Warning earlier.

Despite the unexpected nature of this event, forecasters did update forecasts and issue High Wind Warnings once it was clear the danger was imminent. Forecasters on duty during the event had to make quick decisions as events were unfolding rapidly, and used what avenues were available to get the word out to the public. This included updating web pages, NOAA All-Hazards weather radio, and staying in contact with neighboring NWS offices and the news media through chat messaging programs.

b. Preparing the public

Many challenges in properly preparing the public were realized during and following this event. High Wind Warnings are extremely rare in the Ohio Valley, so the public may not be aware of the dangers associated with such a warning. Since these products were issued while the event was unfolding, this may have negatively affected public response to the situation.

Even if High Wind Warnings were issued well ahead of time, how good is public response on the weekend? As mentioned earlier, the public receives most of their weather information from television, especially during the work and school week. Thus, it is likely that a relatively minimal amount of people watched the local news that morning and were prepared for the imminent high wind event. This presents quite a challenge for operational meteorologists to determine how best to warn the public of a potentially devastating weekend storm. Thus, it is suggested that not only should forecasters consider the outside chance of a 100-year event, but also consider forecasting for it during the work/school week where the public's attention may be more readily reached.

It is also suggested that NWS forecasters continue to partner closely with the media in order to properly prepare the public. Forecasters should work together to advertise any possibility of a rare event, especially if it is to occur on a weekend. Utilizing as many outreach avenues as possible, such as conference calls, website headlines, radio station blurbs, NOAA All-Hazards weather radio messages, or contacting Emergency Managers will help spread the word of rare and potentially devastating events similar to the Ike wind storm. This became the biggest challenge during the event, as NWS forecasters had to play "catch-up" and try to advertise the unfolding severity of the situation in real-time. However, many of the outreach avenues were unavailable in real-time since much of the power across the region was out due to fallen power lines. If anything, this event should refocus the importance of having amateur radio contacts as, at the very least, a last resort communication medium.

8. Acknowledgments

The authors would like to thank everyone who reviewed this paper and who helped collect data to support the claims herein.

9. References

Benjamin, S. G., and B. Schwartz, 1999: Accuracy of ACARS wind and temperature observations determined by collocation. *Wea. Forecasting*, 14, 1032-1038.

Berg, Robbie, 2009: Tropical Cyclone Report: Hurricane Ike, National Hurricane Center Report, 3, 10-11.

Storm Data, 2008: *NCDC Storm Data Publication September 2008.*