THE ANATOMY OF A SIGNIFICANT FREEZING RAIN EVENT

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ABSTRACT

The objective of this project was to examine a winter storm that occurred from January 4th to January 7th of 2025. This storm produced freezing rain accumulations from Kansas to the Maryland/Virginia coastline as it traversed across the United States. Winter Storm Warnings (WSWs) issued by the National Weather Service and precipitation types from the Automated Surface Observation Systems were analyzed herein. Timelines were constructed to visually observe how precipitation types and occurrences corresponded to the timing of WSWs. A comparison of forecasted ice accumulations and measured ice accumulations was also conducted. It was found that, for this winter storm, precipitation frequently began and ended as snow, with much of the freezing rain occurring between the snowfall. For most of the WSWs assessed, precipitation began to be observed after or near the time the warnings went into effect. It was also found that lead times generally increased from west to east. Finally, forecasted ice accumulations were accurate most of the time. It was more common to see forecasted amounts being too low compared to too high.

1. INTRODUCTION

Winter storms can consist of a variety of precipitation types, ranging from rain to snow and everything in between. One of the more notable precipitation types during winter storms is freezing rain. Freezing rain events can cause a large array of impacts on one's daily lives by affecting all modes of transportation, infrastructure and vegetation, and businesses. Although winter storms are extremely impactful, there remain limitations surrounding winter-weather forecasting. The purpose of this study is to analyze a particular winter storm that occurred from January 4th to January 7th of 2025 which traversed all the way from Kansas to the Mid-Atlantic's coast, passing through 28 County Warning Areas (CWAs). The timing of Winter Storm Warnings (WSWs) issued by National Weather Service (NWS) Weather Forecast Offices (WFOs), such as when they were issued, when they went into effect, and when they expired, will be examined. Along with this, the timing of precipitation and the observed precipitation types at the surface will be inspected. Finally, a comparison between forecasted ice accumulations and measured ice accumulations will be conducted.

1.1 *FREEZING RAIN IMPACTS – WHY DOES IT MATTER?*

Freezing rain events have massive impacts on travel. Ice accumulation from freezing rain may cause reduced mobility on roadways, leading to vehicle incidents that can result in injuries and fatalities. During winter storms, injuries resulting from crashes increase by 66% when compared to dry weather conditions (Mills, et al., 2019). Winter precipitation, most substantially freezing rain, has immense impacts on aircraft travel as well. Ice accumulations on aircrafts may allow the machine to become susceptible to overturning, and pilots may experience a loss of control (Cao, et al., 2018). To avoid such situations, flight cancellations and delays frequently occur during winter storms, which save lives although can cost airlines millions of dollars (Degelia, et al., 2015).

One of the longer-lasting impacts of winter storms is the effects on infrastructure, such as

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power and utility lines (Degelia, et al., 2015). Ice accumulations on tree limbs may cause them to bend or snap, which sometimes disrupts utility lines as well as roadways. The utility lines themselves may break when under the weight of heavy ice accretion, resulting in widespread power outages at times. Power outages then have their own effects on businesses and industries that rely on power to operate smoothly and efficiently.

An example of a notable winter storm is the costliest winter storm event on record in the United States, which ocurred from February 10th to the 19th in 2021 (NCEI, 2021). This storm was responsible for the deaths of 262 individuals, with more than 210 of these deaths occurring in the state of Texas. Accompanying the storm was historically below normal temperatures and millions of power outages. Temperatures caused water pipes to freeze, which burst upon thawing, causing water damage to buildings.

1.2 *WINTER STORM FORECASTING*

Despite their many adverse effects, winter storms are nortoriously difficult to forecast with precision. As previously stated, winter storms frequently include varying precipitation types such as rain, freezing rain, sleet, and snow. The type of precipitation that occurs is highly dependent on the thermodynamic structure of the atmosphere, including the depth of melting and freezing layers. Slight inflections in thermodynamic profiles can cause changes in precipitation types, making winter precipitation difficult to correctly forecast (Degelia, et al., 2015). Over the past couple of decades, winter storm forecasting has greatly improved, although there still remains challenges with accurately predicting precipitation types and rates (Novak, et al., 2023).

Within the NWS, A Winter Storm Warning is issued by WFOs “when a winter storm is producing or is forecast to produce heavy snow or signigicant ice accumulations” (National Weather Service Glossary, n.d.). The criteria for a WSW varies between WFO.

2. METHODS

In order to determine the CWAs that were impacted by this winter storm, the Freezing Rain Accumulation National Analysis (FRANA) was examined between the 4th and the 7th of January 2025 (Tripp, et al., 2025). Any ice accumulation shown on FRANA was considered an impact, although the areas with the higher amounts of accumulation were prioritized.

After determining the CWAs that had been impacted, the products issued by their corresponding WFOs were found through the Iowa Environmental Mesonet (IEM) webpage. A focus was put on WSWs that were issued for this event. Within the warnings, timing information such as when the warnings were issued, when they went into effect, and when they expired were noted. Along with this, the initial forecast for ice accumulation amounts was noted for the later comparison.

Once the WSWs were found, Automated Surface Observation Systems (ASOS) were utilized for precipitation timing and precipitation types. Two ASOS stations were selected for each WSW that was considered. The first station analyzed was the station that began reporting precipitation first, while the second station assessed was the station that stopped reporting precipitation last. All stations that were examined were within a WSW.

After the above information was found, timelines were constructed for six separate WSWs. Each timeline included timing information for the WSWs, along with information regarding precipitation type and timing.

Once the timelines were created, comparisons were conducted between the forecasted and measured ice accumulations. The forecasts used were from the first products issued regarding each WSW. Total ice accumulations were calculated from 1 hour ice accretion data from specific ASOS stations. All accumulations were considered beginning at WSW issuance and ending at warning expiration. The ASOS stations used to determine measured accumulations were the same stations used in the timelines.

3. RESULTS

3.1 *TIMELINES*

All six timelines below follow the same format. The solid blue bar labled “WSW” depicts the WSW corresponding to the WFO mentioned in the figure captions. On the WSW bar is a star that indicates when the product went into effect. Below the WSW bars are the ASOS reports for the station that began reporting precipitation first within the WSW. The third and final bar represents the ASOS reports for the station that stopped reporting precipitation last. A key to interpret the colors on the ASOS bars is provided in Figure 1.

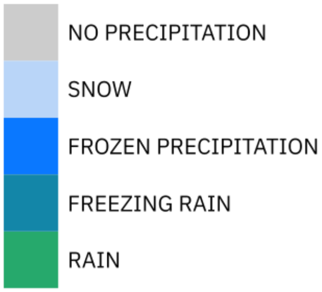

Figure 1 – Key to depict the different colors of precipitation types in the timelines below.

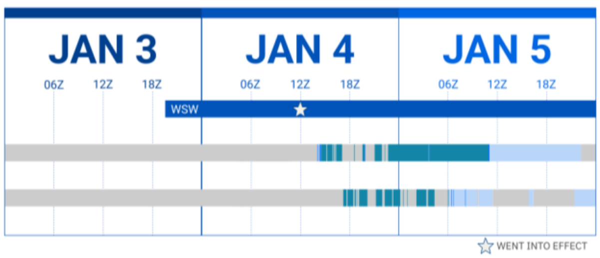

Figure 2 – Timeline of the WSW issued by the Wichita, Kansas WFO.

The WSW depicted in Figure 2 was issued on January 3rd at 19:31Z, went into effect on January 4th at 12:00Z, and expired on January 6th at 00:00Z. The first and second ASOS stations used were from Wichita Dwight D. Eisenhower National Airport and Salina Municipal Airport respectively.

This warning had the shortest amount of time between warning issuance and precipitation start time at 18 hours and 34 minutes. Precipitation reports in this WSW were most infrequent, with numerous reports of no precipitation. The ASOS stations considered for this warning were the only stations, out of the 12 total stations examined, that began reporting precipitation as freezing rain. The 10 other stations that were assessed had begun reporting precipitation as snow, which then transitioned into other forms of precipitation, which can be seen in the following figures.

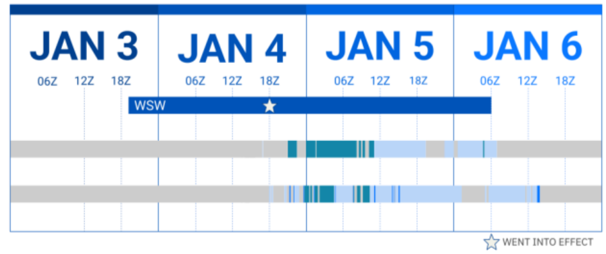

Figure 3 – Timeline of the WSW issued by the Kansas City/Pleasant Hill, Missouri WFO.

Figure 3's WSW was issued on January 3rd at 18:56Z, went into effect on January 4th at 18:00Z, and expired January 6th at 06:00Z. The ASOS stations were from Lee's Summit Municipal Airport and Sedalia Memorial Airport.

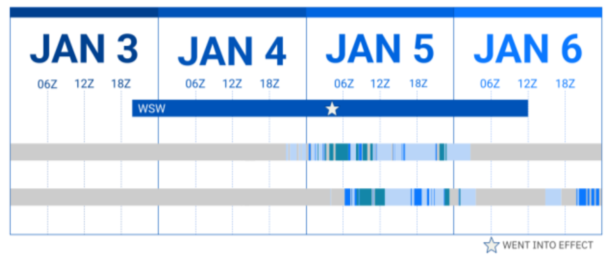

Figure 4 – Timeline of the WSW issued by the St. Louis, Missouri WFO.

The WSW in Figure 4 was issued January 3rd at 19:29Z, went into effect on January 5th at 04:00Z, and expired January 6th at 12:00Z. The ASOS stations were from Columbia Regional Airport and St. Louis Downtown Airport.

This WSW was the only warning that went into effect more than an hour after precipitation began and was also the warning to be in effect for the shortest amount of time at 32 hours. The ASOS station at the St. Louis Downtown Airport was the only station out of the 12 studied that did not report the ending precipitation as snow, but rather frozen precipitation. These stations were most inconsistent with the precipitation types reported as they flipped between snow, frozen precipitation, and freezing rain frequently.

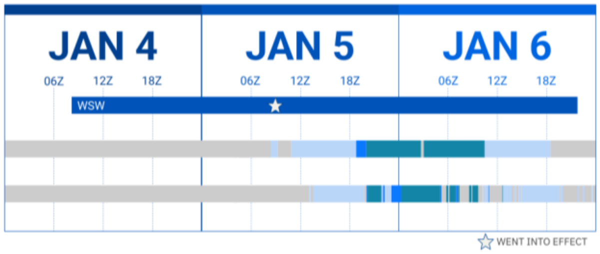

Figure 5 – Timeline of the WSW issued by the Louisville, Kentucky WFO.

The WSW above in Figure 5 was issued January 4th at 08:38Z, went into effect on January 5th at 09:00Z, and expired on January 6th at 21:54Z. These ASOS stations were from Louisville Muhammad Ali International Airport and Frankfort, Capital City Airport.

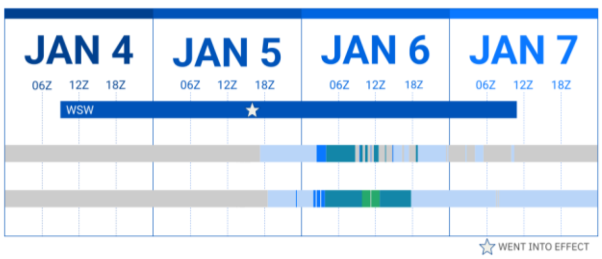

Figure 6 – Timeline of the WSW issued by the Charleston, West Virginia WFO.

The next WSW in Figure 6 was issued January 4th at 08:53Z, went into effect on January 5th at 16:00Z, and expired January 7th at 11:00Z. The ASOS stations were from Huntington, Tri-State Airport and Charleston, Yeager Airport.

This warning had the longest amount of time between warning issuance and precipitation start time at 32 hours and 22 minutes. It was in effect for a total of 48 hours, which is the longest of the six warnings considered for this study.

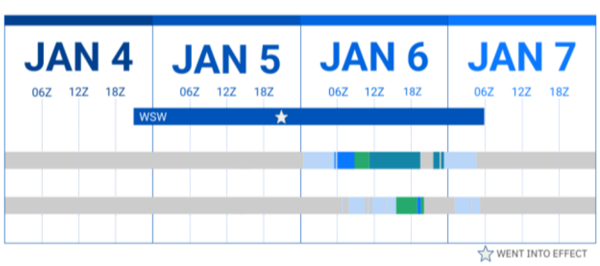

Figure 7 – Timeline of the WSW issued by the Wakefield, Virginia WFO.

The final WSW in Figure 7 was issued on January 4th at 21:01Z, went into effect on January 5th at 21:00Z, then expired on January 7th at 05:54Z. The ASOS stations examined within this warning were from Richmond International Airport and Ocean City Municipal Airport.

This warning had the second longest amount of time between warning issuance and precipitation start time at 27 hours and 19 minutes. Unlike the other five warnings, there were no precipitation reports from the ASOS stations examined once the warning had expired. These stations, along with one of the stations in Figure 6, were the only stations that had reports of rain. In general, the stations in Figure 7 were most consistent with the precipitation types reported and were also most frequent with precipitation reports with few reports of no precipitation in between the bouts of precipitation.

3.2 *FORECAST VERIFICATION*

In general, many of the WFOs had successfully forecasted ice accumulations for this storm. Out of the 12 ASOS stations considered for this study, seven had total ice accretions that were within the forecasted amounts. Four stations had total accumulations that were higher than forecasted, and the final station had a measured accumulation that was lower than the forecasted amount.

The Wichita, KS and St. Louis, MO WFOs were the most successful, with both ASOS stations considered for each WSW receiving ice accumulations within the forecasted amount. The Wichita, KS WFO forecasted total ice accumulations to be between 0.10 and 0.50 inch, and the two ASOS stations measured 0.28 inch and 0.47 inch. The St. Louis, MO WFO predicted ice accumulations to be up to 0.25 inch, and the two stations reported 0.21 inch and 0.12 inch, making the forecast a success.

Three out of the six WFOs used in this study produced forecasts that were correct for one out of the two ASOS stations considered for each WSW. Their forecasts are below.

The Kansas City, MO WFO had two separate predictions within their WSW, one for the southern counties and one for the northern counties. The forecasts were up to 0.20 inch and between 0.20 to 0.40 inch respectively. The northern forecast included an ASOS station that recorded 0.84 inch of ice accretion; however, the southern forecast saw a station record 0.25 inch, making the southern forecast verify.

The next WSW that verified for one of its two stations was issued by the Louisville, KY

WFO. This WFO also forecasted two separate totals, one being between 0.20 to 0.50 inch and the other between 0.20 to 0.60 inch. One station recorded 0.44 inch of accumulated ice, while the other recorded more than forecasted at 0.63 inch.

Charleston, WV was the final WFO that produced a successful forecast for one of the two ASOS stations considered within its WSW. Their prediction of up to 0.25 inch proved effective for one station, recording 0.19 inch, although it was too low for the other station that measured 0.34 inch.

The final WSW that was assessed was issued by the Wakefield, VA WFO. This office predicted accumulations of 0.10 to 0.20 inch and stated that locally higher totals were possible. Neither station considered reported accumulations within this forecast, as one measured 0.32 inch and the other a trace.

4. SUMMARY AND CONCLUSIONS

This study examined a winter storm that occurred from January 4th to January 7th of 2025. This storm traversed across a wide portion of the United States, impacting 28 separate CWAs. Six of these CWAs were assessed along with their WSW products issued by their corresponding WFOs. The timing of these products was considered, along with the predicted ice accumulations that were mentioned within the warnings. Further, precipitation type and ice accretion during these warnings were analyzed by using ASOS stations. The main conclusions of this study are the following:

- The time between warning issuance and the first precipitation report generally increased as the storm moved from west to east, indicating that the eastern WFOs had a better understanding of the incoming impacts compared to the western WFOs.
- The time that the warnings went into effect was frequently on par with when precipitation began to be reported, although it was common to see precipitation reports after the warning expired.
- WFO ice accumulation forecasts were accurate most of the time, and it was more common to see measured accumulations higher than forecasted compared to lower than forecasted.

Although the WFOs performed relatively well with this winter storm, there are still improvements to be made regarding winter storm forecasting.

A better understanding of winter storms and their corresponding impacts must be established to provide everyday people with ample warning time and accurate forecast information. As seen in this study, WSW lead times are shorter where the storm began, although improvements in lead times may be able to occur with a better understanding of these types of storms. More insight into winter storms may also be able to result in more accurate forecasts to improve the protection of lives and property.

5. ACKNOWLEDGMENTS

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DATA AVAILABILITY STATEMENT

ASOS observations were collected via https://mesowest.utah.edu/

IEM data were collected via https://mesonet.agron.iastate.edu/