
ANALYSIS OF ANTI-ICE COATINGS ON FIELD OPERATIONAL ANEMOMETERS

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ABSTRACT

Ice accumulation on anemometers, a side effect of freezing precipitation, makes reliable wind measurements nearly impossible to collect during winter conditions. Over the last decade, the Oklahoma Mesonet has lost more than 26 days worth of wind measurements at its location in Norman, Oklahoma, USA as a result of this freezing precipitation. This study tested the reliability of two anemometers with anti-ice technologies through icing conditions: an R. M. Young Wind Monitor coated in NeverWet™, a superhydrophobic coating, and an R. M. Young Alpine Wind Monitor. Wind measurements collected between 19 Nov. 2013 and 30 Nov. 2015 showed little difference between the performance of the anemometers with anti-ice technologies and an unaltered R. M. Young Wind Monitor through six periods of freezing precipitation. At best, the Alpine anemometer remained iced for 40 fewer minutes than the uncoated anemometer (0.7% of the length of the freezing precipitation event) and the coated anemometer remained iced for 80 fewer minutes (5.1% of the length of the freezing precipitation event). In these six events, the anti-ice technologies did not prove to be more reliable alternatives to the R. M. Young Wind Monitor during freezing precipitation and their implementation would not provide sufficient benefit for operational use in the Oklahoma Mesonet.

1. INTRODUCTION

Thousands of observation stations across the United States include various types of anemometers, which allow atmospheric scientists and other professionals access to an extensive archive of wind measurements. The data are used to measure the severity of storms, increase aircraft safety during takeoff and landing, and assemble climatological information. However, wind measurements can be unreliable during winter ice storms due to the impacts of icing conditions. Freezing precipitation causes ice to accumulate on anemometers as the supercooled rain droplets freeze upon contact. The accumulated ice restricts the anemometer's ability to rotate and causes wind speed reports to be severely underestimated. Much of the United States receives ten or more hours of freezing precipitation annually (Fig. 5 in Cortinas

2004), which results in hundreds of millions of dollars in damages (Changnon 2002). Freezing precipitation forms in two ways: when raindrops supercool and freeze upon contact with surface objects at below-freezing temperatures (Rauber et al. 2001; Changnon and Kunkel 2006) or when supercooled raindrops form through collision-coalescence, a process called the "supercooled warm rain process" (Huffman and Norman 1988).

There are two reigning technologies used to make surfaces resistant to ice accumulation: heat and icephobic coatings. Fortin et al. (2005) replicated the conditions of a freezing rainstorm with misters in a wind tunnel at sub-zero temperatures and tested the reliability of cup anemometers in this artificial environment. When covered in ice, the NRG#40 cup anemometer underestimated wind speeds by up to 30 percent prior to their complete stoppage. A heated, ice-free NRG anemometer

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subjected to the same conditions reported non-zero wind speed values for a longer timespan than the unheated anemometer. However, it underestimated the actual wind speed by a maximum error of 50 percent and prompted the conclusion that the heating of the ice-free NRG anemometer was “insufficient” for the experimental conditions in which it was tested. Makkonen et al. (2001) tested the anti-ice capabilities of the Metek USA-1 heated 3-D sonic anemometer, which has less surface area for ice to accrete to than a mechanical anemometer and utilizes no moving parts, and found that it was a promising anti-ice technology but “its sensor heating is insufficient in the most severe icing conditions.” Seifert (2003) also pointed out that heated anemometers have a tendency to melt snow and observed “the melted snow immediately ‘re-freeze’ on the outer radius” of the anemometer.

In addition to the use of heat as an anti-ice technology, many studies (Kulinich and Farzaneh 2011; Saito et al. 1997; Wang et al. 2013) analyze the success of hydrophobic (water-repellant) and icephobic coatings. A recent study (Susoff et al. 2013) investigated the icephobic properties of various hydrophilic (water-adhesive) and hydrophobic coatings used to keep wind turbines ice-free. To compare ice adhesion, adhesion reduction factor (ARF), which is the ratio between the shear stress of bare aluminum and the coating, is calculated. A coating with less adhesion to ice than aluminum is given an ARF greater than one, and vice versa. Polydimethylsiloxane, a hydrophobic coating similar to that used on the RM Young Alpine Wind Monitor, proved to have much less adhesion than bare aluminum, with ARF values reaching 100. However, ice adhesion is not the only factor that corresponds to a coating’s icephobic ability. Cao et al. (2009) also found a correlation between the size of supercooled droplets and a material’s icephobic properties: as the droplet radius increased, the icing probability increased as well. Cao et al. also recognized that laboratory conditions do not necessarily exhibit the exact behavior of the natural environment: “Icing of supercooled water on superhydrophobic surfaces is a complex phenomenon, and it may also depend on ice adhesion, hydrodynamic conditions, and structure of the water film on the surface.”

The Oklahoma Mesonet, commissioned in 1994, is an automated network of 121 remote meteorological stations across Oklahoma (Brock et al. 1995; McPherson et al. 2007). Each station measures core parameters that include: air temperature and relative humidity at 1.5 m; wind speed, gust, and direction at 10 m; wind speed at 2

m; atmospheric pressure; global down-welling solar radiation; rainfall; bare soil temperature at 10 cm below ground level; and vegetated soil temperature at 10 cm below ground level (doi: 10.15763/dbs.mesonet). Additionally, most stations also measure bare soil temperature at 5 cm, vegetated soil temperature at 5 and 30 cm, and soil moisture at 5, 25, and 60 cm. The Oklahoma Mesonet uses an R. M. Young Wind Monitor for wind measurements at 10 m. Mesonet data are collected and transmitted to a central facility every 5 minutes, where they are quality controlled, distributed, and archived (Illston et al. 2013; Shafer et al. 2000; <http://mesonet.org>).

From 1948-2000, ice storms were most frequent in the central United States, Midwest, and New England, (Fig. 5 in Changnon 2002). Data compiled by Kovacik et al. (2010) found that Caddo county in central Oklahoma had seven ice storms between 2000 and 2009, more than any other county in the south central United States. The impact of frequent freezing precipitation is evident in the Oklahoma Mesonet’s wind data for Norman, Oklahoma, which has lost 26 days, six hours, and 50 minutes of wind observations from 2006 to 2016 due to ice accumulation. In Kingfisher, Oklahoma, on 30 Jan. 2002 to 2 Feb. 2002, an analysis of the wind data revealed that two hours after rain started, the anemometer’s rotation stopped due to the significant amount of ice that had accumulated from 9.65 mm of freezing precipitation. Oklahoma Mesonet Manager Dr. Chris Fiebrich (2003) noted: “Ice extended outward approximately 115 mm from the cups, appearing to defy gravity. From these ice radials, multiple icicles formed downward for about 200-250 mm.”

This study tested the reliability of two anemometer anti-ice technologies through icing conditions as well as through the summer months and analyzed the practicality of the implementation of these technologies into the Oklahoma Mesonet.

2. DATA AND METHODS

The anti-ice capabilities of two anemometers were tested against an unaltered R. M. Young Wind Monitor from 19 Nov. 2013 to 30 Nov. 2015 at the Oklahoma Mesonet station at the University of Oklahoma Westheimer Airport in Norman, Oklahoma. One was an R. M. Young Wind Monitor coated in NeverWet™, a superhydrophobic chemical by Rust-Oleum® designed to prevent water, mud and ice from accumulating on surfaces. NeverWet™ was applied to the anemometer per the instructions included in the Multi-Surface Liquid

Repelling Treatment kit. The second was an R. M. Young Heavy Duty Wind Monitor-HD-Alpine, which has an ice-resistant coating and black color scheme, “developed to endure the most extreme environments” (<http://www.youngusa.com>). Both anemometers were calibrated to an accuracy of 0.3 m/s or 1% of the wind speed reading. They can measure wind speeds up to a maximum of 100.0 m/s, have a resolution of 0.1 m/s, and have a minimum threshold of 1.0 m/s.

The three anemometers—an unaltered R. M. Young Wind Monitor, an R. M. Young Wind Monitor coated in NeverWet, an R. M. Young Heavy Duty Wind Monitor-HD-Alpine—were mounted to poles at three meters of height and three meters apart so that wind speeds were not impacted by other anemometers. Wind speeds were reported every five minutes, concurrent with the data reported by the Oklahoma Mesonet. Six case study

dates with periods of freezing rain were identified over this two-year study using quality assurance data for Norman. These case study dates are 22 Nov. 2013 – 24 Nov. 2013, 20 Dec. 2013 – 24 Dec. 2013, 4 Feb. 2014 – 5 Feb. 2014, 2 Mar. 2014 – 3 Mar. 2014, 28 Feb. 2015 – 1 Mar. 2015 and 27 Nov. 2015 – 28 Nov. 2015.

Ice accumulation on the anemometers can be identified by looking for steep drops in the reported wind speeds or wind speed measurements that vary by greater than 0.6 m/s between two of the anemometers (+/- 0.3 m/s error for each anemometer). Wind speed values under 1.3 m/s are within the error of 0.3 m/s of the minimum threshold of the anemometers (1.0 m/s) and as a result can not be considered to be accurate to 0.3 m/s. Quality assurance was applied to the raw data of anemometer wind speed measurements. All wind speed observations fell

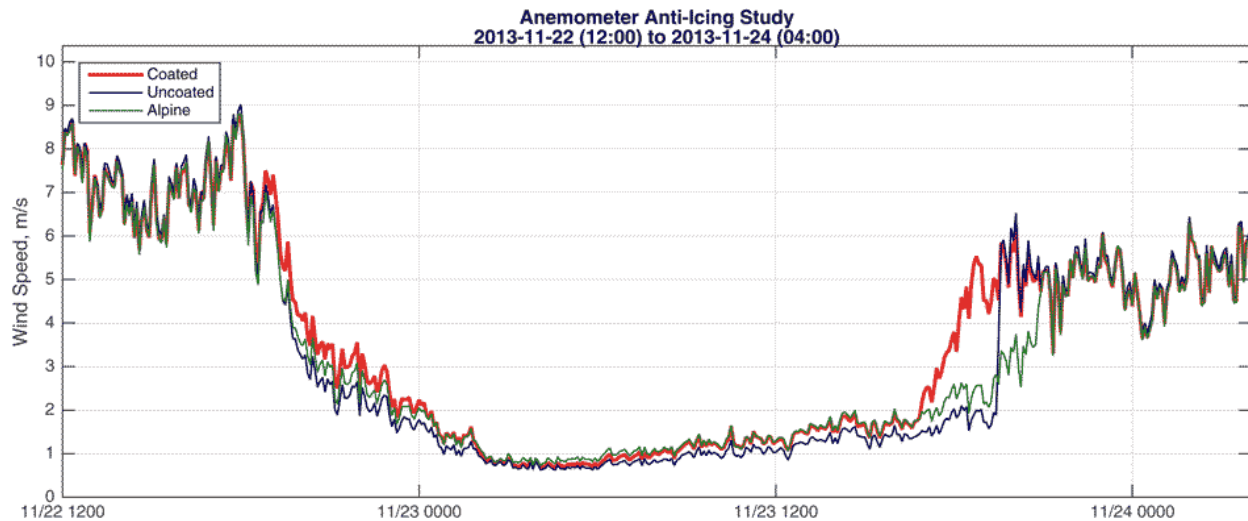


Figure 1. The wind speeds recorded by the R. M. Young Wind Monitor coated in NeverWet™ (“coated”), the unaltered R. M. Young Wind Monitor (“uncoated”), and the R. M. Young Alpine Wind Monitor (“Alpine”) at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 1200 UTC on 22 Nov. 2013 to 0400 UTC on 24 Nov. 2013.

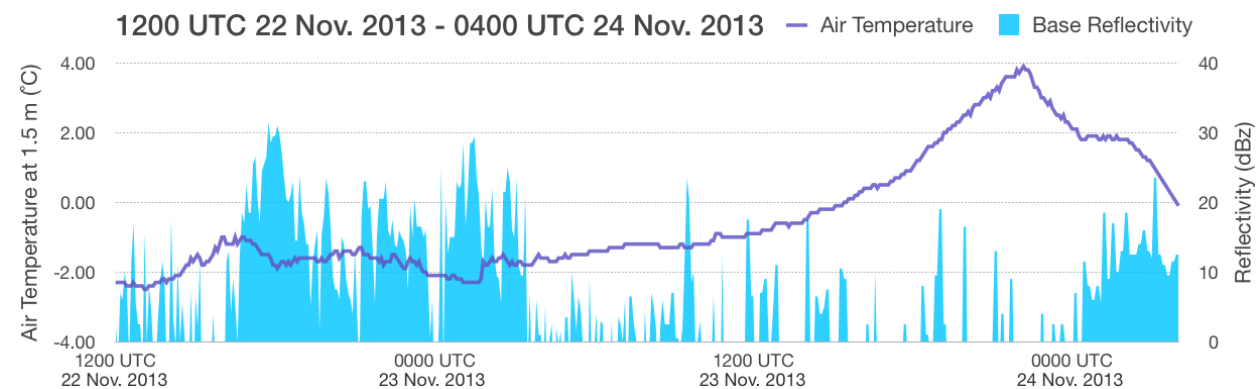


Figure 2. The reflectivity at 0.5° according to the KTLX radar in the Oklahoma City area, and the air temperature at 1.5 m at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 1200 UTC on 22 Nov. 2013 to 0400 UTC on 24 Nov. 2013.

below 20.0 m/s and were therefore in a reasonable range. Temperature measurements at 1.5 m and 24-hour rainfall measurements were supplied by the Oklahoma Mesonet station in Norman. Since the rain gauges used by the Oklahoma Mesonet cannot measure frozen precipitation until it has melted, we used base reflectivity observations from the KTLX radar in Oklahoma City to detect precipitation. Alongside analyses over periods of freezing rain, the anemometers are analyzed over the meteorological summers (1 June to 31 Aug.) of 2014 and 2015 to ensure their reliability in hot weather. Any two wind observations that differed by greater than 2.0 m/s for a single observation were not included in this part of the study, as they are likely errors due to non-meteorological conditions rather than the equipment.

3. RESULTS

22 Nov. 2013 – 24 Nov. 2013

Freezing rain began to impact wind speeds at 1400 UTC on 22 Nov. 2013. All three anemometers began to accumulate ice at 1900 UTC, at which the uncoated, coated, and Alpine anemometers reported respective wind speeds of 6.5 m/s, 7.0 m/s, and 6.3 m/s. The reported wind speeds dropped below 3.0 m/s by 2110 UTC (Figure 1). Atmospheric observations also show freezing precipitation conditions with the 1.5 m air temperature at $-1.6\text{ }^{\circ}\text{C}$ on 1900 UTC on 22 Nov. 2013 and base reflectivity observations by the KTLX radar in the Oklahoma City area showed intermittent precipitation between 1655 UTC on 22 Nov. 2013 and 0325 UTC on 23 Nov. 2013 (Figure 2). The temperature rose above freezing at

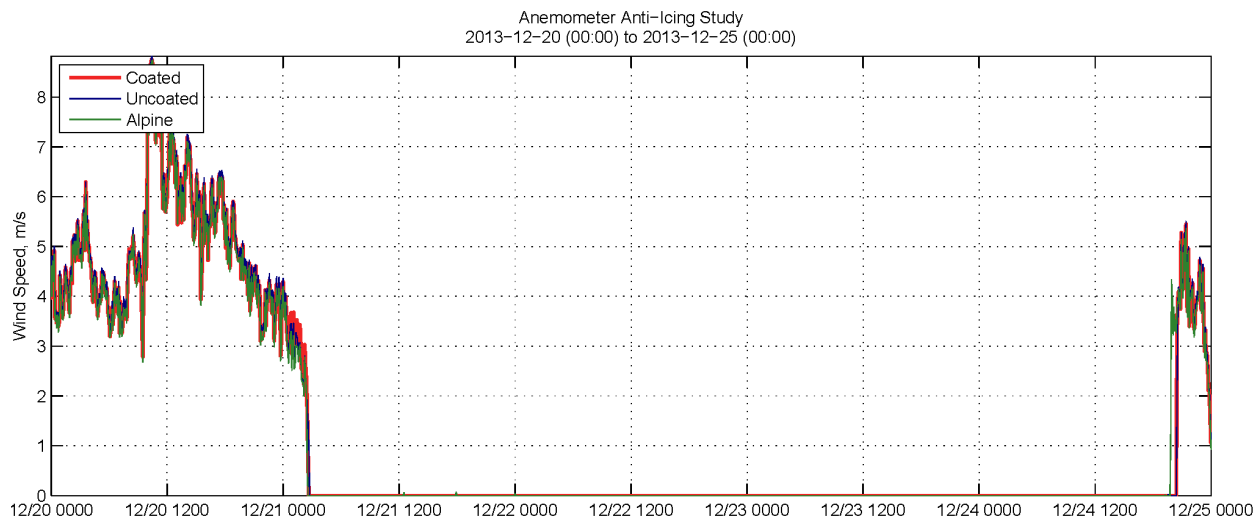


Figure 3. The wind speeds recorded by the R. M. Young Wind Monitor coated in NeverWet™ (“coated”), the unaltered R. M. Young Wind Monitor (“uncoated”), and the R. M. Young Alpine Wind Monitor (“Alpine”) at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 0000 UTC on 20 Dec. 2013 to 0005 UTC on 25 Dec. 2013.

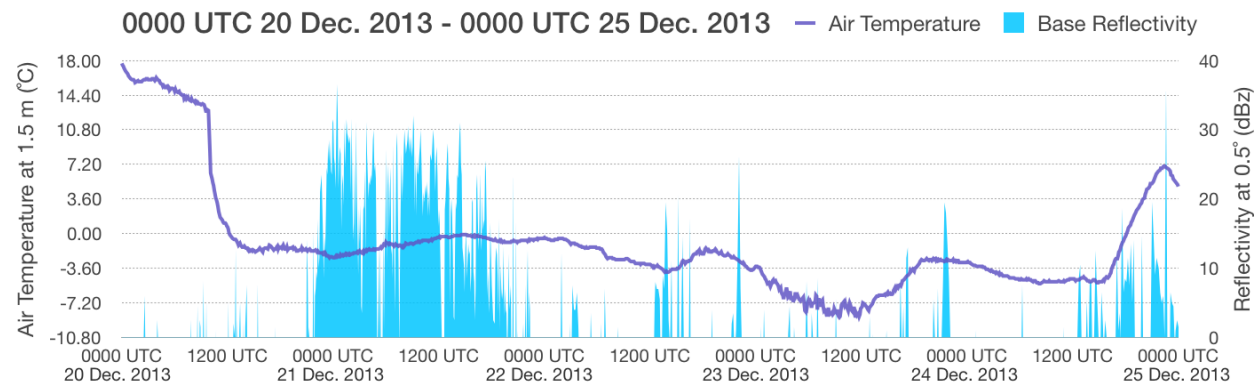


Figure 4. The reflectivity at 0.5° according to the KTLX radar in the Oklahoma City area, and the air temperature at 1.5 m at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 0000 UTC on 20 Dec. 2013 to 0000 UTC on 25 Dec. 2013.

1535 UTC on 23 Nov. 2013, allowing precipitation measurements to be collected, and at 2315 UTC the gauge measured 4.57 mm of precipitation for the event. Radar observations show that little to none of this precipitation fell after the temperature exceeded 0 °C. A sharp increase in the wind speeds reported by the coated anemometer shows that it thawed at 1815 UTC on 23 Nov. 2013 after 24 hours and 35 minutes of ice accumulation. The uncoated anemometer thawed 80 minutes later at 1935 UTC after 25 hours and 55 minutes of ice accumulation, and the Alpine anemometer thawed another 80 minutes after that at 2055 UTC after 27 hours and 15 minutes of ice accumulation.

20 Dec. 2013 – 24 Dec. 2013

Freezing rain began to impact wind speeds at 0005 UTC on 20 Dec. 2013. All three

anemometers began to accumulate ice at 0015 UTC on 21 Dec. 2013, at which the uncoated, coated, and Alpine anemometers reported respective wind speeds of 4.1 m/s, 4.0 m/s, and 3.9 m/s. The reported wind speeds dropped to 0.0 m/s by 0245 UTC, 0250 UTC and 0255 UTC (Figure 3). The 1.5 m air temperature at 0015 UTC on 21 Dec. 2013 was -2.5 °C and base reflectivity observations show precipitation between 2230 UTC on 20 Dec. 2013 and 1720 UTC on 21 Dec. 2013 (Figure 4). The temperature rose above freezing at 1810 UTC on 24 Dec. 2013. 38.1 mm of precipitation fell during the event, though only one fifth of that was reported due to an error with the rain gauge. A sharp increase in the wind speeds reported by the Alpine anemometer shows that it thawed at 1955 UTC on 24 Dec. 2013 after three days, 19 hours and 40 minutes of ice accumulation. The uncoated and coated anemometers thawed 40 minutes later

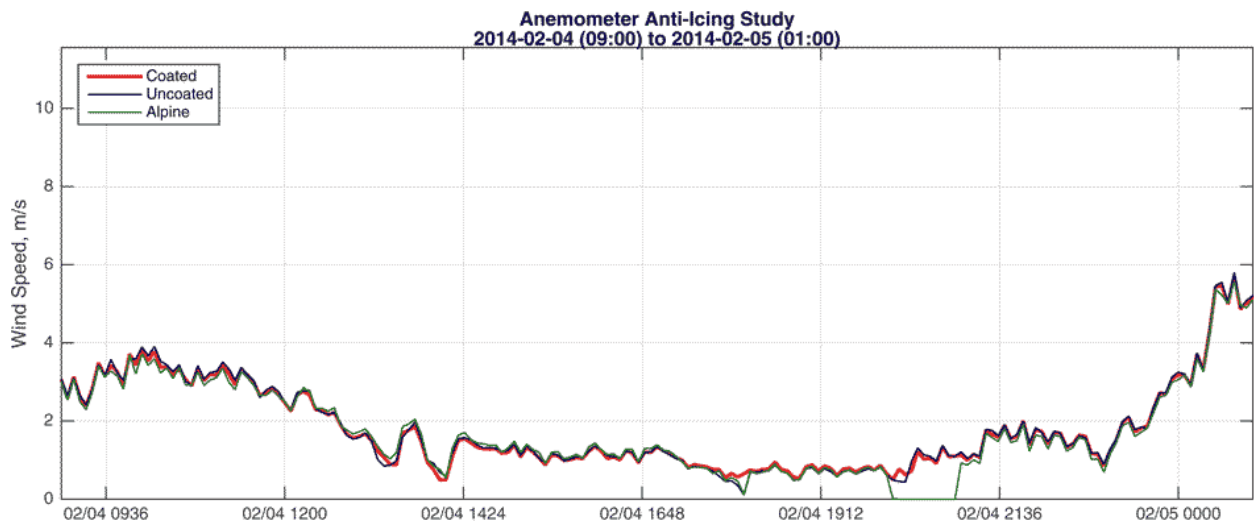


Figure 5. The wind speeds recorded by the R. M. Young Wind Monitor coated in NeverWet™ (“coated”), the unaltered R. M. Young Wind Monitor (“uncoated”), and the R. M. Young Alpine Wind Monitor (“Alpine”) at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 0900 UTC on 4 Feb. 2014 to 0100 UTC on 5 Feb. 2014.

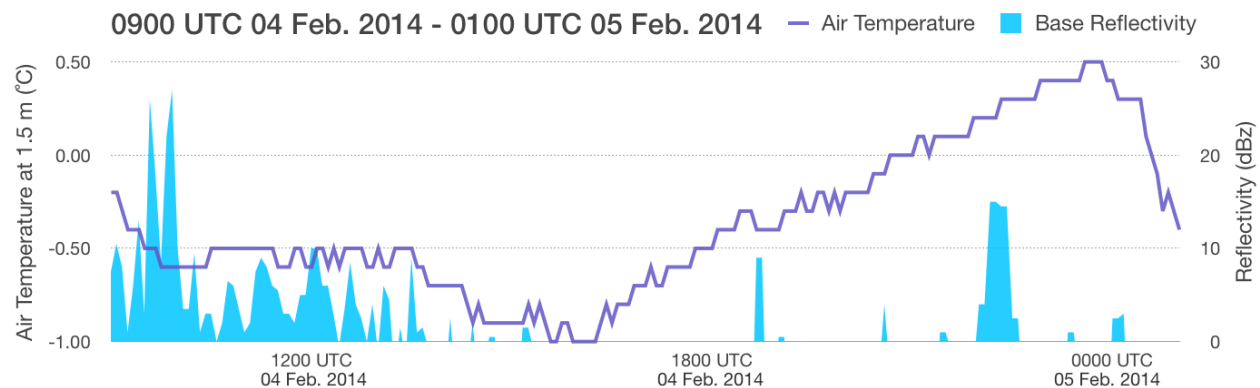


Figure 6. The reflectivity at 0.5° according to the KTLX radar in the Oklahoma City area, and the air temperature at 1.5 m at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 0900 UTC on 04 Feb. 2014 to 0100 UTC on 05 Feb. 2014.

at 2035 UTC after three days, 20 hours and 20 minutes of ice accumulation.

4 Feb. 2014 – 5 Feb. 2014

Freezing rain began to impact wind speeds at 1000 UTC on 4 Feb. 2014. Icing is evident on the Alpine anemometer from 2105 UTC to 2100 UTC as its wind speeds drop to zero. The wind speeds for the uncoated and coated anemometers are under 1.3 m/s (the minimum threshold of 1.0 m/s plus the maximum error of 0.3 m/s) for most of this period of time, so differences in reported wind speeds are not significant (Figure 5). However, at 2050 UTC, the uncoated, coated, and Alpine anemometers reported respective wind speeds of 1.4 m/s, 1.3 m/s, 0.0 m/s—indicative of ice accumulation on the Alpine anemometer. Atmospheric observations also show freezing precipitation conditions. The 1.5

m air temperature at 1000 UTC on 4 Feb. 2014 was -0.6°C and base reflectivity radar observations show some precipitation between 0935 UTC and 0955 UTC on 4 Feb. 2014 (Figure 6). The temperature rose above freezing at 2105 UTC, when the Alpine began reporting nonzero wind speeds. At 0020 UTC on 5 Feb. 2014 the gauge measured 4.31 mm of precipitation for the event. By 0030 UTC, the reported wind speeds rose above 5.0 m/s.

2 Mar. 2014 – 3 Mar. 2014

Freezing rain began to impact wind speeds at 0300 UTC on 2 Mar. 2014. A difference of 0.6 m/s first occurred at 0555 UTC, at which the uncoated, coated, and Alpine anemometers reported respective wind speeds of 5.8 m/s, 5.7 m/s, and 6.4 m/s (Figure 7). Large measurement differences were frequent until 0735 UTC on 3 Mar. 2014

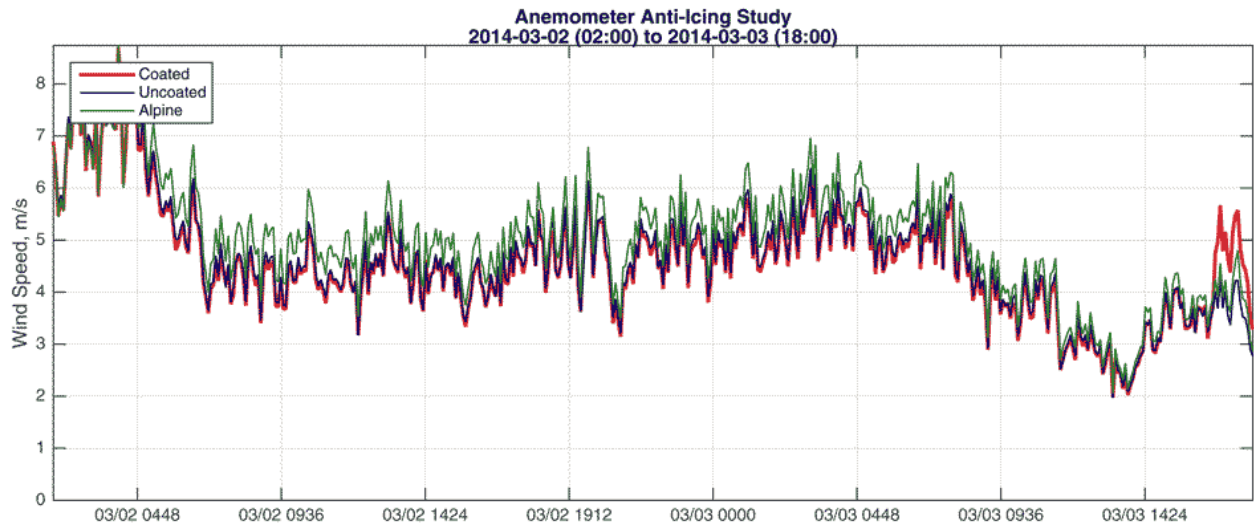


Figure 7. The wind speeds recorded by the R. M. Young Wind Monitor coated in NeverWet™ (“coated”), the unaltered R. M. Young Wind Monitor (“uncoated”), and the R. M. Young Alpine Wind Monitor (“Alpine”) at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 0200 UTC on 2 Mar. 2014 to 1800 UTC on 3 Mar. 2014.

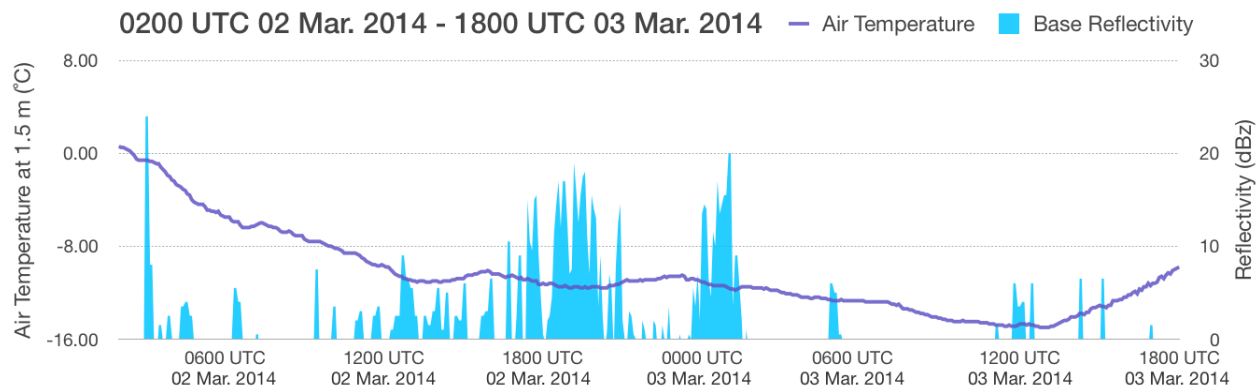


Figure 8. The reflectivity at 0.5° according to the KTLX radar in the Oklahoma City area, and the air temperature at 1.5 m at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 0200 UTC on 02 Mar. 2014 to 1800 UTC on 03 Mar. 2014.

and then from 1645 to 1750 UTC. Atmospheric observations show freezing precipitation conditions through the event. The 1.5 m air temperature at 0555 UTC on 2 Mar. 2014 was -5.4 °C and base reflectivity observations show small amounts of precipitation at 0300 UTC on 2 Mar. 2014 and 0100 UTC on 3 Mar. 2014 (Figure 8). The temperature rose above freezing at 1705 UTC on 4 Mar. 2014, which allowed precipitation measurements to be collected, and at 2325 UTC the gauge measured 5.59 mm of precipitation for the event.

28 Feb. 2015 – 1 Mar. 2015

Freezing rain began to impact wind speeds at 1800 UTC on 28 Feb. 2015. The 1.5 m air temperature at this time was -5.0 °C and base reflectivity observations by the KTLX radar in the Oklahoma City area show intermittent periods of

light precipitation between 1405 UTC and 1540 UTC on 28 Feb. 2015 (Figure 10). At 2310 UTC on 1 Mar. 2015, 2.54 mm of precipitation were recorded for the event, just before the temperature rose above freezing at 0005 UTC on 2 Mar. 2015. No observation saw a measurement difference of 0.6 m/s or more, so it is difficult to tell if ice accumulated to any of the anemometers (Figure 9).

27 Nov. 2015 – 28 Nov. 2015

Freezing rain began to impact wind speeds at 2120 UTC on 27 Nov. 2015. All three anemometers began to accumulate ice at 0400 UTC on 28 Nov. 2015, where the uncoated, coated, and Alpine anemometers reported respective wind speeds of 4.1 m/s, 3.4 m/s, and 4.1 m/s. The reported wind speeds dropped below 1.0 m/s by 0735 UTC (Figure 11). The 1.5 m air temperature

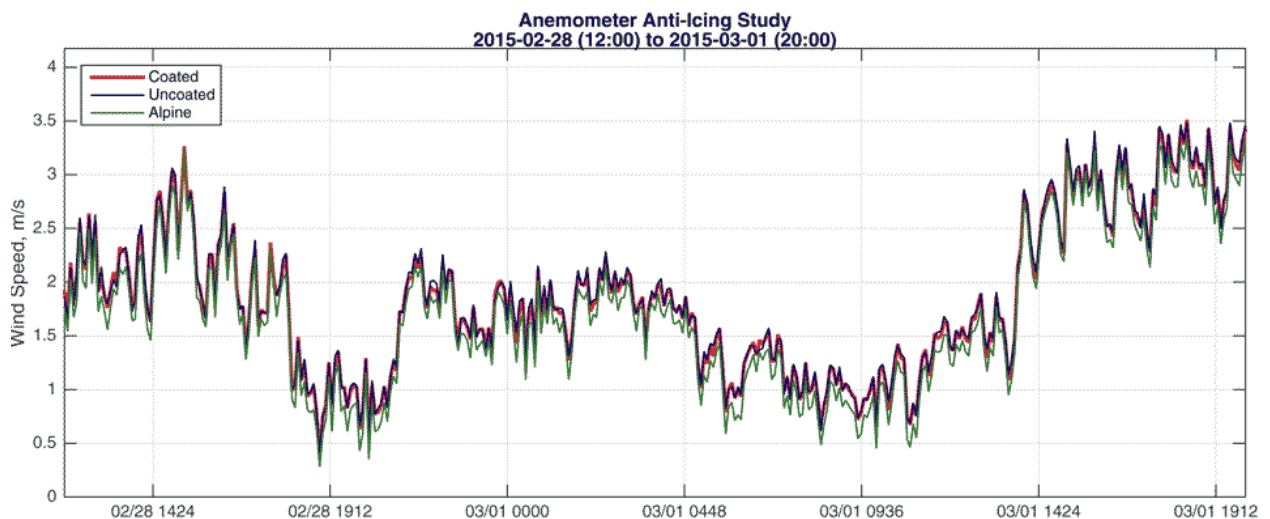


Figure 9. The wind speeds recorded by the R. M. Young Wind Monitor coated in NeverWet™ (“coated”), the unaltered R. M. Young Wind Monitor (“uncoated”), and the R. M. Young Alpine Wind Monitor (“Alpine”) at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 1200 UTC on 28 Feb. 2015 to 2000 UTC on 1 Mar. 2015.

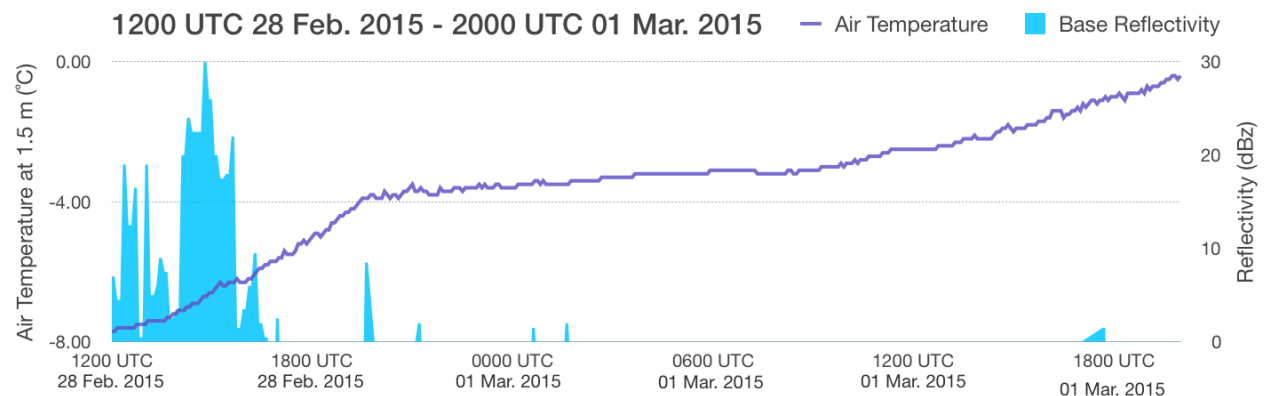


Figure 10. The reflectivity at 0.5° according to the KTLX radar in the Oklahoma City area, and the air temperature at 1.5 m at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 1200 UTC on 28 Feb. 2015 to 2000 UTC on 1 Mar. 2015.

at 0400 UTC on 28 Nov. 2015 was $-0.4\text{ }^{\circ}\text{C}$ and base reflectivity observations show near constant precipitation through the event (Figure 12). The air temperature rose above freezing at 1035 UTC on 28 Nov. 2015, which allowed precipitation measurements to be collected, and at 2005 UTC the gauge measured 21.08 mm of precipitation for the event; however, some of this came from rainfall after the air temperature rose above freezing. A sharp increase in the wind speeds reported by the uncoated and Alpine anemometers indicated that they thawed at 1855 UTC on 28 Nov. 2015 after 16 hours and 20 minutes of ice accumulation. The coated anemometer thawed 25 minutes later at 1920 UTC after 16 hours and 45 minutes of ice accumulation.

Summer 2014 and 2015 (June 1 – Aug. 31)

Over 1 June 2014 to 31 Aug. 2014 and 1 June 2015 to 31 Aug 2015, there were only two measurements, 30 July 2014 at 1230 UTC and 1235 UTC, that fell outside of the 0.6 m/s margin of error. This is less than 0.01% of the total measurements taken over the summers of 2014 and 2015. Through this period of time, there were 44 days that reached a maximum temperature of $35\text{ }^{\circ}\text{C}$ or higher.

4. DISCUSSION

Three of the cases (22 Nov. 2013 – 24 Nov. 2013, 20 Dec. 2013 – 24 Dec. 2013, 27 Nov. 2015 – 28 Nov. 2015) saw more than four hours of precipitation, making the impact of ice accumulation more apparent. Over the course of these three events, the coated anemometer froze for a total

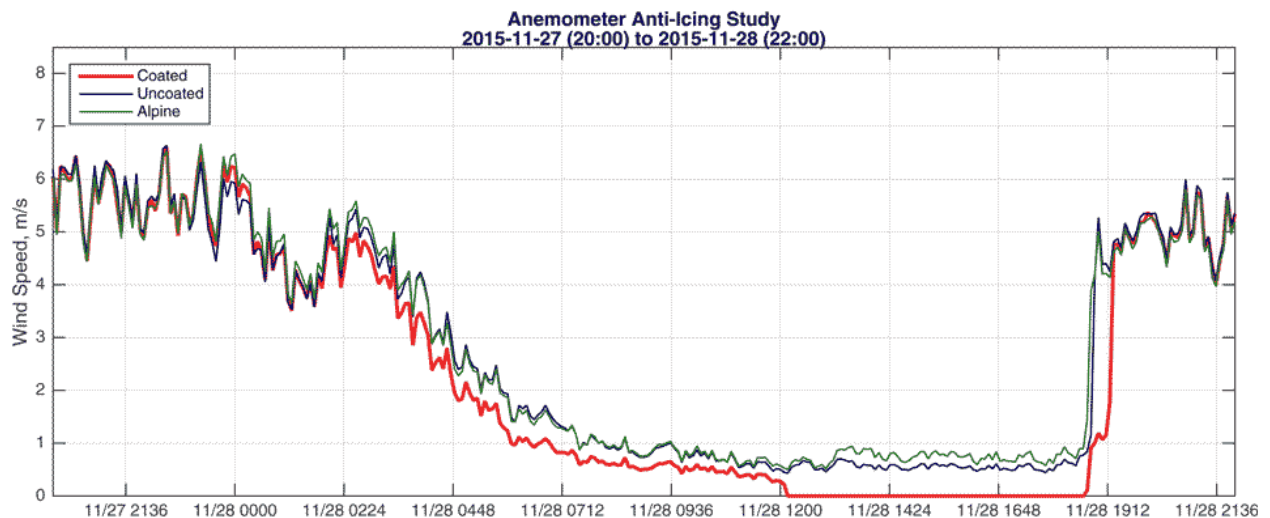


Figure 11. The wind speeds recorded by the R. M. Young Wind Monitor coated in NeverWet™ (“coated”), the unaltered R. M. Young Wind Monitor (“uncoated”), and the R. M. Young Alpine Wind Monitor (“Alpine”) at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 2000 UTC on 27 Nov. 2013 to 2200 UTC on 28 Nov. 2015.

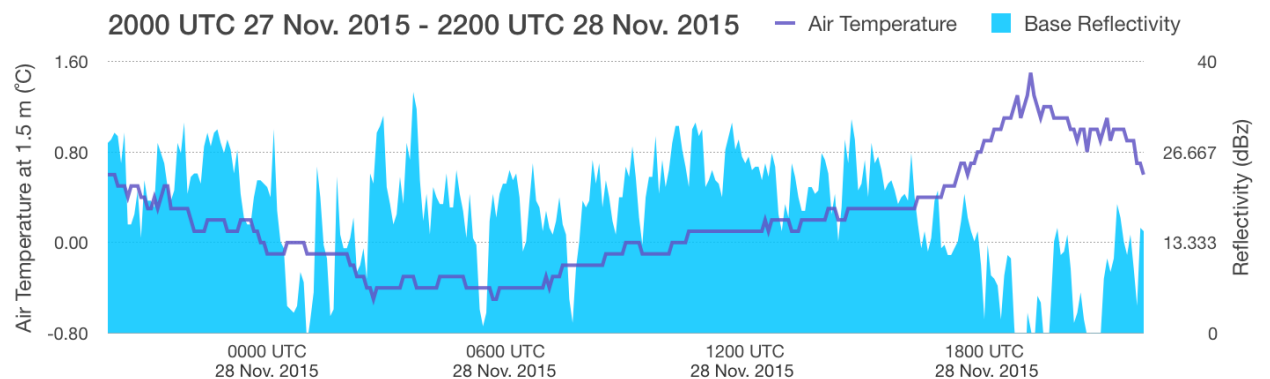


Figure 12. The reflectivity at 0.5° according to the KTLX radar in the Oklahoma City area, and the air temperature at 1.5 m at the Oklahoma Mesonet instrument testing facility in Norman, Oklahoma, USA from 2000 UTC on 27 Nov. 2015 to 2200 UTC on 28 Nov. 2015.

of 5 days, 13 hours and 40 minutes, 55 minutes shorter than the uncoated anemometer, which froze for 5 days, 14 hours and 35 minutes and the Alpine anemometer froze for 5 days, 15 hours and 15 minutes, 40 minutes longer than the uncoated anemometer. The coated and Alpine anemometers only differed with the uncoated anemometer by 0.68% and 0.49%, respectively, leading the conclusion that there is little difference between the performances of the three anemometers. Only during the 22 Nov. 2013 – 24 Nov. 2013 event did the coated anemometer perform better than the uncoated anemometer, icing for 80 fewer minutes, or 5.1% less time. The Alpine anemometer performed better than the uncoated anemometer during the 20 Dec. 2013 – 24 Dec. 2013 event as it iced for 40 fewer minutes than the uncoated anemometer, or 0.7% less time. However, both anti-ice technologies had instances where they performed worse than the uncoated anemometer as well. In the 22 Nov. 2013 – 24 Nov. 2013 event, the Alpine anemometer iced for 80 minutes longer, and it did not show any difference for the 27 Nov. 2015 – 28 Nov. 2015 event. The coated anemometer iced for an extra 25 minutes during the 27 Nov. 2015 – 28 Nov. 2015 event and there was no difference for 20 Dec. 2013 – 24 Dec. 2013.

In the three cases with less than four hours of precipitation (4 Feb. 2014 – 5 Feb. 2014, 2 Mar. 2014 – 3 Mar. 2014, 28 Feb. 2015 – 1 Mar. 2015) the Alpine and coated anemometers did not perform considerably better than the uncoated anemometer. In the case of 2 Mar. 2014 – 3 Mar. 2014, the coated anemometer reported higher wind speeds than the uncoated anemometer for 65 minutes. In the 4 Feb. 2014 – 5 Feb. 2014 event, the Alpine anemometer was observed to perform worse than the uncoated anemometer in one observation as it reported 0.0 m/s.

The anti-ice technologies did not impact the reliability of the anemometers during hot weather. Through 184 days of summer observations, there were only two observations (.004%) that fell outside of the margin of accuracy.

The inability to measure to wind speeds through freezing precipitation makes it difficult to analyze the efficacy of anti-ice technologies because the actual wind speeds are not known. The use of video surveillance would have been supplemental in observing the status of ice accumulation on the anemometers during the 4 Feb. 2014 – 5 Feb. 2014, 2 Mar. 2014 – 3 Mar. 2014, and 28 Feb. 2015 – 1 Mar. 2015 case studies, where ice accumulation on the anemometers was less

apparent through wind speed measurements. With only six case studies, observed at one location, there is not sufficient evidence to prove that the R. M. Young Alpine Wind Monitor or R. M. Young Wind Monitor coated in NeverWet™ will not work in other freezing precipitation conditions or atmospheric environments, and should be tested for reliability in other situations.

5. CONCLUSION

As our understanding of meteorology increases, technology must improve to facilitate our advances in accuracy. This study sought to find a solution to inaccurate wind measurements during freezing precipitation events. However, these six case studies did not find the R. M. Young Alpine Wind Monitor or the R. M. Young Wind Monitor coated in NeverWet™ to be effective anti-ice technologies and their implementation would not help increase wintertime measurements in the Oklahoma Mesonet. In the best events, the Alpine anemometer performed only 0.7% better and the coated anemometer performed only 5.1% better than the uncoated anemometer. As our understanding of icephobic agents increases, we are more likely to find a solution to this problem. Hopefully new anti-icing technologies will arise and drastically improve the accuracy of wind measurements, but for now ice storms leave meteorologists in the dark.

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