Drivers' Awareness of and Response to Two Significant Winter Storms Impacting a Metropolitan Area in the Intermountain West: Implications for Improving Traffic Flow in Inclement Weather

Kevin Barjenbruch,[a] Carol M. Werner,[b] Randall Graham,[a]
Cody Oppermann,[c] Glenn Blackwelder,[c] Jeff Williams,[c]
Glen Merrill,[a] Scott Jensen,[d] and Justin Connolly[d]

[a] *National Weather Service, Salt Lake City, Utah*
[b] *University of Utah, Salt Lake City, Utah*
[c] *Traffic Operations Center, Utah Department of Transportation, Salt Lake City, Utah*
[d] *Weathernet, Salt Lake City, Utah*

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ABSTRACT

Over the past several decades, Utah has experienced rapid population growth, resulting in increased demand on Utah's existing interstate and arterial infrastructure. In the Salt Lake City, Utah, metropolitan area, recurring traffic congestion (i.e., peak commute times) and nonrecurring congestion (weather related) result in an estimated average annual cost of $449 million. Recent Utah Department of Transportation (UDOT) studies have confirmed that inclement weather plays a significant role in nonrecurring congestion and associated negative impacts. In an effort to measure and potentially mitigate weather-related traffic congestion, a cooperative research study between academic (University of Utah), state [Utah Department of Transportation (UDOT)], federal (National Weather Service), and private sector (Weathernet) entities was undertaken.

Driver awareness surveys were conducted for two significant winter storms along the Wasatch Front urban corridor. Participants typically used media and personal sources for gathering weather and road information, with government sources (UDOT and NWS) used less frequently. Use of government and personal sources were significant predictors of behavior change. Satisfaction with all information sources was high. The most frequent commuting changes reported were route changes and shifts in travel schedule, especially leaving early to avoid the storm. Self-reported actions from interviewees were supported by measured changes in speed, flow, and travel time from the Performance Measurement System (PeMS) utilized by UDOT. The long-term goal is to use these results to provide insight into how the weather enterprise might more effectively communicate hazard information to the public in a manner that leads to improved response (change travel times, modes, etc.).

1. Introduction

Freeway and arterial commutes are easily slowed when unusual events—including inclement weather—disrupt the efficient flow of traffic. Research shows that storms are associated with multiple traffic problems, including reduced and variable traffic speeds, congestion, and driver stress, as well as crashes and their associated property damage, injuries, and even fatalities (Pisano et al. 2008). Although motorists may accommodate winter storms in various ways, little is known about what weather information they access or what influences their decisions of whether and how to alter their commutes to avoid weather-related problems. The purpose of the present project was to use interviews after two major winter storms in order to learn how drivers gathered information about the storm, what they knew about the storm before traveling, and whether and how they changed their travel plans in order to accommodate the storm. The survey data are complemented with actual traffic data to ascertain whether it corroborates any of the self-reported behavior change.

The project is a preliminary step in determining how drivers obtain winter storm information, how well forecasters communicate information, and what information

Corresponding author address: Kevin Matthew Barjenbruch, National Weather Service, 2242 West North Temple, Salt Lake City, UT 84116.
E-mail: kevin.barjenbruch@noaa.gov

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appears to influence driving decisions. This article begins with a brief description of an innovative collaboration for improving weather and road condition forecasting and information dissemination. It continues with a literature review on the practical and psychological problems that can occur when storms contribute to hazardous driving conditions, explains the research methodology and results, and ends with suggested communication strategies that clarify potential storm impacts and encourage drivers to adjust their commute schedule or mode of travel in order to reduce congestion and crashes during winter storms.

a. Utah weather partners

In 2001, the National Weather Service Forecast Office in Salt Lake City, Utah, was involved in a one-of-a-kind partnership involving public, private, and academic groups in support of the approaching 2002 Olympic Games (Horel et al. 2002). Out of this effort the NWS and the Utah Department of Transportation (UDOT) began a partnership across a broad spectrum of activities. They were joined by the private Weathernet group (formerly NorthWest Weathernet) embedded at the UDOT Traffic Operations Center; these parties are collectively referred to as Utah Weather Partners. The initial goal between NWS and UDOT was to maximize societal benefits with respect to safe and efficient vehicular travel (aligned with the NWS mission to protect lives and property and to enhance the nation's economy). Over time, the Utah Weather Partners endorsed the idea that consistent messaging among forecasters might result in better driving responses than varied or conflicting information.

During significant events, conference calls among the partners have been the primary method utilized to increase message accuracy and consistency. In addition to the conference calls, the partners have often collaborated using NWSChat (https://nwschat.weather.gov), an instant messaging program utilized by NWS personnel to share forecast and warning information, as well as to interact with partners and customers, such as other government agencies, emergency managers, and the media.

b. Weather-related traffic problems

The Utah Weather Partnership was motivated by concerns about the frequency and severity of traffic delays and vehicle crashes during inclement weather. Delays and crashes can be particularly severe when both visibility and vehicle control are impaired at the same time. One review of multiple studies found that across an array of indicators, such as average speed, saturation flow rate, traffic volume, etc., the reduction in flow due to inclement weather ranged from a modest 6% to a substantial 50% (Goodwin and Pisano 2003). Data from a case study of Denver, Colorado, commuters indicated that commutes during a major winter snowstorm averaged 60–90 minutes (instead of the typical 15–30 minutes), with 22% of participants reporting it took more than two hours to reach home (Drobot 2007).

Weather-related crashes exacerbate the delays and increase the costs and consequences of inclement weather events. In the period between 2002 and 2012, approximately 23% of crashes were weather related. In the United States, this translates into yearly weather-linked averages of over 6253 people killed, over 480 000 injured, and almost 1 million people involved in property-damage-only (PDO) crashes (U.S. DOT 2014). Nationally, annual weather-related costs associated with police-reported crashes are estimated to be $5.7 billion in property damage, $3.1 billion for medical care, and $8.2 billion for lost productivity (household and workplace). Extrapolating from police-reported crashes, the estimated annual totals for all weather-related crashes (both reported and unreported) are $13.3 billion for property damage, $7.2 billion for medical care, and $18.9 billion for lost home and workplace job productivity (Pisano et al. 2008; Blincoe et al. 2002). In their review of similar statistics, Maze et al. (2006) suggested that the consequences of driving in poor weather were more severe than the consequences of driving impaired, and they suggested poor weather was an adequate reason for closing roads in the interest of public safety.

Several researchers have analyzed traffic issues related to inclement weather and have identified a number of consistent patterns involving the relationship between storm types and the frequency and severity of crashes. A meta-analysis designed to assess differences in crashes in dry and wet weather ($n = 29$ studies) found that all levels of crashes increased with storms, whether the crashes included fatalities or injuries or were physical-damage-only (i.e., PDO) crashes (Qiu and Nixon 2008). The analysis showed that fatalities increased the least and PDO crashes increased the most. Such reductions in severity are often attributed to traffic patterns, especially storm-related reductions in traffic volume and speed (e.g., Call 2005, 2011; Eisenberg and Warner 2005). However, reduced severity does not mean there is a complete elimination of the chance of crashes. Indeed, the meta-analysis (Qiu and Nixon 2008) adjusted accident rates for reduced traffic volume and found that the accident and fatality rates still increased with precipitation, especially icy conditions. Similar results were obtained in a Canadian study (Andrey et al. 2013). Although snowy days can disrupt traffic, several articles reiterated the theme that crashes are less severe and fatalities less likely in inclement weather (Call 2005;

Eisenberg and Warner 2005; Qiu and Nixon 2008), possibly because of slower speeds in denser traffic or people deciding not to drive in poor weather (Call 2011).

As researchers continue to study storm impacts, a more nuanced picture is beginning to emerge. For example, Black and Mote (2015) examined storm-related traffic crashes in 13 U.S. cities and found no relation between storm type and crash frequency; however, they did find a relation between storm intensity and crash rates. An analysis of 25 years of crash data showed a significant increase for the first storm of winter, especially among elderly drivers (Eisenberg and Warner, 2005); however, other analyses did not find increased accident rates related to seasonal timing or driver experience (Andrey et al. 2013; Black and Mote 2015). In sum, multiple studies have underscored the importance of understanding relationships between inclement weather and a variety of traffic-related perturbations (delays, mild and severe crashes, and so on).

Although there is a wealth of data documenting the costs and dangers of winter driving, there is little research on how people gather information about weather and road conditions and whether and why they decide to alter their driving in stormy conditions. A case study of a severe winter storm in Denver used an online survey to query drivers about their decisions of whether to drive (Drobot 2007). The case was particularly interesting because of the severity of the storm and because the event began after the morning commute, potentially leaving commuters ignorant of, or complacent about, the impending storm. Peak snowfall rates were 5–7.5 cm (2–3 in.) per hour, with 30–61 cm (1–2 ft) of snow accumulating by evening. Survey responses indicated that roughly half of the participants (52%) had stayed home and most of this group (65%) had made that decision independently rather than because their school or business had closed. For the trip home, most participants departed earlier than usual, 37% by their own decision and 39% because their business or school had closed; 24% left at their usual time.

There is considerable research on how people gather information and prepare for hurricanes and tornadoes; however, there have been few studies on the impacts of winter storm forecasts on drivers' decisions. This project provides an initial investigation of the sources drivers used, how satisfied they were with the information received, and how that information informed their driving decisions. This information was compared to content analyses of televised and online NWS weather forecasts to see how early a storm was forecast, how specifically the arrival time and severity were forecast, and whether specific advice was given for how drivers should respond to the storm. Interviewee reports were also compared with traffic volume and speed data from the Utah Department of Transportation Performance Measurement System (Choe et al. 2002; L. Dunn 2010, poster presentation; Varaiya 2001) as a check on the accuracy of self-reported behaviors (modifying commute times, etc.).

The research questions were guided by knowledge of available weather sources and prior research on how people prepare for weather events, such as tornadoes and hurricanes. Some research suggests that when people are uncertain about potential storm impacts, they gather information from multiple sources and compare location, timing, and other details in order to decide what to do (Hayden et al. 2007). To assess use of multiple weather information sources, participants were asked which they had used. Another area of exploration was to assess whether people who reported using mass transit previously would be more likely to use mass transit during the storm. People unfamiliar with using mass transit are unlikely to choose to try out mass transit during a storm or other contingencies (Brown et al. 2003). A final question was whether experienced winter drivers would be more likely to drive because they had more confidence in their ability to negotiate the storm or would they avoid driving in the storm because they were more aware of potential congestion and dangers?

In the Salt Lake City metropolitan area, recurring traffic congestion (AM/PM peak commute times) and nonrecurring congestion (weather related) result in an estimated average annual cost of $449 million (Schrank et al. 2012). In Salt Lake County, the core location of the current study, weather-related traffic delays can be particularly difficult because many people drive more than 20 miles one direction between home and work. Commutes from downtown to the study area extremes are 16 mi (southern Davis County), 23 mi (southern end of Salt Lake County), and 31 mi (Summit County), commutes that are estimated to take approximately 30–40 minutes depending on traffic flow. When a storm arrives during the peak commute period, it can take individuals two or more hours to complete their commutes. These broad statistics, while compelling, overlook the personal costs to the hundreds of thousands of vehicles caught in traffic delays annually. Extensive research on freeway and arterial commuting shows its psychological and physical health costs in general, but especially when there are unexpected delays (Evans et al. 2002).

On a fair weather day during January 2013, on the same day of the week as the two events studied, 109 crashes were reported in the study area. In contrast, for the first storm in this study, there were 249 reported crashes, and for the second storm, which was the worst ice storm in almost 30 years, there were 557 reported crashes (Table 1).

TABLE 1. Number of crashes in a 24-h period for a nonstorm day and for storms 1 and 2.

Event	Davis	Salt Lake	Summit	Total
Nonstorm day (17 Jan 2013)	15	91	3	109
Storm 1 (10 Jan 2013; snowstorm)	46	194	9	249
Storm 2 (24 Jan 2013; ice storm)	191	357	9	557

Added to this are the material and hospital costs associated with crashes. Reducing the number of vehicles on the road during storms has potential to greatly improve traffic flow and reduce crashes and injuries.

There were several important differences in the two targeted storm events, including forecast confidence, lead time, message cohesiveness, precipitation type, and the time of day in which the impact occurred. The first event was a heavy snowstorm that was predicted with high confidence 80 h in advance; Utah Weather Partners' messages highlighted potential evening commute impacts for several days in advance of the event. The second event was a freezing rain event that affected a morning commute. The severity of the storm threat could not be confirmed far in advance and Utah Weather Partners could only begin forecasting the potential for travel impacts associated with freezing rain 18 h before event onset, although they had been messaging about possible impacts on the commute from snow for several days. These differences in forecast lead time and associated messaging might encourage more drivers to modify their driving behavior (e.g., change commute times) for the snowstorm than for the freezing rain event.

2. Methods

a. Study area

UDOT was interested in understanding traffic patterns on particular freeways in Salt Lake County, the major metropolitan area of Utah. The county comprises 807 mi^2 and includes 721 mi of roadway that are maintained by UDOT (https://www.udot.utah.gov/ugate/; ESRI 2014). It attracts drivers from several adjacent and even distant counties, but UDOT was particularly interested in understanding the reasoning and behaviors of drivers from Salt Lake County, southern Davis County, and the Park City area of Summit County. Accordingly, analysis of traffic data and commuter interviews were restricted to these areas (Fig. 1).

b. Storm selection

The goal of the research was to select two major storms with different forecast confidence and lead times that might result in different kinds of driving challenges (precipitation rate, snow-covered roads, wet conditions, time of day, etc.). This would potentially maximize differences in drivers' experiences between the storms and should provide information about potential variability in driver responses. Event selection was done jointly by the Utah Weather Partners. Details of the anticipated storm impacts on surface transportation were disseminated through separate NWS and UDOT product and service streams. The messaging in these products and services was developed cooperatively by all Utah Weather Partners.

The first storm was associated with a band of heavy snow that moved into the Salt Lake City metropolitan area around 2200 UTC (1500 MST) 10 January 2013. With cold road surface temperatures and high anticipated snowfall rates, it was expected that snowfall would rapidly accumulate on area roadways during the evening commute. Confidence was high that this event would have a significant negative impact on driving conditions; therefore, several days before its arrival, forecasters issued products and statements notifying the public on its possible impacts. By late evening, most of the study area had received 10–20 cm (4–8 in.) of snow with the majority of that accumulating during the evening commute.

The second storm was a freezing rain event that began shortly after 1200 UTC (0500 MST) 24 January 2013. The precipitation intensity was expected to be much lower than in the 10 January storm. Additionally, it was anticipated to be a light snowfall event until approximately 18 hours before onset. Given the lighter precipitation intensity expected, forecasters were not as bold with their descriptions of commute impacts in the days leading up to the storm. When it became evident that the precipitation type might be freezing rain, descriptions of its impact on the morning commute became much stronger, but with much less advance notice than for the snowfall event. Slightly more than 2 mm (2.29 mm or 0.09 in.) of freezing rain were recorded at Salt Lake City International Airport, the worst freezing rain event in the Salt Lake Valley since at least the early 1980s. This event also followed a period of prolonged below-normal temperatures, so that the roads were cold, resulting in extremely icy conditions and contributing to over 550 crashes in the metropolitan area.

c. Survey sampling method and informed consent

Both telephone surveys were conducted by a professional survey firm using random digit dialing of landline and purchased cell phone numbers; cell phone numbers comprised half the target phone numbers. Phone calls began the morning following each event and lasted for seven full days. If the person was not driving at the time of the call, then the surveyor asked four

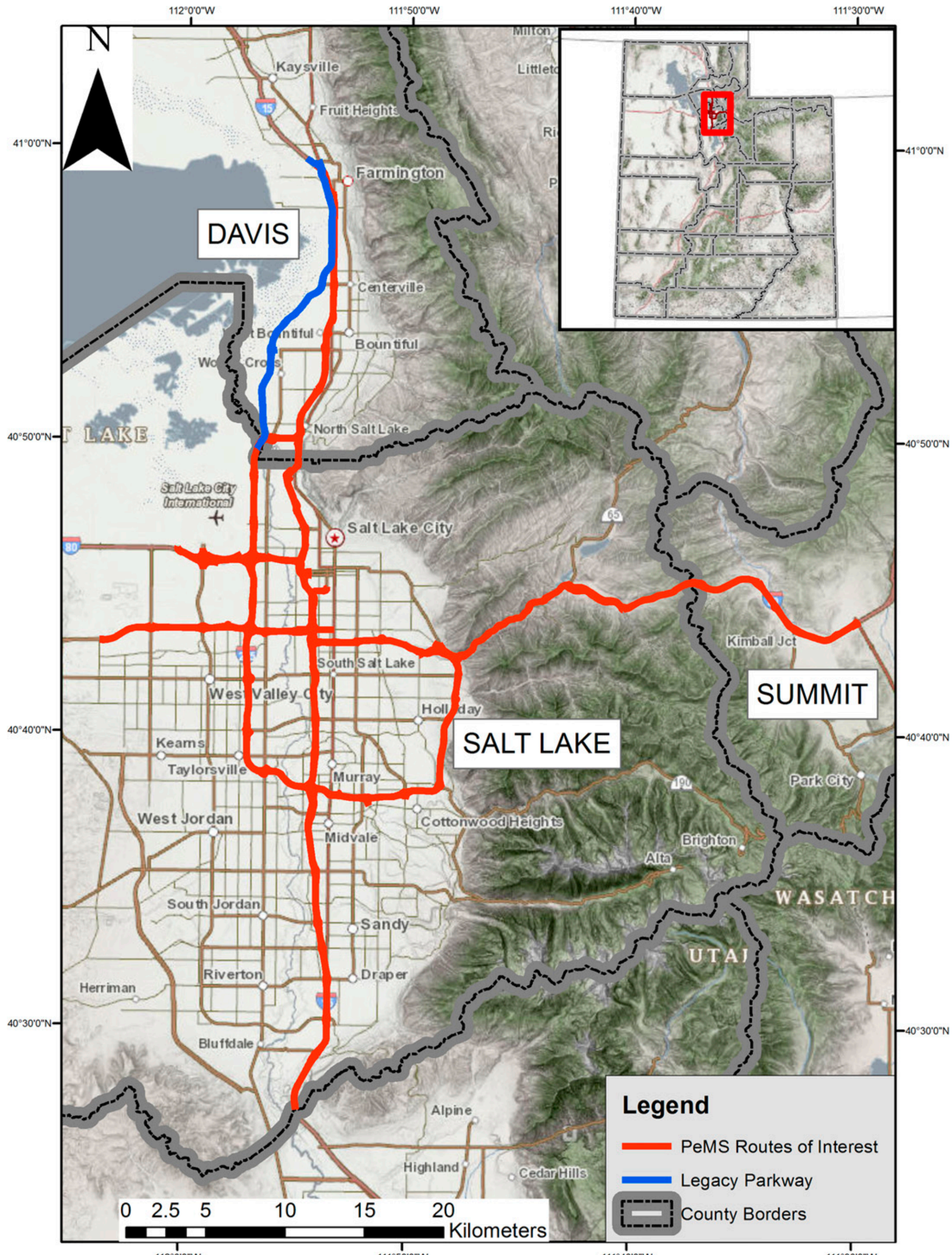

FIG. 1. Map of the Salt Lake City area in northern Utah (see inset) that highlights the routes included in the traffic analysis and commuter surveys. Routes that include PeMS traffic sensors are highlighted in red and blue. County names (Davis, Salt Lake, and Summit) and borders (thick gray lines encompassing black dashed lines) are included for reference.

eligibility questions to determine whether the respondent was 1) 18 years or older, 2) licensed to drive in Utah, 3) a regular driver in Salt Lake County, and 4) living in one of the three target areas. Respondents who answered yes to all four questions were deemed eligible to participate and were read informed consent agreements from both the university's Institutional Review Board and the federal Office of Management and Budget. The survey was administered immediately to respondents who were eligible and willing to participate. For storm 1, there were 402 participants with a response rate of 0.23; for storm 2 there were 404 participants with a response rate of 0.30 [using response rate Eq. (3) in Smith (2011)].[1] Missing information yielded variable sample sizes for many of the analyses. To increase the ability to use survey responses to help interpret driver behavior, only individuals who drove regularly in the study area were included in the sample and the survey responses were weighted to reflect the population using recent census data.[2]

d. Survey topics

The primary purposes of the survey were to 1) assess the weather information that drivers possessed prior to and during a storm; 2) determine sources of weather and road information; 3) explore uses, specifically modification of travel and/or commute plans, based on event information; and 4) examine perceptions of storm impacts and severity, including driver satisfaction with information provided. Respondents were queried about their use of three general types of weather sources: personal sources (could see the snow or freezing rain; checked social media; got weather information from a friend, family member); media sources [local radio, local television (TV), national TV]; and multiple government sources (NOAA Weather Radio All Hazards (NWR), UDOT website, UDOT smartphone application, UDOT 511 service, NWS website).

To assess the role of prior experience in using alternative transportation for the storm, participants were asked whether they had used mass transit or carpooled in recent years. Their responses were compared to the use of these alternatives the day of the storm. Finally, the degree to which respondents seemed to triangulate information was simply assessed by summing up all the reported sources as a rough index of information seeking.

Respondents were then offered four possible ways of responding to the storm and asked which they had used: stay home because of the storm; change the route to avoid road problems; change their travel schedule by leaving early or late; use mass transit instead of driving. Each response was coded no (0) or yes (1) for analyses.

After these judgments, respondents were asked to assess how prepared they had been for the storm using three questions: 1) I understood the possible impacts of the winter storm based on the information that I had (responses ranged from 1 = completely disagree to 5 = completely agree, with 3 = neutral); 2) Across all your sources of information, how satisfied were you with the information that you received about the winter storm and driving conditions? (responses ranged from 1 = very dissatisfied to 5 = very satisfied, with 3 = neither satisfied nor dissatisfied); and 3) Which of the following best represents your feelings about the storm's severity? (response options were as follows: The storm was less severe than I expected; the storm was more severe than I expected; and the storm was as severe as I expected). These three questions did not form a scale (Cronbach's alpha = 0.59) and were analyzed separately.

e. Content analyses of weather alerts and news reports

Televised weather forecasts were obtained from local television stations for 3 days before and the day of each storm. Information provided about the storms was rated on four categories relevant to driving decisions: arrival time, likely to impact study area, safety instructions to drivers, and anticipated severity for driving. Similar content analyses were conducted on the NWS information for the local area, including hazardous weather outlooks and winter storm watches/warnings/advisories (available from the Iowa Environmental Mesonet at mesonet.agron.iastate.edu/wx/afos/list.phtml). For both television and NWS, statements were rated from 0 to 2: 0 = category not mentioned; 1 = vague mention

[1] For storm 1, the snowstorm, there were 5561 working residential phone numbers available (randomly dialed or purchased cell phone numbers). Of these, 12% who answered did not meet the eligibility criteria, 29% hung up or refused to participate, 7.2% (n = 402) participated, and the remaining 52% had not been contacted by the time the survey sampling ended. This response rate was 0.23 [using the response rate Eq. (3) in Smith (2011)]. For storm 2, the ice storm, there were 5361 working residential phone numbers available (randomly dialed or purchased cell phone numbers). Of these, 9% who answered did not meet the eligibility criteria, 29% hung up or refused to participate, 7.5% (n = 404) participated, and the remaining 54% had not been contacted by the time the survey sampling ended. This yielded a response rate of 0.30, using the same American Association for Public Opinion Research (AAPOR) formula.

[2] Only respondents who indicated they were from the target counties were surveyed; therefore, 2010 census data for those counties were used as the reference population. Weights were constructed based upon age, sex, and race (non-Hispanic white or minority). To obtain stable weights, we desired at least three respondents for each sample in the categories age, sex, and race; empirical examination yielded the three age categories of 18–33, 34–46, and 47 or older, for a total of 12 groupings for each sample. Because of missing data for any of the three variables, census weightings could not be constructed for 14 of the 402 respondents in storm 1, the snowstorm sample, nor for 35 of the 404 respondents in storm 2, the freezing rain sample. Final weights ranged from 0.70 to 3.93 for the storm 1 sample and from 0.59 to 4.09 for the storm 2 sample. For example, for storm 1, the responses of older white males were weighted 0.59, reflecting their overrepresentation in the sample compared to their presence in the population. This weight of less than 1.0 would decrease their influence on the results, so that the results would better represent the total population (rather than the sample). In contrast, for storm 1 the responses of older ethnic males were weighted 3.13, increasing their impact on the survey results. More details are available online (https://www.aapor.org/special-pages/search.aspx?searchtext=weights&searchmode=anyword).

(e.g., driving advice: "everybody be careful out there"; timing: "by tomorrow afternoon we'll have snow"); 2 = specific mention (driving advice: "So, if you can, plan to leave early, or if you don't have to drive tomorrow, just let the system pass through"; timing: "Should begin about 6 a. m. Thursday and continue until about noon"). The televised forecasts were repetitive, and specificity could vary across the broadcast; ratings were averaged within each forecast. NWS forecasts did not repeat information, yielding single ratings per forecast.

f. *Objective measures of traffic*

Actual driver behavior was assessed using measured changes in speed, flow, and travel time via the Performance Measurement System (PeMS) utilized by UDOT. Two figures are provided for each event. The upper figures in each pair (Figs. 2a and 3a) show data for the entire study area and are based on vehicle miles traveled. These figures illustrate the number of cars on the road and when traffic was at its peak. The lower figures in each pair (Figs. 2b and 3b) are based exclusively on data from the area most affected by both storms, the northernmost freeway in the study area. These figures show average traffic speeds to trace the impact of the storms over time.

3. Results

a. *Content analyses of televised and NWS forecasts*

Content analyses for storm 1, for both television and NWS (Table 2), show that the first storm was forecast fairly accurately in advance of its Thursday arrival. Between Monday and Thursday, specificity increased from "the storm will arrive some time Thursday" to "the storm will arrive Thursday afternoon, likely between 3 and 5 p.m. and the commute is highly likely to be disrupted by the storm." Thus, for storm 1, people paying attention to televised weather reports or NWS online messages would have had several days to plan and perhaps organize their schedules for coping with the storm.

In contrast, the impact of the second storm, which brought freezing rain to the northern part of the study area, was generally underforecasted. Even the evening before the storm, the media forecasts emphasized that there was still considerable uncertainty about the type of precipitation and how extensive any snow or freezing rain might be. It was not until the morning of the storm, when ice was on the ground, that media forecasts emphasized the potential for serious travel difficulties. The NWS information emphasized the potential impacts of the storm more clearly several days in advance of the event and was more accurate with respect to arrival time and location. However, NWS forecasts also demonstrated uncertainty with respect to the precipitation type and did not mention the potential for freezing rain until approximately 18 hours before the onset of the event.

The general trend for both storms is increasing specificity as lead time before the storm decreases, as shown by significant "prior to versus day of" differences column in Table 2. (details for significant effects are in the note for Table 2[3]). With respect to comparing the two storms, the only significant difference was in the televised forecasts, where the second storm was described as more severe, especially on the day of the storm, $F(1, 13) = 4.95$, $p < 0.04$, partial $\eta^2 = 0.28$.

b. *Survey responses*

The focus of the study is the relationship between information gathered and behavior change; therefore, we focused on the information respondents had gathered about the storm and whether and how that related to changes in travel behaviors. Despite the differences in forewarning for storms 1 and 2, survey results for the two storms were similar. To simplify the presentation, the two surveys were combined into a single analysis except for the questions about how prepared respondents felt for the two storms.

1) DO PEOPLE GATHER WEATHER INFORMATION AND FROM WHAT SOURCES?

To assess total use of information sources, we computed a sum indicating the total number of sources each participant had used prior to traveling (NWS website, local TV weather reports, etc.). These data are presented in Table 3 and show that most participants used two to four sources, with the mean number of sources being 2.80. Thus, participants were fairly active in seeking information about the storms.

2) DO PEOPLE CHANGE THEIR BEHAVIORS AFTER GATHERING INFORMATION?

Participants indicated whether they had done any of four specific behaviors that might reduce congestion and improve traffic safety (Table 4). Of all respondents, 34% indicated that they had not changed their travel behavior at all, even though all but three people reported seeking information about the storm. This is significant, as a majority of the respondents indicated that they

[3]A note on statistics in this manuscript: F, t, and r are different kinds of statistical tests, each indicating the amount of relationship between predictor(s) and an outcome. Where p = "likelihood this difference was due to chance"; p values of 0.05 or smaller support the view that the difference is meaningful, did not occur by chance. Partial η^2 and R^2 both indicate the degree of relationship between predictor and outcome, or the percentage of variability in the outcome measure that is accounted for; higher values indicate a stronger relationship between the predictor and outcome.

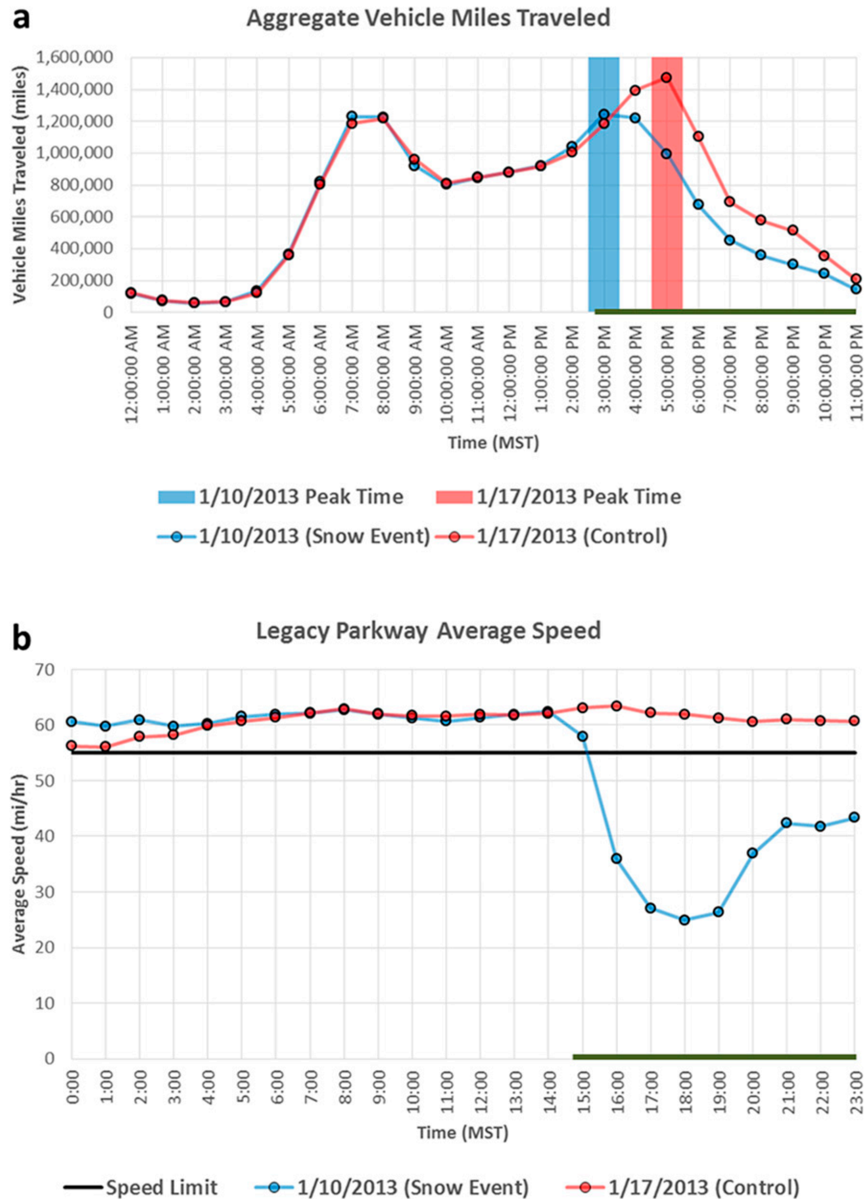

FIG. 2. Traffic data collected by PeMS. (a) Aggregate vehicle miles traveled by hour in the study area on 10 Jan 2013 during a snow event (blue line) and on a control day on 17 Jan 2013 (red line). Vertical shading indicates the time of the peak commute during the snow event (blue) and on the control day (red). (b) Average speeds by hour on Legacy Parkway, which is a route in the northern portion of the study area, on the 10 Jan 2013 snow event (blue) and on the control day, 17 Jan 2013 (red). Thick green horizontal lines at the bottom of both (a) and (b) represents the period of precipitation at the Salt Lake City International Airport.

modified their behavior to accommodate the impact of the storms. Among those who did change their commuting behavior, the most frequent change was a shift in travel schedule, with smaller percentages reporting they had changed routes, decided not to travel at all, or used mass transit. Most respondents indicated they had made only one change in behavior (Table 5).

3) ARE PARTICULAR WEATHER INFORMATION SOURCES MORE LIKELY TO BE USED FOR DECISION-MAKING?

To compare sources for their relation to behavior change, we computed three sums for each participant, one showing the total number of government sources

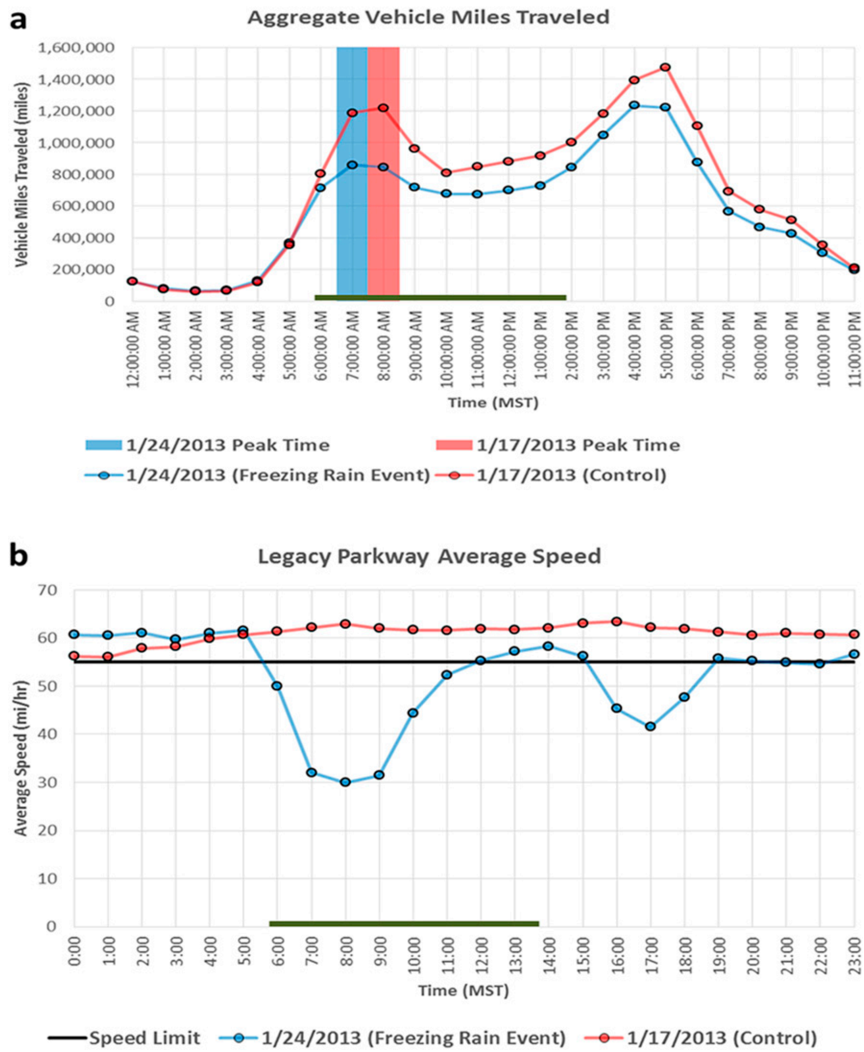

FIG. 3. Traffic data collected by PeMS. (a) Aggregate vehicle miles traveled by hour in the study area on 24 Jan 2013 during a freezing rain event (blue line) and on a control day on 17 Jan 2013 (red line). Vertical shading indicates the time of the peak commute during the freezing rain event (blue) and on the control day (red). (b) Average speeds by hour on Legacy Parkway, which is a route in the northern portion of the study area, on the 24 Jan 2013 freezing rain event (blue) and on the control day, 17 Jan 2013 (red). Thick green horizontal lines at the bottom of both (a) and (b) represents the period of precipitation at the Salt Lake City International Airport.

consulted (highest possible = 4), another showing the total number of personal sources consulted (highest possible = 3), and the third showing the total number of media sources consulted (highest possible = 3). As Table 6 shows, participants typically used media (local radio/local and national TV) and personal sources (family/friends/social media) for gathering weather and road information. More than three-fourths of participants reported using these sources. In contrast, government sources (UDOT and NWS products and services) were used considerably less frequently, with approximately one-fourth of respondents reporting they had used online government sources.

4) ARE PARTICULAR WEATHER INFORMATION SOURCES MORE LIKELY TO BE RELATED TO BEHAVIOR CHANGE?

A regression analysis was used to examine whether the use of different information sources could be used as a predictor of behavior change. Preliminary analyses included all the demographic information. However, most demographic variables did not predict behavior

TABLE 2. Content analyses of TV weather and NWS online forecasts three days prior to and day of storm.

TV weather forecasts: mean rating (std dev)					
	Storm 1		Storm 2		
	3 days prior ($n = 4$)	Day of ($n = 4$)	3 days prior ($n = 3$)	Day of ($n = 6$)	Prior to vs day of
Specificity of arrival time	1.25 (0.50)	2.00 (0.00)	1.00 (1.00)	1.50 (0.84)	$p < 0.10$
Specificity of location	1.00 (0.00)	1.25 (0.50)	0.67 (0.58)	0.67 (0.52)	$p = 0.60$
Safety instructions to drivers	0.00 (0.00)	0.50 (1.00)	0.00 (0.00)	1.50 (0.55)	$p < 0.005$
Severity of storm for driving	0.00 (0.00)	1.00 (1.16)	0.33 (0.58)	2.00 (0.00)	$p = 0.001$
NWS online forecasts: Mean ratings (std dev)					
	Storm 1		Storm 2		
	3 days prior ($n = 11$)	Day of ($n = 4$)	3 days prior ($n = 5$)	Day of ($n = 4$)	Prior to vs day of
Specificity of arrival time	1.00 (0.00)	1.00 (0.00)	1.20 (0.45)	1.25 (0.50)	$p = 0.84$
Specificity of location	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	—
Safety instructions to drivers	0.64 (0.81)	1.50 (1.00)	0.40 (0.89)	1.00 (1.15)	$p = 0.09$
Severity of storm for driving	1.91 (0.30)	2.00 (0.00)	1.60 (0.55)	2.00 (0.00)	$p = 0.11$

Note: Numeric code for ratings: 0 = no mention; 1 = vague mention; 2 = specific information. Column 6 shows p values based on ANOVAs. A dash (–) means there is no variability for analysis. For TV reports, prior to vs day of: safety advice, $F(1, 13) = 11.56$, $p < 0.005$, partial $\eta^2 = 0.47$; severity, $F(1, 13) = 19.81$, $p < 0.001$, partial $\eta^2 = 0.60$.

change; therefore, only two demographics were retained (participant sex and years of experience driving in poor weather conditions). The final model predicted the total number of changed behaviors from five predictors: the number of government sources, the number of media sources, the number of personal sources, participant sex, and years driving in poor weather conditions. Despite being the least-used source, results showed government sources to be a significant predictor of change, as was information from personal sources (Table 7). Using media sources did not have a significant relation to behavior change. The two demographic variables were related to change: women were more likely than men to change their behaviors and respondents with more years of driving experience were less likely to change their behaviors (note the negative coefficient). The overall model was significant and accounted for almost 6% of the variance in the outcome, with respect to the total number of prudent behavioral changes, $F(5, 625) = 8.75$, $p < 0.001$, MSE = 0.46, adjusted $R^2 = 0.058$.

5) DO DIFFERENT WEATHER INFORMATION SOURCES RELATE TO DIFFERENT KINDS OF BEHAVIORAL CHANGES?

The next question examined whether gathering information from specific sources (government, personal, or media) relates to making different kinds of prudent changes. Table 8 shows these correlations and indicates that, indeed, the use of certain sources is related to different kinds of behavior. Respondents who used one or more *government sources* were more likely to change their routes (marginally significant). Respondents who used one or more *personal sources* were more likely to change their schedule (significant) and or to decide not to travel at all (marginally significant). Those who used media sources were more likely to change their schedule (marginally) and to travel instead of staying home (significant). These correlations do not indicate that particular information caused these changes in behavior, only that different sources are related to certain behaviors. Self-selection is a viable causal explanation for these relationships; that is, people inclined to change their route might choose to use government sources, whereas people inclined to travel might choose to use media sources.

6) IS MEDIA INFLUENCE ON PRUDENT BEHAVIOR OBSCURED BY OVERLAP WITH OTHER SOURCES?

Several analyses showed no relationship between media use and prudent behavior change. As noted previously, most respondents indicated that they utilized

TABLE 3. Percent of respondents ($N = 654$) using zero and more sources.

No. of sources	0	1	2	3	4	5	6	7	8
Percent using each number	3	14	26	28	20	7	2	1	0.1

TABLE 4. Percent of respondents making each type of change in behavior.

Type of behavior change	%
Change schedule	62
Change route	26
Stay home	13
Use transit	6

TABLE 5. Percent of respondents making 0 to 4 changes in behavior. The 4 possible changes were change schedule, change route, not travel, and use mass transit.

No. of changes (from 0 to 4 possible)	Percent reporting 0 to 4 changes
0	34
1	51
2	15
3	1
4	0

multiple sources (as many as eight sources; Table 3), especially media sources (Table 6). However, the regression analysis (Table 7) provided compelling evidence that media sources were not related to the total number of prudent changes in commuting behavior (''sum of all changes''). Instead, Table 8 shows that media sources were actually related to a greater likelihood of driving instead of staying home. Thus, a simple conclusion is that the use of media sources does not lead to substantial behavior change, but their use is correlated to driving (albeit earlier than usual). One possibility is that media sources contribute to using alternatives to driving, but this contribution is obscured by summing the three information sources when predicting prudent changes (media, personal, and government sources).

Two additional pieces of information provide evidence that too much overlap among the sources is not an issue. First, the simple correlation between using media sources and the outcome, the sum of the behavioral changes, is very small (0.01; Table 7), supporting the idea that media use is not related to prudent changes to accommodate the storm. Second, the three sources (media, personal, and government) were not correlated with each other (Table 9), and multicollinearity indicators have acceptable values (all tolerance values > 0.90 and condition indices < 10). Thus, the regression should be able to show independent relations to prudent behavior change. In sum, although most people used media sources, that source was not associated with prudent behavior change.

7) MASS TRANSIT USE

If people would use rail-based transit instead of driving during a storm, it would reduce the number of vehicles on the road and reduce the potential for crashes. As shown in Table 4, only 6% of participants reported using mass transit as an alternate to driving on the day of the storm, indicating there is potential to increase this behavior in future storms. An exploratory analysis predicted ''used transit'' from all the demographics, prior experience using mass transit, and prior experience as a carpooler. There were two significant predictors, previous use of mass transit and being a student [mass transit use, Beta = 0.12, $t(414) = 2.46$, $p < 0.01$; student status, Beta = 0.12, $t(414) = 2.32$, $p < 0.02$]; the model was significant, $F(14, 414) = 2.63$, $p < 0.001$, with an adjusted R^2 of 0.05.

8) HOW DID RESPONDENTS RATE THEIR PREPAREDNESS FOR THE STORM?

Because of the similarity in responses, this analysis is an aggregate of survey feedback from both storms. As final measures of the perceived impact of information, three questions asked respondents how prepared they were, based on the information they had gathered about the storm. These questions asked 1) the extent to which they understood the possible impacts of the storm, 2) their degree of satisfaction with the information obtained, and 3) whether they perceived they had accurate information about the storm's severity (storm was less severe, as severe, or more severe than expected). Chi-square analyses indicated that responses to the first two

TABLE 6. Use of personal, media, and government information sources.

Source category	Percent reporting use of source	Source subtypes	Percent reporting use of source subtypes
Personal	80	Personally observed	59
		Friend or family	48
		Social media	15
Media	77	Local TV	57
		Local radio	43
		National TV	22
Government	27	NWS website	12
		UDOT website	12
		UDOT smartphone application NOAA Weather Radio All Hazards	4

Note: The sum of the percent of individuals utilizing source subtypes (friend or family, social media, etc.) exceeds the total percent using the broader source category (e.g., personal, media, government) as a result of users accessing more than one of the source subtypes for a given source category.

TABLE 7. Regression of each information source predicting sum of behavioral changes.

Variable	*B* Strength of relationship	SE *B* Variability	*B* (Beta) Standardized	$t(621)$ statistical test	Simple *r* Correlation coefficient
Government sources	0.134	0.043	0.12	3.15[a]	0.11[a]
Personal sources	0.078	0.033	0.09	2.35[a]	0.13[a]
Media sources	0.015	0.032	0.02	0.48	0.01
Sex	0.163	0.056	0.12	2.94[a]	0.12[a]
Years driving in winter weather	−0.002	0.006	−0.15	−3.77[a]	−0.17[a]

[a] $p < 0.05$.

Note: SE is standard error. A correlation coefficient (column 6) shows how much two variables relate or covary; in this table they show how much each information source is associated with behavioral changes. Positive values indicate that changes are more likely and negative values indicate that changes are less likely. The regression coefficient (*B*, column 2, and its related Beta in column 4) removes the overlap among predictors and shows the unique relationship between each predictor and the outcome. Regression coefficients are based on the original scales of each predictor; beta coefficients are standardized so that the predictors are in the same metric. Reliability or repeatability of effects is based on *t* tests (column 4), which indicate whether the *B* value is significant, i.e., would occur again if the study were repeated (the footnote indicates the relationship is reliable). Model accounts for significant variance, $F(5, 621) = 8.75$, $p < 0.000$; test of multicollinearity, all condition indices < 10, where an index of 30 is of concern.

questions were favorable or highly favorable. As shown in Table 10, most respondents used the most favorable options of ''agree'' and ''completely agree'' that they understood what the storm's impact would be (90%) or indicated they were ''satisfied'' or ''completely satisfied'' with the information they had gathered (88%). However, for the question of whether they understood how severe the storm would be, the distribution of responses was not as favorable; equal numbers said the storm was ''about what they expected'' (39%) and worse than expected (43%), with only 18% thinking the storm was less severe than they expected (Table 10, section 3). Thus, when responses to both storms are combined, respondents understood in advance what the impacts would be and were satisfied with the information they had received; however, almost half felt that the storm was more severe than they had expected.

c. *Comparison of preparedness for each storm*

To this point, data from the two storms have been combined for analyses. However, because the differences in forewarning were quite marked, the next analyses compare the two storms for interviewees' perceptions of preparedness. The first storm (snowstorm) had been announced at least four days in advance as a ''major winter storm'' by all sources; in contrast, the second storm (ice storm) had greater impact than what was initially anticipated and the potential for significant impacts associated with freezing rain were not given until the day before, or even the morning of, the event. Analyses indicated the two storms differed significantly only in anticipating the impact, with people being more confident they could anticipate the impact of the first storm than the second (Table 11; $p < 0.009$). The two storms did not differ in how satisfied respondents were with the information gathered (Table 12; $p = 0.31$) or in how severe the storm would be (Table 13; $p = 0.34$). Thus, while the impact of the ice storm did surprise some respondents, overall they were satisfied with the information and reported having an adequate sense of how severe each storm would be. These verbal reports are consistent with the traffic data reported, in that many people received the information

TABLE 8. Correlation of information sources and behavioral changes.

Weather source	Type of change: Change route	Change schedule	Not travel	Use transit	Sum of all changes
Government sources	0.08[c]	n.s.	n.s.	n.s.	0.11[b]
Personal sources	n.s.	0.13[a]	0.14[c]	n.s.	0.13[b]
Media sources	n.s.	0.08[c]	−0.16[b]	n.s.	n.s.
Sum all sources	0.09[b]	0.17[a]	n.s.	n.s.	0.14[b]

[a] $p < 0.01$.
[b] $p < 0.05$.
[c] $p < 0.10$.

Note: Except for use transit, $n = 471$; for use transit, $n = 183$. The text n.s. is utilized to indicate that the correlation is not significant. The negative correlation between media sources and not travel indicates people who sought more information from radio and television were more likely to travel.

TABLE 9. Correlations among information sources.

	Media	Government
Personal	−0.05	−0.04
Media	—	0.01

about both storms early enough to shift their departures to avoid the worst traffic problems (Figs. 2 and 3).

d. Objective measures of changed behavior

Comparison of the self-reported actions from interviewees with data obtained by UDOT from the PeMS shows the verbal reports are fairly well supported. Two kinds of data are portrayed: first are vehicle miles traveled to compare actual vehicle density with interviewee reports they had not traveled or left early to avoid their storm; the second data are actual traffic speeds from a parkway north of Salt Lake City—this area was severely affected by both storms and provides information about traffic flows before and during the storms.

Figure 2 shows information for travel on the day of the snowstorm (storm 1) compared to a control nonstorm day one week later. Colored bars in the upper portion (Fig. 2a) indicate the peak traffic flow on the control (red) and storm (blue) days, and show that during the storm, the highest number of vehicles on the road occurred at approximately 2200 UTC (1500 MST), whereas on the control day, the highest number occurred roughly two hours later at 0000 UTC (1700 MST). In other words, at 1700 MST, on the day of the storm, traffic volume was reduced by approximately 43% compared to the control day. The blue (snow) and red (control) lines corroborate this overall shift, especially as heavy traffic began and peaked earlier on the snow day than on the control day. This supports interviewee reports that they had shifted their travel time to avoid the storm. The lower portion of the figure (Fig. 2b) shows how travel speeds declined as the full impact of the storm reached the northern part of the study area. Prior to the storm, traffic slightly exceeded the speed limit of 55 mph on the parkway; once the snow began, traffic slowed and remained slow at least until midnight.

Figure 3 shows information for the ice storm (storm 2) compared to the control day, one week earlier. The upper portion (Fig. 3a) shows that vehicle miles traveled peaked earlier than typical, with the peak occurring at around 1400 UTC (0700 MST) versus the usual 1500 UTC (0800 MST). This figure also shows a general reduction in traffic all day, consistent with interviewee reports they had stayed home rather than driving. Indeed, at 1500 UTC (0800 MST) on the day of the storm, traffic volume was reduced by 32% compared to the control day. The lower portion of the figure (Fig. 3b) portrays the average speeds on the parkway (speed limit of 55 mph) and shows the extended period of 30 mph travel during the morning storm; this is substantially lower than the typical speed of 60 mph for this time of day shown in red (control day).

4. Discussion

This project combined information about weather forecasts, driver surveys, and objective automobile speed and density data for two winter storms: one, a snowstorm that affected an evening commute; and the other, a freezing rain storm that affected a morning commute. Content analyses of television forecasts showed that as the storms approached, forecasts became more specific with respect to the storm's arrival time,

TABLE 10. Participants' ratings of the information they had gathered.

1) I understood the possible impacts of the winter storm based on the information that I had.					
	Completely disagree	Disagree	Neutral	Agree	Completely agree
Percent selecting response	<1	4	6	30	60
Comparison of 5 Disagree to Agree Categories: $\chi^2(4, N = 650) = 817.32, p < 0.001$					
2) Across all your sources of information, how satisfied were you with the information that you received about the winter storm and driving conditions?					
	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
Percent selecting response	<1	4	8	36	52
Comparison of five categories: $\chi^2(4, N = 647) = 656.91, p < 0.001$					
3) Which of the following best represents your feelings about the storm's severity?					
	Less severe than expected		As severe as expected		More severe than expected
Percent selecting response	18		39		43
Comparison of three severity categories: $\chi^2(2, N = 644) = 71.65, p < 0.001$					

TABLE 11. Participants understood possible impacts of snowstorm better than ice storm.

	I understood the possible impacts of the winter storm based on the information that I had.				
	Completely disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Completely agree (%)
Storm 1	0	2	5	29	63
Storm 2	1	7	6	31	55

Note: Storm 1 (snow) $N = 362$; storm 2 (ice) $N = 288$. The two storms differ in anticipated impacts: $\chi^2(4, N = 650) = 13.46, p < 0.009$.

location, anticipated severity, and behavioral recommendations. These trends were less evident in content analyses of the online NWS information, in part because of the small samples and related lack of statistical power. Responses from interviewees indicated that people sought information from multiple sources, especially media and personal sources and, to a lesser extent, from online government sources (e.g., NWS, UDOT). Respondents reported they were generally satisfied with the information they had gathered and felt prepared for the storms, especially the first storm.

A primary purpose of the project was to learn what information induced prudent changes in driving behavior. A series of analyses explored the relations between source use and total number of driving changes made. Regression analyses showed that personal and government sources—but not media sources—were independent predictors of reported behavior change. Media was reported to be a frequently used source, but media use predicted increased likelihood of traveling during the storm and was not a significant predictor of alternative behaviors (there was a marginally significant relation to modification of travel schedule). This is surprising because media had been used as a source by most respondents. One possibility is that the lack of effect was an artifact of inadequate variability (i.e., most people used the media, so media use was not a way of discriminating which people changed their behaviors). This does not seem viable, because personal sources were also used frequently and they were a significant predictor of behavior change. The lack of effect is also not likely to be due to overlap among predictors, because the simple correlations among the predictors are not significant. One interpretation of these results is that information from the media provides an important foundation for raising concerns about the storm, but perhaps other information is sought and given weight in the actual decision to change behavior.

In their survey responses, most people reported that they had changed their commuting behavior (66% reported they had changed) and the most typical change for both storms was to change their travel schedule (51% reported changing their schedule). PeMS data corroborated these reports, especially for the first storm, which showed many drivers had shifted their evening commute to midafternoon. There was also a decrease in traffic volume on the day of the ice storm compared to typical traffic volumes; this was consistent with reports from some interviewees that they had stayed home the day of the ice storm. Additional research exploring the role of storm timing on driver behavior modification seems warranted. The shift in the peak commute time was greater in storm 1 than it was in storm 2, while more people chose to not commute at all in storm 2. A variety of factors (forecast confidence, advance notification, etc.) could have contributed to these differences. In addition, perhaps it is easier for individuals to leave early for the afternoon commute than for a morning commute. Also, it is likely easier to stay home when the morning commute is significantly impacted.

The similarity between the PeMS data and verbal reports adds credibility to the results of the surveys and provides empirical evidence for how local residents responded proactively to the anticipated traffic problems. At the same time, it is important to acknowledge that the two storms were two weeks apart, and this relatively short interval might have increased compliance with safety for the second storm. It is difficult to generalize from the first storm to the second because of multiple differences, including the time of day (evening commute vs morning commute), the nature of the storm (snow vs ice), and television reports (slow moving traffic vs cars out of control). It is possible that the memory of driving during the first storm increased compliance with recommendations to stay home during the second storm. However, it is also possible that the televised images of cars careening along ice-covered roads contributed to the traffic reduction by increasing the strength of the message to stay off the dangerous roads.

Implications for behavior change interventions

Before considering the potential for weather sources to improve the use of prudent changes in response to winter storms, it is important to underscore that the normal caveat applies to this correlational study: it is not possible to determine whether the information they gathered actually caused a change in behavior or whether people who sought government and personal

TABLE 12. Across all your sources of information, how satisfied were you with the information that you received about the winter storm and driving conditions?

	Very dissatisfied (%)	Dissatisfied (%)	Neither satisfied nor dissatisfied (%)	Satisfied (%)	Very satisfied (%)
Storm 1	0	4	9	37	50
Storm 2	1	3	7	35	54

Note: Storm 1 (snow) $N = 363$; storm 2 (ice) $N = 284$. The two storms do not differ in satisfaction with information: $\chi^2(4, N = 647) = 4.78$, $p = 0.31$.

information were the kinds of people who made prudent changes in response to inclement weather (i.e., self-selection led to both using certain information and making prudent changes). Similarly, the finding that people who used multiple media sources were more likely to travel does not suggest the media encouraged traveling; instead, it is more likely that people who needed to travel returned to media sources in order to decide whether they would need to change route, time, and so on. And finding that people who had prior experience with mass transit were more likely to use mass transit during the storms does not mean that familiarizing people with that mode will automatically increase its use during winter storms.

That said, this project does have implications for improving drivers' responses to winter storms, although future research will be needed to evaluate these ideas. Simply put, more drivers need to change their behaviors to truly minimize the impact of severe storms on traffic safety. The survey responses revealed that those experienced with driving in winter weather were less likely to change their behavior than those with little experience in such conditions. Consistent with this, other studies (Andrey et al. 2003; Andrey et al. 2013, Black and Mote 2015) have also found that experience driving in winter conditions does not result in a significant reduction in crash rates.

Although drivers accommodated the storms fairly well overall by time shifting or not traveling at all, there were still tremendous delays, with freeway traffic sometimes barely moving or at a complete stop. It is possible that more effective messaging from all sources would result in improved driver behavior modification. For example, messages reminding drivers of their discomfort and frustration during previous storms might attract more interest and activate stronger efforts to avoid traveling during a storm. Forecasts might use more vivid images to alert the audience that an expected storm will have a significant impact on road and driving conditions. Reports could clarify how 5–10 cm (2–4 in.) of snow would impact the commute, such as estimates of potential increases in travel time and increases in vehicular crashes; messages could remind drivers of the inconvenience and frustration of slowdowns and traffic; and videos from previous storms could be used to increase the impact of the verbal message.

Another implication is that forecasters should make behavior change a more explicit component of their message, especially when confidence is high that the storm will have impacts on travel. Our examination of both online and media sources indicated that specific behavioral suggestions were given the day of each storm. However, it would be more useful to give advice the day before the storm, so that drivers have time to plan ahead and consider potential changes to their behavior (i.e., implementation intentions; Gollwitzer1999; Gollwitzer and Sheeran 2006). Finally, because so few respondents used mass transit, greater effort might be put into encouraging mass transit use during regular weather in order to help people develop a routine around mass transit (especially which route to use, how long it would take, and schedule and stop locations); without such preparation and knowledge, it is unlikely that people will use mass transit because of a storm (Brown et al. 2003). Of course, additional research would be needed to explore optimum wording, as well as the impact that such messaging strategies might have on actual behavior modification.

A final implication is suggested by the difference between the present findings and those obtained in other research (Andrey et al. 2003; Black and Mote 2015). Those studies found that crash rates were highest in the

TABLE 13. Which of the following best represents your feelings about the storm's severity?

	Less severe than I expected (%)	As severe as I expected (%)	More severe than I expected (%)
Storm 1	16	40	44
Storm 2	20	37	43

Note: Storm 1 (snow) $N = 360$; storm 2 (ice) $N = 284$. Two storms do not differ in perceived severity: $\chi^2(2, N = 644) = 2.34$, $p = 0.31$.

evening, higher during more intense precipitation, and with little difference in crash rates between snowfall and freezing precipitation. The two storms in the present research yielded different patterns: Storm 2 occurred in the morning, not evening, comprised freezing rain, and had many more crashes. In addition to differences in terrain and road types that might account for these differences, it is also important to note that the previous studies aggregated across multiple storms, so Salt Lake City's two unique storms could easily differ from the averages reported in those articles. These differences highlight the potential to learn from unique events. Thus, future research on the impacts of storms on motorists could explore ways in which the impacts differ during different times of day and for different precipitation types and intensities. This greater detail could be used to alert drivers with more detailed and even ''customized'' storm information and behavior change advice.

Results of these analyses reflect well on how drivers attend to weather information. These two storms were different in time of day and type of driving impacts. In both cases, interviewees reported (and PeMS data corroborated) that they adjusted their commute schedules or stayed home in order to avoid traveling when conditions were poor. While useful, these two surveys are just a beginning at understanding how drivers seek and use information about storms and road conditions. More research is needed, especially studies that follow up on the lack of relation between media sources and behavior change, and research that specifically connects drivers' routes and travel schedules to their information seeking and decision-making. Research is also needed in other geographic regions, timing and accuracy of predictions, and a broader cross section of events in regard to storm type, intensity, and predictability. Impact-based information dissemination in Utah has benefited from the collaborative work of Utah Weather Partners in developing and presenting coordinated messaging. The authors hope to increase local media participation in this effort and would like to see similar collaborations in other geographic regions. Indeed, the Surface Transportation Weather Collaboration: The Pathfinder Project (Green et al. 2014) focusing on the I-80 corridor between California and Wyoming is a second-generation initiative involving collaboration among public and private partners in the weather enterprise, emulating the partnership efforts in Utah.

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