9.5 DEVELOPMENT AND TESTING OF AN ICE ACCUMULATION ALGORITHM

Gary D. McManus[1], S. F. Piltz[3], S. Sperry[4], R. A. McPherson[1], A. D. Gartside[2], D. McClain[2],
T. Meyer[2], C. Fetsch[2], and M. A. Shafer[1]

[1]Oklahoma Climatological Survey, Norman, OK
[2]Oklahoma Mesonet, Norman, OK
[3]National Weather Service Forecast Office, Tulsa, OK
[4]Oklahoma Association of Electric Cooperatives, Oklahoma City, OK

Lead Author's note: This extended abstract is a working draft of ongoing work in deploying decision support tools between state, federal and private entities. The lead author takes responsibility for content, copy editing errors, and inaccuracies.

1. INTRODUCTION

Significant ice storms were once a rarity in Oklahoma. Based on data from 1948-2000, the state experienced an average of approximately three freezing rain days per year (Changnon and Karl, 2003). Since 2000, however, Oklahoma has experienced an increased frequency of significant freezing rain events. Six ice storms with widespread ice depositions of at least one inch have occurred since December 2000 (Table 1).

Storm	Widespread Ice Accumulation	Maximum Ice Accumulation	Power Outages
December 2000	2.0 inches	3.0 inches	170,000
January 2002	2.0 inches	3.0 inches	255,000
December 2002	1.0 inches	1.5 inches	55,000
December 2006	1.0 inches	1.5 inches	7,000
January 2007	1.5 inches	2.5 inches	120,000
December 2007	1.0 inches	2.0 inches	640,000

Table 1. A summary of significant ice events in Oklahoma since 2000.

Those six storms resulted in catastrophic damage to electric utility infrastructure in every region of the state, with damage totals of more than one billion dollars. The observed increase in frequency since 2000 suggests that significant ice storms will continue to affect Oklahoma for the foreseeable future.

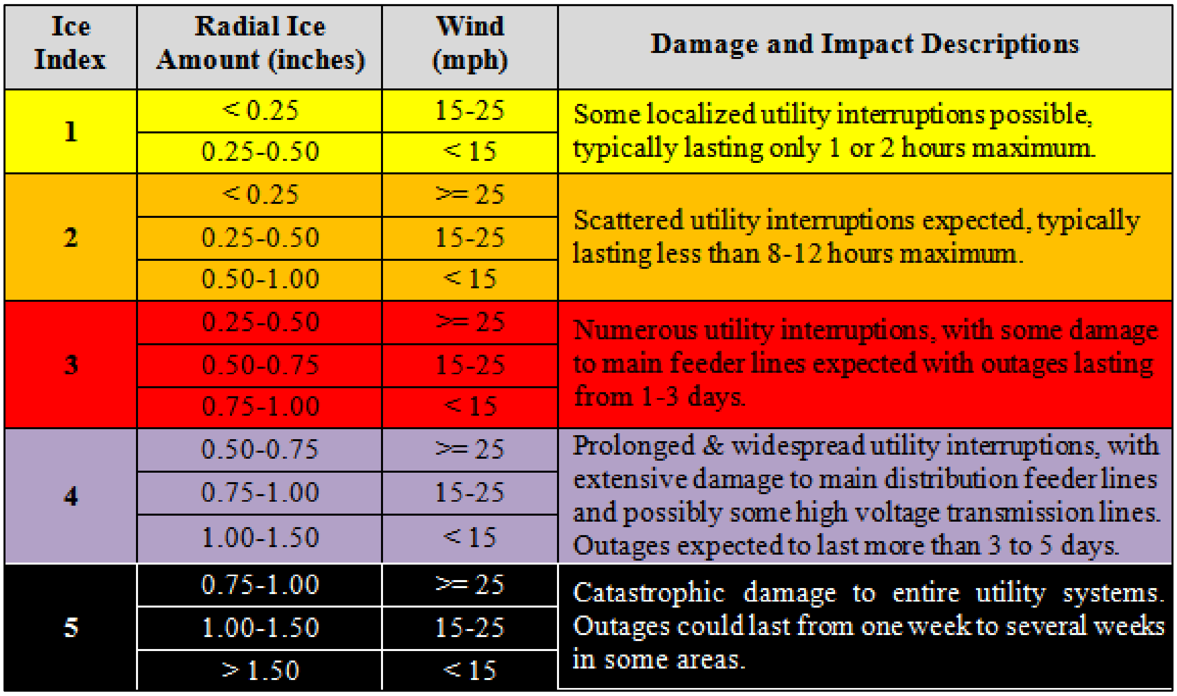
The Oklahoma Association of Electric Cooperatives (OAEC) sought help for real-time assessment and forecasts of ice accumulation on their power lines. OAEC had partnered with the Oklahoma Climatological Survey (OCS) on development of a decision-support system that consolidated available information, but fell short of actual ice assessments and forecasts. OAEC worked with the National Weather Service (NWS) Forecast Office in Tulsa, Oklahoma, to address those needs. Using their experiences with previous ice storms, OAEC and NWS-Tulsa developed the Sperry-Piltz Utility Ice Damage Index. The index relies heavily on local NWS forecasters' experience with ice accumulations and real-time data from the Oklahoma Mesonet (McPherson et al. 2007). The algorithm is undergoing a more systematic evaluation in collaboration with OCS. Students at OCS are calculating frozen precipitation accumulation and wind speed at each Mesonet site for ice events dating back to 1994, including both severe and less substantial events. These data will be used to calculate the ice accumulation index for each Mesonet site for each event, which will then be compared against damage and power outage reports to quantitatively validate the algorithm.

2. THE UTILITY ICE DAMAGE INDEX

The Sperry-Piltz Utility Ice Damage Index (Table 2) categorizes damage potential in five levels through the use of radial ice thickness and wind speed. Utility systems may be able to handle moderate ice accumulations, but stressed lines under wind forces are more likely to break. Therefore, one inch of ice may be a Level 2 or Level 3 ice event, but if wind speed exceeds 25 mph, it becomes a Level 5 event. The algorithm was tested in several ice events during the winter

---

* *Corresponding author address:* Gary D. McManus, Oklahoma Climatological Survey, University of Oklahoma, 120 David L. Boren Blvd., Suite 2900, Norman, OK 73072; email: gmcmanus@ou.edu.



Ice Index	Radial Ice Amount (inches)	Wind (mph)	Damage and Impact Descriptions
1	< 0.25	15-25	Some localized utility interruptions possible, typically lasting only 1 or 2 hours maximum.
	0.25-0.50	< 15	
2	< 0.25	>= 25	Scattered utility interruptions expected, typically lasting less than 8-12 hours maximum.
	0.25-0.50	15-25	
	0.50-1.00	< 15	
3	0.25-0.50	>= 25	Numerous utility interruptions, with some damage to main feeder lines expected with outages lasting from 1-3 days.
	0.50-0.75	15-25	
	0.75-1.00	< 15	
4	0.50-0.75	>= 25	Prolonged & widespread utility interruptions, with extensive damage to main distribution feeder lines and possibly some high voltage transmission lines. Outages expected to last more than 3 to 5 days.
	0.75-1.00	15-25	
	1.00-1.50	< 15	
5	0.75-1.00	>= 25	Catastrophic damage to entire utility systems. Outages could last from one week to several weeks in some areas.
	1.00-1.50	15-25	
	> 1.50	< 15	

Table 2. The Sperry-Piltz Utility Ice Damage Index. The categories are based upon combinations of precipitation totals, temperature and wind speed.

of 2007-2008. Anecdotal evidence suggests that the algorithm performed exceptionally well, with observed damage consistent with the scale. In some cases, the algorithm out-performed local utility managers, either indicating more severe problems than they anticipated (prior to getting crews in the field) or areas of less damage within the overall storm pattern. Use of the algorithm has implications on deployment of repair crews during and after the event to restore power to customers as quickly as possible, and also has positive implications for use by the Oklahoma Department of Transportation to predict ice accumulation on streets, highways, and bridge surfaces.

3. TEST DATA

Limitations of available data arise due to the frozen nature of the precipitation. Radial ice thickness from liquid precipitation totals and wind speeds are vital inputs to the algorithm. Each of the four primary data sources available have negative and positive aspects for inclusion in the study. The negative aspects make each unsuitable as a singular data source. Therefore, it was determined that a combination of the data sources was needed to satisfy the requirements of the study.

3.1 Oklahoma Mesonet

The Oklahoma Mesonet, which has data on unprecedented scales spatially and temporally, is of limited use during a freezing rain event since it employs unheated precipitation and wind sensors. The network is, however, a very efficient detector of freezing rain through use of its anemometers. Freezing rain will cause the anemometer to slow and eventually stop spinning which is then noted by OCS quality assurance personnel. Through this process the edges of the freezing rain footprint can be accurately identified.

3.2 ASOS

The Automated Surface Observing Systems (ASOS) program of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD) offers heated precipitation and wind sensors. ASOS spatial coverage is very sparse, however. In the January 2007 ice event which struck southeastern Oklahoma, the lone ASOS installation within the heavy icing footprint was located at McAlester, Oklahoma. Due to the loss of electrical power, data was lost from the McAlester ASOS station.

3.3 NWS Cooperative Observer Network

The NWS Cooperative Observer Program (COOP) network has similar spatial coverage to the Oklahoma Mesonet. In addition, as with the ASOS network, the ability exists to obtain liquid precipitation measurements from frozen precipitation. At the mandated observation time, the cooperative observer will melt the frozen precipitation from the gauge to get the liquid equivalent. Unfortunately, the precipitation amounts are limited to a 24-hour time frame. Therefore an accurate precipitation amount during an icing event is not possible using this network alone. Wind speeds are not measured in the NWS COOP program as well.

3.3 Radar Estimated Precipitation

Radar-estimated precipitation totals were considered but rejected due to poor coverage and beam-elevation issues in remote areas of the state. Again, in the case of the January 2007 event, radar coverage in southeastern Oklahoma was not satisfactory.

4. METHODOLOGY

The identification of ice accumulations for inclusion in the Sperry-Piltz algorithm begins with an estimation of the amount of liquid precipitation that fell while the environment was at or below freezing at each Mesonet site. This process necessitates a combination of Oklahoma Mesonet and COOP data due to the limitations listed previously. The COOP precipitation data is obtained at 1300 UTC each morning by the cooperative observer. The Oklahoma Mesonet precipitation totals reset at 0000 UTC. Reconciling those different observation times is required to obtain the final precipitation estimate. The process is as follows:

1) The COOP precipitation totals are objectively analyzed throughout the event to match the locations of the Oklahoma Mesonet stations. The result is a COOP liquid precipitation total for each Mesonet site from 0000 UTC the morning the event began until the event ended (i.e. rose back above freezing).

2) The time at which each Mesonet site across the state dropped below freezing and then rose back above freezing is recorded.

3) The amount of liquid precipitation that fell on that date was calculated from 1300 UTC until the time of freezing for each Mesonet site's precipitation data. If the time of freezing was beyond 0000 UTC (the time at which the Mesonet precipitation data resets), the precipitation that fell from 0000 UTC forward to the freezing point was added to that amount of the previous day (from 1300-0000 UTC).

4) That total is then subtracted from the objectively analyzed COOP precipitation total for each corresponding Mesonet location. Those totals obtained for each Mesonet site are the estimated liquid precipitation amounts for the freezing rain event

5) The liquid precipitation amounts must then be converted to radial ice thicknesses for input into the Sperry-Piltz algorithm. In forecasting ice accumulations, the forecasters at the NWS office in Tulsa use their experience to determine the percentage of rainfall to convert to ice thickness. Several factors determine that ratio, including temperature and wind speed. It is hoped that a comparison between the liquid precipitation totals and reported ice accumulations will reveal an improved ratio.

6) The maximum wind gust for each Mesonet site at a point three hours prior to the freezing of the anemometer is then recorded. That wind gust is then used as the wind speed required by the Sperry-Piltz algorithm.

With the two required parameters now obtained for each Mesonet site, it is a simple exercise to input those into the Sperry-Piltz algorithm and determine the damage index level.

5. SUMMARY

The bulk of time and effort of this study has been spent developing the methodology for converting precipitation amounts from differing networks to an estimated liquid precipitation total. Impediments to that effort included discovering and understanding the limitations of the various available datasets. With this phase of the study complete, the focus of the work now turns to a singular case for testing. The January 2007 ice storm which devastated southeastern Oklahoma has been chosen as the first case due to its abrupt beginning and ending points and smaller damage footprint. With each successive test case, it is hoped an improved system of significant ice mitigation will emerge. Another benefit is an emerging climatology of ice events across Oklahoma through the Mesonet's inception in 1994.

6. REFERENCES

Changnon, S., and T. Karl, 2003: Temporal and Spatial Variations of Freezing Rain in the Contiguous United States: 1948–2000. *J. Appl. Meteo.,* 42, 1302–1315.

McPherson, R. A., C. Fiebrich, K. C. Crawford, R. L. Elliott, J. R. Kilby, D. L. Grimsley, J. E. Martinez, J. B. Basara, B. G. Illston, D. A. Morris, K. A. Kloesel, S. J. Stadler, A. D. Melvin, A.J. Sutherland, and H. Shrivastava, 2007: Statewide monitoring of the mesoscale environment: A technical update on the Oklahoma Mesonet. J. Atmos. Oceanic Tech., 24, 301-321.