Traffic Fatalities in Winter: An Evaluation of Weather Regimes and NWS Guidance During Killer Storms

JOSEPH BURZDAK*

National Weather Center Research Experiences for Undergraduates Program
Norman, Oklahoma

ANDREW ROSENOW

Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma and NOAA/OAR/National Severe Storms Laboratory
Norman, Oklahoma

HEATHER REEVES

Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma and NOAA/OAR/National Severe Storms Laboratory
Norman, Oklahoma

SHAWN HANDLER

Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma and NOAA/OAR/National Severe Storms Laboratory
Norman, Oklahoma

ABSTRACT

The effect of snow on roads constitutes a major threat to human health and safety, causing more fatalities in the US than all other types of high-impact weather (e.g. tornadoes, floods, lightning). The National Highway Traffic Safety Administration keeps a record of all automobile accidents resulting in fatalities. Included in this archive are a number of useful metadata parameters, such as the time of day, number of vehicles, the present weather observed by the reporting officer, etc. Herein, this metadata are examined as well as the prevailing synoptic forcing to better understand the factors leading to winter-storm-related road fatalities. A number of counterintuitive results were discovered. For example, fatalities do not occur more often in areas with infrequent snowfall or early in the season (i.e. in places and at times when drivers are less acclimated to snow). Rather, they have a democratic temporal and spatial distribution. While media attention is often focused on major pile-ups involving a large number of vehicles, the vast majority of fatalities involve just one or two vehicles. Despite the fact that primary and secondary roads are more likely to receive treatment and regular plowing, most fatalities (about 75%) occur on these types of roads. The meteorological conditions during crashes that occurred over two winter seasons are investigated. A large majority (about 77%) of the events happen within midlatitude cyclones or lake-effect snowbands. These are fairly predictable forms of weather, begging the question of what type of messaging was produced by the National Weather Service at the time of the accident. Only 45% of all accidents occur within a watch or advisory polygon, suggesting a more graduated approach for the warning/advisory system in winter storms, as opposed to binary polygons, has potential life-saving benefits.

1. Introduction

Winter precipitation (e.g. snow, sleet, freezing rain) constitutes a major hazard to life and property. These precipitation events have significant impacts on the surface transportation network, as even a small amount of winter precipitation can create problems for vehicles. On average, there are more deaths per year due to winter-related traffic accidents than all other meteorological hazards (Black and Mote 2015). Between the years of 1996 and 2011, Black and Mote (2015) found that there were an average of 817 winter-related traffic fatalities per year.

**Corresponding author address:* Joseph Burzdak, Western Connecticut State University, 181 White Street, Danbury, Connecticut 06810
E-mail: burzdak001@wcsu.edu

That was more than the average of 600 total weather-related fatalities per year reported in the National Oceanic and Atmospheric Administrations (NOAA) yearly publication *Storm Data* for those years. *Storm Data* is the National Weather Service (NWS) record of storms in the United States, including economic damages, injuries, and fatalities. The disconnect between winter-related traffic deaths and the fatality numbers presented in *Storm Data* comes from how Storm Data defines weather-related deaths. In *Storm Data*, vehicular crashes are explicitly categorized as an indirect fatality. Indirect fatalities are intentionally not included in the numerical fatality summaries produced from *Storm Data*. (NOAA 2018).

Perhaps due in part to their exclusion from official fatality numbers, the number of studies in the literature focusing on the interaction between winter weather and roadway fatalities is relatively small. Most studies that have examined these crashes have tended to focus on comparisons with a meteorological variable, such as quantitative precipitation estimate (e.g. Stevens et al. (2019)) This study seeks to improve the understanding of the meteorological conditions that contribute to these fatal crashes by determining which types of snow events cause the most fatal traffic crashes, and what types of warnings are currently being used to communicate the threat of snow to the public.

2. Data

This study uses Fatality Analysis Reporting System (FARS) data produced by the National Highway Traffic Safety Administration (NHTSA). The FARS dataset consists of standardized information collected for all fatal collisions involving motor vehicles on United States public roadways from 1975 to the present. These data are collected from police reports, state registration information, license and highway department files, and medical forms such as death certificates, coroners reports and EMS reports, which are then aggregated and quality controlled during the FARS production process. (NHTSA 2018).

The primary FARS data used in this study were the atmospheric conditions reported on the incident report at the time of the crash. Only cases that had an atmospheric condition of snow at the time of the crash were used. This was done to ensure that as many crashes as possible in this study occurred during winter precipitation. Work by Tobin et al. (2019) showed the accuracy of the atmospheric conditions data from FARS depended heavily on the precipitation type reported. For accidents with an atmospheric condition of snow, 77.87% of incidents agreed with nearby surface observations. Other winter precipitation types showed far worse agreement, with only 26.58% of freezing rain and 8.47% of sleet cases agreeing with nearby observations. As a result, this study will only examine different types of snow events, as the FARS reports of other winter precipitation types are far too uncertain to use. All cases where the police report indicated alcohol intoxication as a factor were also eliminated to reduce the number of variables that could have contributed to the crash. This study also used mosaicked WSR-88D radar data, as well as NWS warning or advisory data. The Weather Prediction Centers (WPC) operational surface analysis was used for the surface meteorological analysis.

3. Methods

For this study, the date, time, and location of each crash recorded in FARS was retrieved. Out of necessity, this study assumes that the FARS-reported date and time are correct, which introduces some uncertainty. The location and time were used to get the most recent radar image and surface analysis created prior to the crash time. If both the radar and surface observations in the region clearly did not support snow, the crash was removed from the dataset, as there was likely an error in entering the date/time that cannot be corrected for. However, this quality check only caught egregious date/time/location issues (e.g. snow in Brownsville, TX in August).

Using the meteorological information for each crash, the snow event coincident with the crash was classified into one of four categories: mid-latitude cyclone, lake-effect snow, non-lake-effect convective snow, and other. Precipitation was classified in the cyclone category if the radar or satellite presentation of the precipitation was contiguous with an analyzed cyclone on the Weather Prediction Center (WPC) surface analysis. The latest WPC analysis prior to the time of the crash was used to record the minimum pressure of the low-pressure center that was closest to the crash. However, if there was a parent low with a pressure more than 10 mb lower than the closest low-pressure, the pressure of the parent low was recorded instead.

The lake-effect category was assigned if snow initiated over a lake and winds from nearby surface observations crossed the lake. Non-lake-effect convective snow was any snow with a radar presentation of either isolated cells or a linear squall not fitting the definition of lake-effect snow. Finally, any case that did not fit into one of the previously mentioned criteria was classified as other. If multiple categories criteria fit, the category was assigned using the order of importance of cyclone, lake-effect, convective and then other. Therefore, cases which included lake enhancement within a cyclone would just be classified as a cyclone. The crash location and time was also compared to the archived Winter Storm Warnings, Blizzard Warnings, and Winter Weather Advisories in effect at the time of the crash to determine whether a warning or advisory was in effect at the time of the crash.

Winters of 2015-16 and 2016-17 Snow-Related Fatal Crashes

Types	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Cyclone	1	38	71	67	64	38	17	1	297
Lake Effect	0	5	16	25	10	1	1	0	58
Convective	0	7	16	17	15	12	2	2	71
Other	0	2	18	28	3	5	2	0	58
Total	1	52	121	137	92	56	22	3	484
Daily Avg.	0.02	0.87	1.95	2.21	1.61	0.90	0.37	0.05	0.99

TABLE 1. Combined number of fatal crashes that were reported as having snow falling at the time of the crash for the 2015-16 and 2016-17 winters combined, binned by month and type of snow event. The daily average for each month is also for both winters.

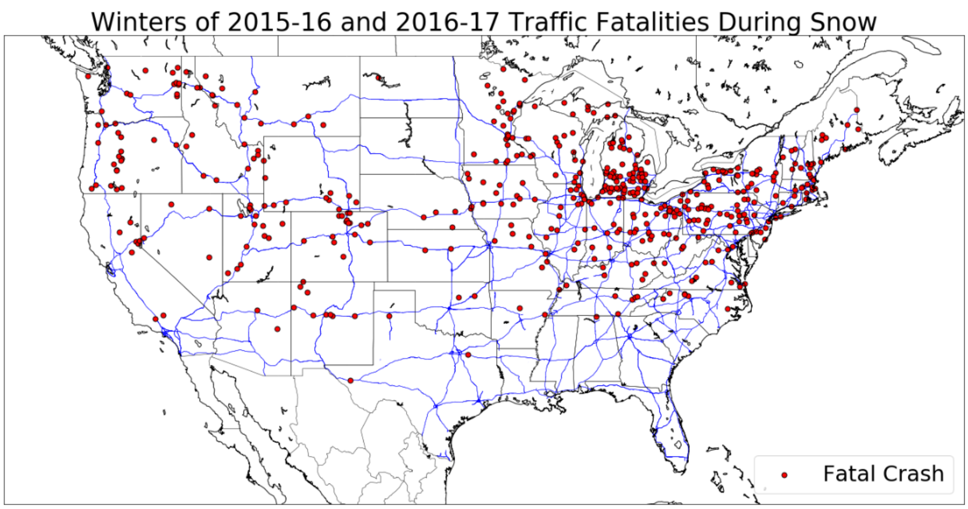

FIG. 1. Map of all the fatal crashes for the two winters in this study where the police report stated snow was falling at the time of the crash, excluding any with drug or alcohol involvement. Each dot represents one fatal crash, with a total of 484 over the two winters.

4. Results

For the two winters of FARS data analyzed in this study, (2015-16 and 2016-17), cyclones accounted for the majority of the fatal crashes during snow events within the database with a total of 297. The other categories were much smaller, with convective snow accompanying 71 fatal crashes, and lake-effect snow and other snow occurring during 58 crashes each (Table 1). There were 484 total crashes for all snow event types combined over the two winters. The majority of fatalities (about 72%) occurred from December to February, which is the heart of winter. To account for the varying number of days per month, the number of fatal crashes per day was calculated. This value peaked in January, with 2.21 fatal crashes per day. December and February had slightly fewer, with 1.95 and 1.61 fatal crashes per day respectively.

Cyclone-related fatal crashes accounted for the largest percentage of the monthly totals at either end of the season. In November, February, March and April, cyclones accounted for about 70% of the fatal crashes each month. Cyclones made up about 50 - 60% of the fatal collisions in December and January. This is due to the higher numbers of the other three categories events in December and January, rather than a lull in cyclone fatalities. Lake effect events skewed more towards the beginning of the winter season, with a sharp drop from January to February and then to March. That is when the lakes become too cold to create the lake-induced instability needed to initiate lake-effect convection. Convective snow, on the other hand, had no distinct peak throughout the season, which suggests the conditions that produce convective snow have less seasonal variability than those that produce lake-effect snow. The other category was only significant in December and January but determining the causes of these snow events is outside the scope of this study.

The locations of all crashes in the FARS dataset included in this study are shown in Figure 1. These locations are more concentrated in the Northeast and Great Lakes Regions, with another concentration in the mountains in the Western U.S. The Northeast and Great Lakes have an overlap between high population and large amounts of snow, making these regions susceptible to snow-involved vehicular crashes. The highest concentrations of crashes are immediately downwind of the Great Lakes, where the combination of lake effect snow and frequent cyclones increase the amount of time these regions experience snowy driving conditions. In the Western mountains, locations at higher elevations are colder and can receive snow more often, and orography can act to produce or enhance snowfall.

The majority of crashes, at 74.6%, occurred on major interstates and highways (Fig. 2). People tend to be traveling faster on these roadways, so accidents are more likely to cause a fatality. However, these roads are normally the first treated during a snow event, which should contribute to safer driving conditions, even at high speeds.

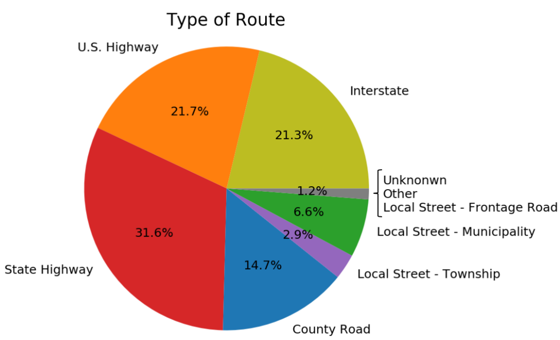

FIG. 2. Percent of all fatal crashes in this study based upon what type of road they occurred on.

The overall percentages of crashes with winter weather warning or advisory products valid at crash time are presented in Figure 3. Over the two winters analyzed, 54.3% of all the fatal crashes during snow had no active warning or advisory from the NWS. Only 14% of these crashes occurred during a large enough event to merit a Winter Storm Warning, with the remaining 31.6% of crashes happening with a Winter Weather Advisory in effect.

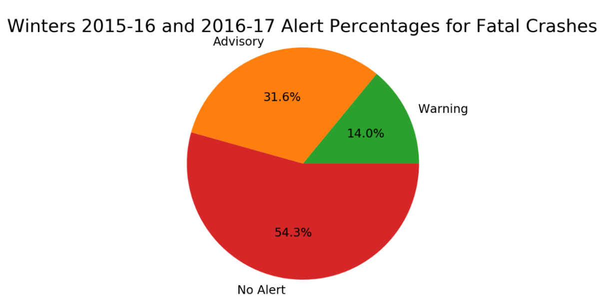

FIG. 3. Percentages of all the fatal crashes in this study based upon whether they happened while under a warning, advisory or neither from the National Weather Service.

Figure 4 shows the breakdown of the messaging from the NWS at the time of each crash based on event type. The majority of fatalities were during snow caused by mid-latitude cyclones, which are usually easier to forecast and therefore, should be better predicted than other categories of snow events. While cyclones did have the lowest percentage of fatal crashes without a warning or advisory, 45.8% of the crashes that caused fatalities still came with no warning or advisory (Fig. 4a). The other categories consist of meteorological setups that can be more challenging to predict than mid-latitude cyclones, or that typically produce less snow than a mature cyclone, and this is reflected in the warning/advisory percentages for these categories.

Lake-effect events were even worse, with 65.5% without warnings or advisories (Fig. 4b). Lake-effect events are usual well-forecast like cyclones, but the high percentage of no alert cases suggests that the majority of fatalities from lake-effect snow occur either in the lighter events or at the edges of the heavier bands, where there is not enough accumulation for an alert.

Convective events had the worst percentage without an advisory or warning at 83.1% of cases (Fig. 4c). These are the hardest events to predict, and usually do not produce the accumulations needed to qualify for an advisory or warning. It should be noted that the NWS has begun issuing Snow Squall Warnings, which could reduce the number of fatal crashes from convective snow without a warning in the future.

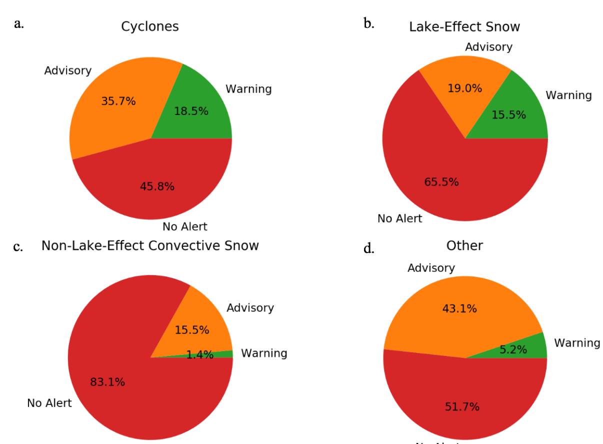

FIG. 4. As in Figure 3, except the crashes have been separated by type of snow event.

The FARS data also includes the number of vehicles in each fatal collision. Almost half of the fatal crashes during snow have two vehicles involved in the crash. However, the next highest, at over 40%, are single-vehicle crashes (Fig. 5). Crashes with more than two vehicles account for around 10% of all fatal crashes, meaning that large pileups that cause fatalities are quite rare compared to one- and two-car crashes, even though multi-car crashes receive the most media coverage.

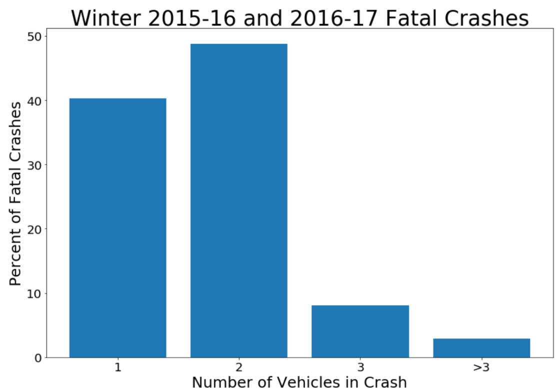

FIG. 5. Percentage of crashes in this study grouped by the number of vehicles involved in the crash.

5. Discussion and Conclusions

This study used the FARS dataset of fatal crashes in the United States to classify the type of snow events that cause the majority of fatalities on the road and where they occur. Each case was separated into one of the following categories: cyclone, lake-effect, convective or other. The number of vehicles involved and whether there was a warning or advisory from the NWS were also examined.

The majority of fatal crashes occurred during cyclones and during the height of winter and holiday travel in December and January. As cyclones are generally well-forecast, cyclones had the best percentage of cases that were accompanied by a warning or advisory. However, the majority of cases, regardless of type of event or month of the year, had no winter weather alert. This implies that the current system for alerting the public of hazardous snow events may not be sufficient to capture the range of conditions that contribute to fatal crashes during snow. Improving communications with the driving public for events below the current NWS criteria for warnings and advisories may be able to improve awareness of the danger these lighter events pose to drivers. Additionally, changes to the current warning and advisory system could reduce the number of collisions falling outside of a warning or advisory.

While major pile-ups consisting of dozens of cars can become national news, one-car crashes are surprisingly common in winter. These crashes accounted for more than 40% of all the cases, which means that for these crashes, any driver mistakes are being made by the driver of that vehicle and not an outside influence (e.g. another car). This result implies that another potential avenue for improving the number of fatal collisions is to ensure drivers understand their driving abilities in snow, and that it is not always another driver that makes the mistake that causes crashes.

Future work could include using a refined classification scheme of the different types of snow events, particularly one capable of being run automatically would be beneficial. An automated way of classifying snow events could be applied to predictions (e.g. numerical weather prediction) to give some guidance on the potential danger of a future event to drivers. The binary in/out approach of this study with regards to warnings and advisories could also be changed to see if the crash occurred in spatial or temporal proximity to a winter weather warning or advisory. That would clarify if making changes to the typical issuance times or locations for winter weather warnings and advisories would see more crashes being covered by these products. Additional quantitative data sets, such as precipitation rates or radar reflectivity, could be used to examine how precipitation intensity changes around the times of fatal crashes.

6. Acknowledgements

This work was prepared by the authors with funding provided by National Science Foundation Grant No. AGS-1560419, and NOAA/Office of Oceanic and Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA11OAR4320072, U.S. Department of Commerce. Radar and National Weather Service warning and advisory information was retrieved from Iowa State Universitys archive. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, NOAA, or the U.S. Department of Commerce.

References

Black, A. W., and T. L. Mote, 2015: Characteristics of winter-precipitation-related transportation fatalities in the united states. *Weather, Climate, and Society*, **7**, 133–145, doi:10.1175/WCAS-D-14-00011.1.

NHTSA, 2018: 2017 fars/crss coding and validation manual. National Highway Traffic Safety Administration, U.S. Department of Transportation Doc. DOT HS 812 559, 141–143 pp. Accessed on 22 May 2019. [Available online at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812559].

NOAA, 2018: Storm data preparation. National Weather Service Instruction 10-1605. Accessed on 15 July 2019. [Available online at https://www.nws.noaa.gov/directives/sym/pd01016005curr.pdf].

Stevens, S. E., C. J. S. III, S. Saha, J. E. Bell, and K. E. Kunkel, 2019: Precipitation and fatal motor vehicle crashes: continental analysis with high-resolution radar data. *Bulletin of the American Meteorological Society*, doi:10.1175/BAMS-D-18-0001.1, in press.

Tobin, D. M., M. R. Kumjian, and A. W. Black, 2019: Characteristics of recent vehicle-related fatalities during active precipitation in the united states. *Weather, Climate, and Society*, in press.