Investigation of Ice Free Wind Sensor Problems during December 2007 Ice Storm: Interim Report: January 18, 2008

Introduction

During mid December 2007, a prolonged ice event resulted in widespread heavy ice accumulation across several central U.S. states. Back to back rounds of significant freezing rain, first December 9 - 10 and then again on December 11 - 12 resulted in more than a quarter of an inch of ice accumulation across large parts of Nebraska, Kansas, Oklahoma, Missouri, Illinois and Iowa. Within the area most severely affected there are dozens of ASOS sites equipped with ice free wind sensors. Most of the sensors performed very well during the event. However, there were some sites where the sensor experienced problems ranging from a handful of erroneous observations to complete failure. In addition, the ice free wind sensor at Worcester, MA reported erroneous high winds during a snowstorm not long after the events that took place in the central U.S. The purpose of this investigation is to gauge how widespread the ice free wind sensor winter problems are and to determine what corrective action should be taken. It should be noted that this is a work in progress and that the information contained with this interim report should be considered preliminary.

Weather:

A shallow arctic airmass was in place for several days across the central Plains and Middle Mississippi Valley during the second week of December 2007. The leading edge of the arctic airmass was delineated by a stationary front draped across northern Texas, southeastern Oklahoma and northern Arkansas. South of the front, southerly winds with a long fetch over the Gulf of Mexico provided copious amounts of warm, moisture-laden air for repeated prolonged rounds of freezing rain. In addition, the tropical air over running the shallow layer of cold air near the surface was very unstable, resulting in freezing rain producing thunderstorms over Oklahoma, Kansas and Missouri.

The persistent and at times convective freezing rain resulted in widespread significant ice accumulation. Ice accumulations ranged from a quarter of an inch to well over an inch across large portions of the central Plains, southern Plains and middle Mississippi Valley. The area hardest hit was along the I-44 corridor in Oklahoma, as well as adjacent parts of southeastern Kansas and southwestern Missouri. According to NWS spotters, 1 to 2 inches of ice were reported in these areas. The severe icing resulted in widespread power across these states. In Oklahoma alone, more than 640,000 homes and businesses were without power. Portions of central and northeastern Oklahoma were declared federal disaster areas. Ice accumulations of an inch or greater were also reported by NWS spotters across a wide swath of central and northeast Kansas, northwestern Missouri and southern Iowa.

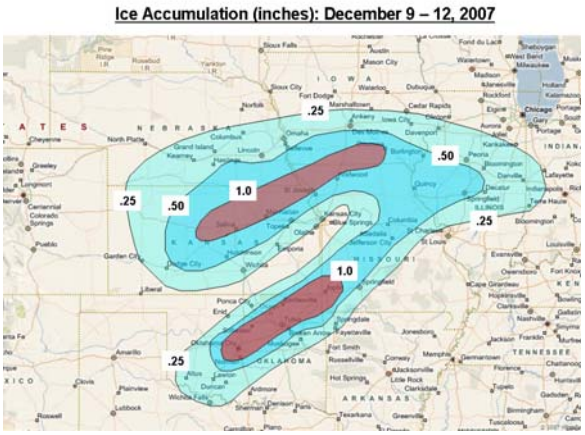

Figure 1: Ice storm accumulation

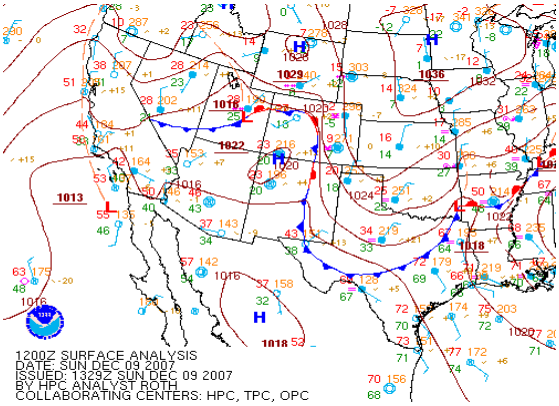

Figure 2: 12Z surface map for Dec 9, 2007

Methods:

NWS spotter reports were analyzed in order to gauge the extent and magnitude of icing. Data from ASOS sites within the areas hardest hit by the storm were closely analyzed in order to assess the performance of the sensor. 22 sites have been identified within an area which received half an inch of ice or greater. 6 of these sites were identified within an area which received an inch or more of ice accumulation.

The following sites were in the area that received an estimated ½ to 1 inch of ice:

FNB, CNK, RSL, DDC, HUT, TOP, LWD, BRL, CDJ, IRK, JEF, SGF, DEC, SPI, UIN and OTM

The following sites were in the area that received an estimated 1 inch of ice or more:
SLN, MHK, GOK, STJ, JLN, CFV

Analysis:

Of the 22 sites investigated, 17 sites had no problems during the event. This includes Manhattan, Kansas (MHK), Coffeeville, Kansas (CFV) and St. Joseph, Missouri (STJ) where ice accumulations of an inch or more were reported by NWS spotters in the vicinity of these sites. Temperatures ranged from -3 to -8 deg C, and the winds were generally between 10 and 15 knots.

Problems were observed at 5 sites: Guthrie, OK; Joplin, MO; Kirksville, MO; Ottumwa, IA; and Lamoni, IA. The problems ranged from a few erroneous peak wind reports in the 5 minute observations to total failure of the sensor due to ice-up. 3 additional sites that were not part of the sites identified as being hardest hit by the ice storm were also analyzed. One is Muskogee, Oklahoma where the sensor completely failed and another is Worchester, Massachusetts where erroneous peak winds were reported during a subsequent winter storm. The third is Springfield, Illinois. While the sensor performed well during the ice storm, a large bird perched on the sensor a few days

prior, resulting in about an hours worth of missing data and an erroneous peak wind report. As the case in Springfield illustrates, there is an overlap with the winter related problems and the bird related problems.

Muskogee, OK (MKO): Sensor failure and erroneous peak winds

After 3 hours of intermittent "UP", the sensor began to exhibit problems. The first of dozens of 1786 (wind sensor data quality check error) and 1791 errors (wind 425NWS sensor is in-operational) were recorded shortly after 1100Z. The last good wind observation from MKO was at 1053Z. At 1142Z, a peak wind report of 97 knots was issued. At 1220Z, an erroneous wind report of 09082KT was issued, followed by 06042G84 at 1227Z. The 1253Z wind report was missing, as were the wind reports for the rest of the 9th, 10th and the 11th. At 2205Z on the 11th, a technician logged on and restored power to the sensor, according to the SYSLOG. Report processing was turned back on at 1339Z on the 12th and the first valid wind observation was issued at 1353Z. No valid wind observations were issued between 1142Z on December 9th and 1353Z on December 12th, a period of 74 hours. An investigation of the sensor head at Muskogee revealed that the sensor probably suffered a failure of the heat control circuit. The defective sensor will be returned to the NWS facility at Sterling, VA for further testing and ultimate return to NLSC for repair.

Guthrie, OK (GOK): Sensor failure and erroneous peak winds

The sensor at GOK began to exhibit problems shortly after 0330Z on 12/9 (evening of Dec 8th). Erroneous wind observations were generated at 0351Z and 0353Z with prevailing winds of 39 knots and gusts to 51. The wind report processing was turned off at 0416Z. Several 1786 and 1791 SYSLOG error messages are recorded between 0430Z and 0930Z. Freezing rain began at 0742Z; 4 hours after the sensor began to experience problems. According to the 5 minute observations, temperatures were just below freezing and the visibility was between 1 and 2 miles in mist when the sensor started having problems. It is possible that super cooled droplets contacting the transducers began to freeze, resulting in rime ice. Guthrie is in the area that was hardest hit by the ice storm. By 22:16 local time on the 9th, the technician turned off report processing and powered down the sensor. The sensor stayed off until 12/10 at 10:09 local time. The sensor was deconfigured several times after this and was ultimately not put back into service until the afternoon of the 12th. The 2 day ice storm produced over an inch of ice accumulation in the area according to NWS spotters. At 2044Z on the 12th, the sensor is configured and the first valid observation is produced for the 21Z METAR. Wind reports had been missing for 99 hours. According to a subsequent discussion with electronics technicians at Norman, the sensor heater had failed during the storm. The sensor from Guthrie will be returned to the NWS facility at Sterling, VA for further testing.

Joplin, MO (JLN): Erroneous peak wind and missing data

Joplin was particularly hard hit by the ice storm. Freezing rain producing thunderstorms were observed, with NWS spotters reporting ice accumulations of 1 ½ inches in the vicinity of the site. Numerous power outages in the area resulted in unreliable AC power. After several hours of freezing rain, the ACU UPS switched to battery power at 1222Z according to the SYSLOG. By 1300Z, the UPS battery was low and the system went down entirely. The site was down for almost 3 hours before the system warm-started at 1544Z. However, ACU-DCP communications had not resumed until 0048Z. The first few wind observations were erroneous, with peak winds of 140 knots being reported during the first 10 minutes the system was back in operation. This was likely triggered by ice accretion on the transducers that was allowed to occur while power to the heaters was interrupted. After this initial start up period, the wind observations improved. While the unstable power resulted in frequent data outages over the next 36 hours, no additional erroneous high peak winds were reported. At Joplin, the sensor worked fine so long as there was adequate power for the heaters to keep the ice accretion at bay. However, as is the case with bird related erroneous peak winds in the summer months, when something is allowed to result in a path blockage, be it ice accretion or a bird, erroneous high peak wind speeds and erroneous variable winds can be reported by ASOS.

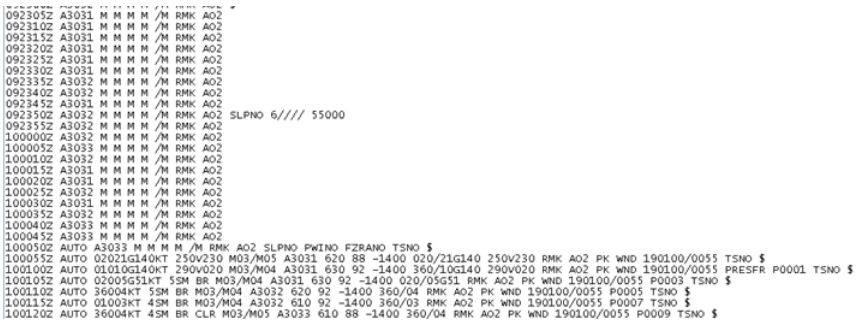

Figure 3: 5 minute observations from JLN on Dec 9, 2007 showing missing data followed by erroneous peak winds.

Kirksville, MO (IRK): Erroneous peak wind

The wind sensor performed well at Kirksville; however there were some intermittent data outages. Local power problems caused the site to go down for about 2 hours between 0300Z and 0500Z on December 12. When the system came back up, the first wind observation to go out in the 5 minute observations contained a bogus peak wind of 104 knots. Thereafter, the wind observations appeared to be accurate. As was the case in Joplin, path blockage due to ice build up during the power interruption and before the heaters could melt the ice probably resulted in the erroneous high peak wind report.

Ottumwa, IA (OTM): Missing data

Ice accumulations of ½ inch to an inch were reported across much of southern Iowa, with 1.0 inches of ice reported by an NWS spotter near Ottumwa. The wind sensor

performed well at Ottumwa, however numerous data outages occurred. Wind data was missing on December 11 from 1035Z through 1635Z and again from 2300Z through 1800Z on December 12. Analysis of the SYSLOG data reveals that this was most likely due to local power outages and the resultant power and communications problems at the site. Further analysis is being conducted of the SYSLOG messages in order to determine the stability of the system at this site and to check for any additional problems. It is worth noting that no erroneous peak winds or erroneous variable wind direction reports were issued by the site.

Lamoni, IA (LWD): Erroneous peak wind

According to NWS spotters, about an inch of ice accumulation was observed in the vicinity of Lamoni. For the most part, the sensor performed quite well during the event. However, there was a 10 minute period around 1700Z on December 11 when some erroneous high peak winds were reported by ASOS. The wind ob at 1700Z was 34010G35. While not as outlandish as the 100+ knot peaks reported at some stations, these peak winds are likely not real and probably due to a temporary partial blockage of the transducers.

Springfield, IL (SPI): Erroneous peak wind and missing data

NWS spotters in the vicinity of Springfield, Illinois reported anywhere from 0.4 to 0.7 inches of ice accumulation. During the event, the sensor performed well with the exception off periodic brief data outages. However, between 03Z and 07Z on December 8th during a rain changeover to freezing rain event that occurred before the ice storm, intermittent wind data outages occurred. At 0615Z, an erroneous high peak wind observation was generated: 01012G79. Intermittent wind data outages occurred for about an hour. SPI is one of the sites equipped with a data logger and camera for the Ice Free Wind Problem Resolution Project. Data from the camera reveals that a large bird was perched on the sensor, evidence that while the bird problem may be reduced during the cold months, it is still present. The time in which the bird was perched on the sensor coincides with the time when the bogus gust was reported, and when wind data went missing.

Worcester, MA (ORH): Numerous erroneous peak winds

Several days after the ice storm that affected the central states abated, a nor'easter lashed New England. During the snowstorm, the ASOS at Worcester, MA (ORH) generated multiple erroneous high peak winds and erroneous variable winds. Erroneous wind reports and missing wind reports occurred for about 9 hours. The first signs of trouble appeared at 1130Z on December 16 when ASOS reported the following: 04010G69KT. At the same time, the first of dozens of 1786 and 1791 errors were recorded in the SYSLOG. Weather-wise, heavy snow was followed by a changeover to

freezing rain. Temperatures were very cold, ranging from -11C to -5C. Unlike the cases in the central states, the winds were strong. Legitimate winds of 15-25 knots were observed, with gusts over 40. Winds of this type are common during strong nor'easters. Prior to the events of Dec 16, several rounds of freezing rain and heavy snow had occurred at the site without any wind sensor issues. During the Dec 16 event, it appears that the combination of heavy snow, cold temperatures and strong winds may have allowed for periodic partial path blockages. More thorough investigation is underway to deduce whether the sensor had problems or was the combination of heavy snow, wind and cold beyond the sensor's required performance specifications.

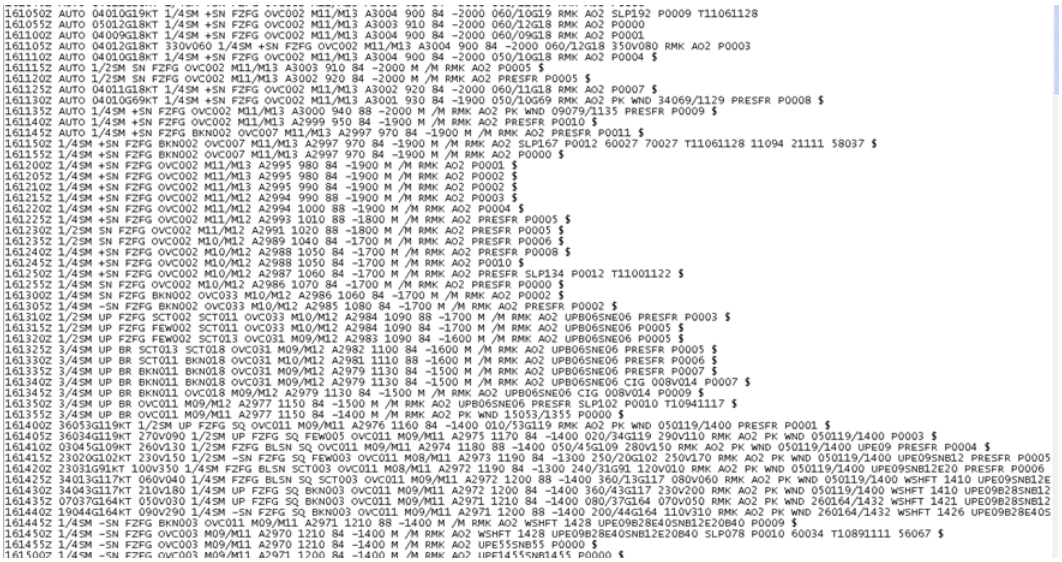

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Figure 4: 5 minute observations from ORH on Dec 16, 2007showing erroneous peak winds.

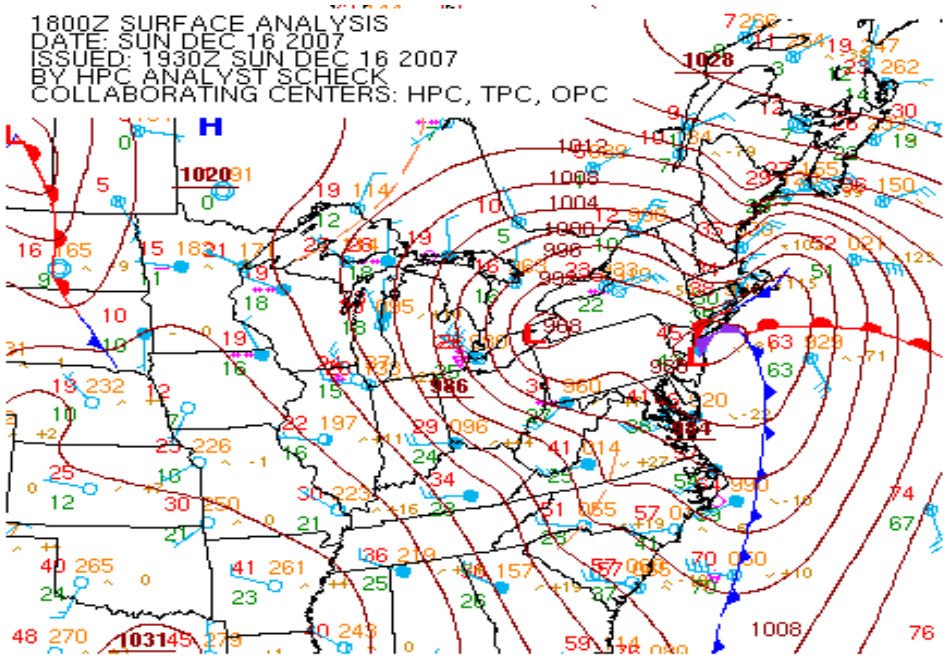

Figure 5: 18Z surface map for Dec 16, 2007

Conclusions and further study:

During the December 2007 Plains Ice Storm, the majority of the IFW sensors performed satisfactorily. Of the 22 sites in the area most severely affected, 17 had no problems. 5 sites, however, did experience problems. The problems ranged from a few erroneous wind reports to complete sensor failure. The sensor at Guthrie, OK (GOK) completely failed. It is believed that the sensors heating array had failed. The sensor head will be tested to verify this. While not in the area most severely affected and hence not part of the 22 sites used in the analysis, the heating array in the IFW sensor head at Muskogee, OK appears to have failed as well and will also be tested at the Sterling, VA R&D Center. The sensors at GOK and MKO were the only two sensors to have completely failed. One of the problems at MKO and GOK was that as the sensor began to ice over, erroneous high peak winds and variable winds were reported by ASOS. This is similar to what is experienced when large birds perch on the sensor and create path blockages.

Data was missing from JLN for 12 hours and from IRK for 2 hours due to power outages and power interruptions in the local area. However, in both instances when power was restored and the sensor was up and running again, ASOS reported erroneous peak winds during the first 5 to 10 minutes of operation. This was likely due to blockages resulting from ice that built up during the power interruption. While the power outages and resultant loss of data were not the fault of the ASOS or its IFWS, the bogus wind reports generated were. These symptoms are similar to what has been observed with bird related blockages and blockages due to ice accretion resulting from heater array failure. A 10 minute period of bogus peak winds were reported by the ASOS at LWD. The bogus peaks were in the 35 – 40 knot range. While not the outlandish 100+ knot bogus peaks seen at other sites, these reports were invalid none the less.

The last site identified as having problems was OTM. This site experienced two prolong periods of missing wind data. The first period was for about 6 hours followed by a 7 hour period of valid data. The second was and outage of about 19 hours. These data outages were likely due to unreliable power in the area during the ice storm, and no bogus wind observations were generated. Therefore, the outages experienced at OTM do not appear to be the fault of the IFWS. However, the complex nature of the SYSLOG messages indicate that the overall stability of the ASOS at OTM needs to assessed. At the time of writing, further investigation is being conducted.

Problems were reported on Dec 16 at the ASOS site in ORH. Multiple erroneous high peak wind and erroneous variable wind reports were issued over a period of about 9 hours during a nor'easter. Strong winds, cold temperatures and heavy snow characterized the conditions during the event. The site demonstrated the same symptoms as sites that are experiencing either bird or ice related blockages. At the time of writing, more thorough investigation was being conducted in order to deduce whether the sensor had problems or was the combination of heavy snow, wind and cold beyond the sensor's required performance specifications.

Sporadic data outages were observed at SPI for about an hour, and one bogus observation did manage to go out in the 5 minute observations. SPI is one of the evaluation sites for the bird related IFWS problem resolution project and is equipped with a data logger and a camera. The data logger will have the DCP 5 second samples, which are the building blocks the wind algorithms use to compute the wind velocity, gusts and peak winds. Analysis of the 5 second data and the camera reveals that the problems at SPI were bird induced.

At the time of writing, this is a work in progress and the conclusions contained within this report should be considered preliminary. The sensor heads from Muskogee and Guthrie will be undergoing further testing at Sterling, and more analysis is currently being performed on data from OTM and ORH. In addition, AOMC trouble ticket information will be analyzed. The feasibility of increasing the sensor's heating capacity is being investigated in order to determine whether or not an increase in heat will reduce blockages. That said two preliminary recommendations can be made. First, an evaluation of the condition and performance of the IFW sensor's heating array should be conducted at each site just prior to the cold season as part of preventative maintenance in order to mitigate the risk of failure during winter time operation. The second recommendation is an algorithmic recommendation. A filter should be implemented that removes the bogus high peak winds and variable winds from the data stream. The filter should be robust enough to capture and filter out the bogus wind reports generated by a myriad of factors, such as birds, ice blockage, snow blockage, etc, yet be sophisticated enough not to have an affect on data collected during real metrological phenomenon which generate rapidly fluctuating winds. This should, of course, be done in concert with efforts to mitigate bird related IFW problems. As with the bird-related problems, a two pronged approach to mitigation should be employed: a hardware solution to reduce the number of causal factors (bird abatement, preventative maintenance) and an algorithmic solution in order to prevent the transmission of erroneous and at times outlandish wind observations during those times when problems are unavoidable, such as ice build up during a power outage.