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Localized Risk, Generic Warnings: A Framework for Closing the Awareness-Action Gap in South Texas Winter Storms

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Abstract

Five years after Winter Storm Uri exposed critical vulnerabilities in Texas's cold-weather preparedness, Winter Storm Fern brought sub-freezing temperatures, icing, and renewed pipe-freeze risk to South Texas in January 2026. Using publicly available National Weather Service (NWS) products and storm records, this conceptual study reconstructs the Fern warning timeline and describes how warning type, lead time, and geographic coverage varied across the region. This research adds new components in the Protective Action Decision Model (PADM) based on recent cold-weather preparedness. We propose a framework for natural hazards in regions unaccustomed to cold weather. Specifically, we argue that: (1) informal social-cue pathways in the original PADM might be different in transient, linguistically diverse Gulf Coast and nearby communities; (2) a personal relevance gap, where residents see regional warnings as not applying to them, is an overlooked barrier between threat perception and action; (3) there is a need for localized, probability-based messaging; and (4) there is a geographic/cultural filter. This research is a basis to synthesize storm-timeline reconstruction and existing hazard-communication research to motivate a testable, revised model.

Keywords: winter storm; risk perception; Protective Action Decision Model; warning message specificity; Wireless Emergency Alerts; household preparedness; awareness-action gap

1. Introduction

Extreme winter weather has become an increasingly consequential hazard for the U.S. Gulf Coast and Texas interior, a region whose housing stock, water infrastructure, and public expectations were built around mild winters. During February 2021, Winter Storm Uri caused widespread failures of the Texas electric grid, left millions without power, burst residential pipes, and forced boil-water notices across the state [1,2]. Five years later, Winter Storm Fern moved through South Texas from 24 to 25 January 2026, bringing freezing rain, sleet, and record-breaking low temperatures [3,4]. Texas's governor declared a state of emergency in advance of the storm, and utilities across the San Antonio area issued freeze warnings. Fern therefore offers a timely opportunity to examine, using the public record, whether the lessons of Uri appear to have changed how warnings were issued, distributed, and geographically targeted across South Texas [2]. Social vulnerability and marginalization also create physical and psychological barriers throughout disaster preparation, response, and recovery [5,6]. Other frameworks, including social learning and planned behavior theories, highlight how social capital and context shape norms that support adaptation [7].

A recurring finding in the hazard literature is that warning receipt, and even accurate risk perception, do not reliably produce protective action, a pattern often called the

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awareness–action gap. The Protective Action Decision Model (PADM [8]) offers the most widely used framework for explaining this gap. The PADM begins when individuals notice environmental cues, social signals, or formal warnings. Once filtered through exposure, attention, and comprehension, these inputs shape threat perception, protective options, and source trust. These perceptions, together with situational facilitators and impediments, determine whether a protective-action decision is reached and ultimately acted upon. The model was developed and validated primarily using evidence from hurricanes, earthquakes, and industrial hazards [9–11]; its applicability to short-fuse, infrastructure-centered cold-weather events in a historically warm-climate region remains comparatively untested.

A related body of work examines self-efficacy, a person's belief in their ability to take protective action [12], alongside response efficacy and response cost, the two additional pillars of Protection Motivation Theory [13]. Recent work on cold-weather preparedness suggests that message effectiveness, source trust, and risk perception jointly drive household action, with trust mediating the link between warning receipt and behavior [14]. This research conducted an empirical survey of 405 residents in El Paso and Lubbock. In contrast, our work is conceptual. We reconstruct the Winter Storm Fern timeline from public records and build on their findings. A parallel line of research examines the delivery channel itself: Wireless Emergency Alerts (WEA) act as a primary short-fuse warning mechanism in the United States. Yet national survey evidence shows many recipients don't fully understand WEA message classes, opt-out options, or the geotargeting logic that determines who receives an alert [15,16]. A long-standing companion concern is the "false alarm" or "cry wolf" effect, in which warnings perceived after the fact as having overstated a hazard measurably weakened subsequent public response [17]. Similar warning challenges have been documented for other severe weather hazards across South Texas, which is called inadequate warnings [18].

Using only public records and existing literature, this research addresses three questions: (1) How did warning lead time, geographic coverage, and messaging specificity vary across the South Texas region during Fern, based on the documented advisory and emergency-declaration timeline? (2) Which parts of the PADM best explain the gap between warning receipt and protective action in this warm-climate, transient, linguistically diverse population? (3) How should the PADM be modified to fit short-fuse, infrastructure-centered cold-weather hazards here, and how could these modifications be tested in a future survey?

2. Background and Theoretical Framework

This section moves from the general to the specific. It begins with the early warning system (EWS) framework. It then turns to the models that explain how individuals decide to act, namely the Protective Action Decision Model (PADM) and Protection Motivation Theory. It ends with the dissemination channel (WEA) and the false-alarm effect.

2.1. Early Warning Systems (EWS): Conceptual Foundations and Components

Effective early warning should not be understood solely as meteorological forecasting or the dissemination of warning messages. Early warning systems (EWS) are framed as integrated processes comprising risk knowledge, hazard monitoring and forecasting, warning dissemination & communication, and the capacity of exposed populations [19]. They stress a people-centered approach, in which the needs, vulnerabilities, and decision-making contexts of warning recipients shape every component rather than technical performance alone. The components of an early warning system depend on one another. A weakness in any one of them, such as an accurate forecast that is poorly communicated or a warning that people cannot act on, can undermine the whole system and its contribution to disaster risk reduction. Within this framework, Wireless Emergency Alerts (WEA) mainly operate at the

dissemination and communication stage. The Protective Action Decision Model (PADM), protection motivation, and self-efficacy help explain how recipients interpret warnings and decide to respond, which corresponds to the response capacity component.

Another study by [20] illustrates how these components interact in practice. The U.S. National Weather Service is considering a move from deterministic to probabilistic warnings. The authors examined how probabilistic hazard information (PHI) forecast graphics might be embedded in 360-character WEA messages for tornadoes. The PHI graphics come from the forecasting component. The WEA messages come from the communication component. The authors used questionnaires and focus groups with 31 community members in Denver, Colorado. The PHI-enhanced messages elicited high understanding and believability. Average ratings were about 6.0 for understanding and 5.9 for belief on a 7-point scale. Yet only 19 of 31 participants (61%) intended to take shelter at an approximately 50% probability of impact. This figure fell to 16 participants (52%) after group discussion. All participants intended to take shelter at an approximately 90% probability.

Participants also questioned messages in which the urgency of the text did not match the probability shown in the graphic. Many sought confirmations from their surroundings and other people before acting. These results show that improving one component does not by itself ensure effective response. Here, that component is the presentation of forecast information. Outcomes also depend on message content, social context, and recipients' capacities. These factors interact with one another.

Taken together, these works support viewing WEA as one element of a broader, people-centered warning chain. They also provide the conceptual basis for the present study. The present study examines how warning content and format relate to public understanding and response.

Four main components of an early warning system are identified by [21]. These are risk knowledge, monitoring and warning, warning dissemination and communication, and response capability. They argue that major weaknesses often arise in communication and response capacity. Forecasting is less often the problem. A warning can be accurate and still fail to reduce harm. Three things must happen after the forecast is issued. People must receive and understand the warning. They must judge that it applies to their own circumstances. They must also have the practical means to act on it.

This distinction matters for the present study. Much of the warning literature focuses on message content, geographic coverage, and lead time. These factors concern dissemination. They do not show whether recipients can respond. Response depends on resources, knowledge, time, and access to supplies. It also depends on institutional support. The PADM captures some of this through situational facilitators and impediments. Self-efficacy and response cost capture part of it as well. The EWS perspective adds a systems view. Communication and response are linked components, and a gap in either one can limit the whole system. This view builds on these studies [19,22]. In this study, it separates three questions. Was the warning issued? Was it understood and seen as relevant? Could people act on it?

2.2. Critical Links Between Early Warning System Components

Early warning systems can fail even when each component works, ref. [22] makes this point clearly. They show that failures often occur in the processes that connect the components. A forecast may be accurate, and a message may be sent on time. Warning can still fail if the link between the two is weak. This view extends the people-centered framework of [19]. It shows that the quality of each component is not enough. The links and acting on components also matter.

This idea helps explain the findings of [20]. In their study, probabilistic hazard information graphics were added to WEAs. The forecasting and dissemination components were both functioning. Participants understood and believed the messages. Even so, only 61% intended to take shelter at an approximately 50% probability of impact. Participants also questioned messages when the urgency of the text did not match the probability in the graphic/text. Many sought confirmations from others before acting. These problems arose in the links between forecast information, message content, and personal interpretation. They did not arise in the components themselves.

This synthesis informs the conceptual framework of the present study. Warning information must reach people, and it must also be seen as personally relevant. Perceived relevance connects dissemination to response. Without it, understanding and belief may not lead to protective action. The present study therefore examines this link. It asks how warning information relates to perceived personal relevance and to protective behavior.

2.3. Local Context, Trust, and Coordination

Warning systems also depend on factors beyond the components themselves, including local context, public trust, impact-oriented communication, and coordination among institutions. Recent winter storm documentation shows the institutional side most clearly. A joint FERC and NERC review of Winter Storm Fern linked stronger performance to lessons from earlier storms, advance commitments by generators, better situational awareness, and cold weather reliability standards [23]. The same review named better communication between the natural gas and electric industries and better load forecasting as areas that still needed work. Before Fern, the Southwest Power Pool monitored conditions, coordinated with operators inside and outside its footprint, and issued advisories to grid partners [24]. The region avoided widespread outages, although some individual utilities still had local outages [25]. Local context therefore shaped who was affected, even when the regional system held. Texas shows the public-facing side. The Texas Division of Emergency Management urged residents to follow forecasts from trusted local sources (e.g., NWS, NOAA).

2.4. The Protective Action Decision Model

Within the EWS framework, the PADM explains how recipients move from receiving a warning to deciding to act. The PADM explains how people respond to a warning: they first notice, pay attention to, and understand the cues around them, such as the weather, what others are doing, and official alerts. This shapes how serious they think the threat is, what they can do about it, and whether they trust the source, and then they decide whether to act, depending on what helps or gets in their way [8]. The model's origins lie substantially in hurricane, earthquake, and industrial-hazard research [9–11]. Settings in which affected communities typically have repeated hazard exposure and dense local social networks. Whether the same weighting of pathways, particularly the social-cues pathway, holds in a historically warm-climate region (South Texas Region) experiencing an infrequent, short-fuse cold-weather hazard is an open question that this paper addresses conceptually.

2.5. Self-Efficacy, Response Efficacy, and Response Cost

The EWS perspective shows where warnings can fail. The next two subsections examine the individual-level models that explain why. Protection Motivation Theory decomposes the decision to act into three evaluations: can I do it (self-efficacy) [12], will it work (response efficacy), and can I afford it (response cost) [13]. Recent cold-weather preparedness research indicates that these evaluations, together with source trust and message specificity, jointly shape household action [14]. Even people who know about a hazard and feel capable of handling it may not act if they doubt the warning is about them. They may also hold back if

they aren't sure the recommended action is worth the cost. These evaluations correspond to the response capacity component of an EWS and complement the PADM. This is a distinction we build on in Section 4.

2.6. Wireless Emergency Alerts and the False-Alarm Effect

WEA geotargeting operates by defining a geographic polygon and delivering alerts only to devices within it [16]. This is analytically important for infrastructure hazards like freezing events, where the plumbing of households is vulnerable to the freezing temperatures that occur during winter storms. Coarse geotargeting has been shown to reduce recipients' confidence that a message applies to them, and imprecise or repeated over-alerting is associated with warning fatigue and reduced future compliance [16,17]. Effective hazard messages should clearly state what the hazard is, where it will occur, what action to take, and when to act. Such "actionable risk" communication can reduce delays and increase preparedness actions compared with generic risk messages [21]. These strands motivate our focus, in Section 4, on message specificity and geographic targeting as levers distinct from lead time alone.

2.7. People-Centered Warning Systems

Amber alerts have relevance to WEA in a similar way to messages used in NWS products and warnings [20]. Both systems can warn millions of customers regarding imminent threats and other emergencies. The framework of all WEA messages for both natural disasters and other emergencies (e.g., amber alert) supports a strong foundation for how the action-awareness gap and risk perception is utilized when consumers interact with these messages. Public responses to WEA alerts, including how hazards are utilized in short messages, is an important part of the framework that is part of the PADM model. Subtle differences in the wording of WEA alerts are also important to how one interprets and reacts to the warning. This suggests areas of improvement that can be addressed using the PADM model framework and applying it to winter storms and extreme cold weather.

3. Reconstructing the Winter Storm Fern Warning Timeline: Data and Approach

3.1. Public Record Sources

This research reconstructs the Fern warning and impact timeline using public records, including NWS advisories and warnings, emergency declarations, utility and municipal notices, local media, and storm reports [3]. Where useful, we compare this timeline against the analogous public record for Winter Storm Uri in February 2021 [26] to situate Fern within the region's recent cold-weather history. In the NWS products used for Winter Storm Fern, forecasters mentioned dangerous cold and long-duration freeze in the key messages portion of the Area Forecast Discussions. These discussions also mentioned ice accumulations while providing updates to the Winter Storm Warning and other warnings issued throughout the South-Texas region. This helps local media and government translate these warnings and emergency declarations to the public, an essential part of the awareness-action gap.

The NWS defines its tiered winter weather products as follows:

- Winter Storm Outlook: Issued 3–7 days ahead when a significant winter storm is possible.
- Winter Storm Watch: Issued 12–48 h ahead when conditions are favorable for significant snow, sleet, or ice.
- Winter Storm Warning: Issued 12–36 h ahead when significant or hazardous winter weather is expected or imminent.

A timeline of a winter storm Fern January-2026 is shown in Figure 1. As the winter storm developed, NWS provided the weekend watch on wintry weather. And as the days advance, NWS upgrades the forecast accordingly. On 25 January protect the 4 P's (People, Pets, Plants, and Pipes) were issued (Figure 1), and wintry conditions had largely subsided by 27 January.

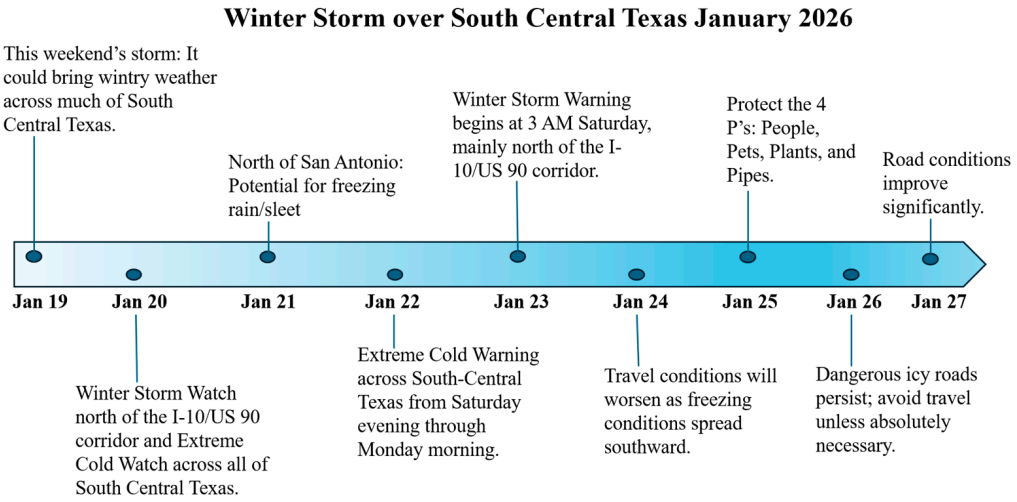


Figure 1. Timeline of Winter Storm Fern, January 2026, over South-Central Texas region and around. (Source: NWS Austin/San Antonio).

Figure 2 illustrates the broader multi-day minimum temperature ranges across the San Antonio forecast area during this exact event window (23–27 January), serving as an ideal visual introduction to the meteorological severity of the storm. In this 5-day coarse-resolution forecast of minimum temperature, southern areas of San Antonio seem to have a wide range of temperature, 25–30°F (Figure 2). Well-informed and connected residents tend to monitor weather updates for improvements over time.

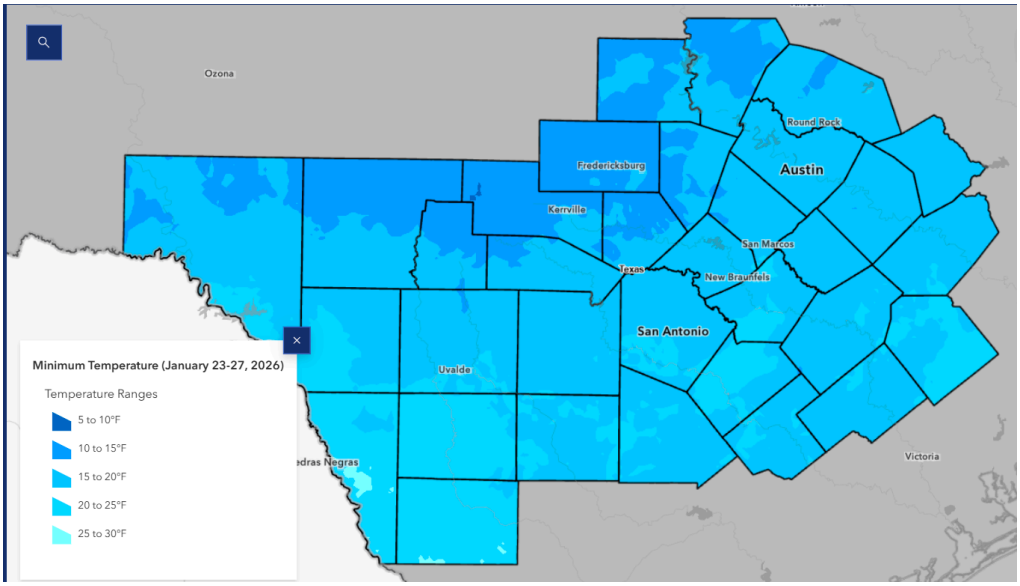


Figure 2. Five-day range of minimum temperature (freezing) around San Antonio in 23-27 January 2026. (Source: NWS Austin/San Antonio area).

3.2. Scope and Interpretive Approach

Our geographic focus is the South Texas region (San Antonio and Corpus Christi areas), mirroring the service area of the institution conducting this research. Rather than a systematic, independently coded content analysis, this is a narrative timeline reconstruction intended to characterize, at a descriptive level: (a) when formal advisories and warnings were issued relative to storm onset; (b) which counties or forecast zones were placed under a Winter Storm or Extreme cold Warning as opposed to a lesser advisory or no formal product; and (c) whether messaging in public-facing communications referenced specific, actionable guidance (e.g., pipe protection or water-shutoff instructions) or relied on general hazard-category language. For example, the City of San Antonio issued messages stating: "Residents should prepare for extreme cold weather. City opens Overnight Refuge Centers and Daytime Warming Centers. Visit ... Reply with YES to confirm receipt." Studies of Spanish-speaking immigrant workers show that limited multilingual information and structural constraints can block protective action even when risks are recognized [27]. This reconstruction is offered as context for the conceptual framework in Section 4, not as a hypothesis-tested empirical result.

One pattern in the public record is analytically important on its own terms: portions of the Corpus Christi area were also under a Winter Storm warning during the event. Nearby areas of Corpus Christi observed near freezing and freezing temperatures. Because WEA delivery is gated by warning-polygon boundaries [16], residents of Corpus Christi still have the opportunity to receive a WEA regardless of their individual risk perception or self-efficacy. This is a structural, geotargeting-level source of the awareness–action gap that a purely perception-focused household survey could easily misattribute to individual psychology rather than warning-product design, a distinction we return to in Section 4. Figure 3a,b here visually supports the temperature gradient and data backing that observation between 24 January (pre-freeze/mild) and 25 January (sub-freezing lows). Temperatures throughout South Texas were in the 60s a day before the arrival of the cold front that brought freezing temperatures. Temperatures dropped into the 30s on 25 January. Forecasts of sudden plummets of temperature are difficult to predict in several lead times. This forecast lead time falls in the category of extreme events [28]. Weather models have difficulties in forecasting extreme events.

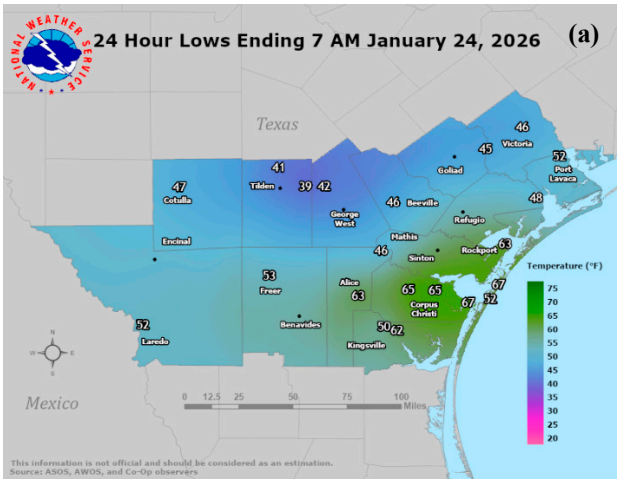


Figure 3. *Cont.*

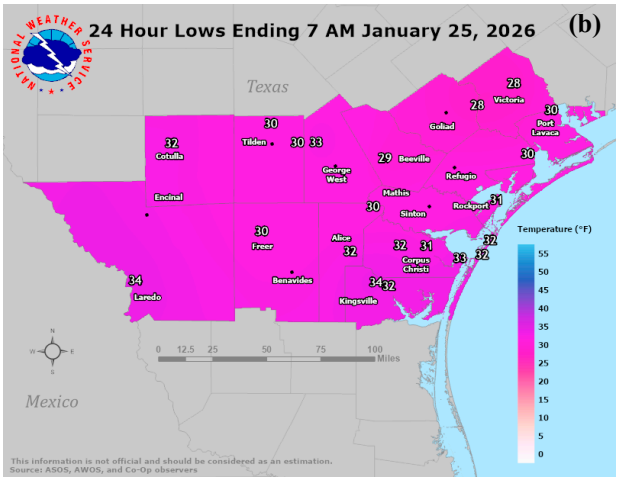


Figure 3. Lowest temperature around Corpus Christi area on the morning of (**a**) 24 January 2026 (**b**) 25 January 2026. These numbers represent the lowest temperature of a particular county on that day and time. (Source: NWS-Corpus Christi).

4. A Modified Conceptual Framework: PADM for Short-Fuse Winter Storms in Historically Warm Climates

Based on the storm timeline and literature review, we propose modifications to the standard PADM framework for short-fuse, infrastructure-centered cold-weather hazards. The framework is tailored to diverse, transient populations in historically warm-climate regions such as San Antonio and Corpus Christi. Sections 4.1–4.7 explain the rationale for each modification and present them as testable propositions, not established findings. Figure 4 provides the exact regional NWS map showing these advisory and warning boundaries across Texas on 25 January, directly illustrating the structural geotargeting gaps analyzed in the text. Surprisingly, parts of South Texas and coastal regions received extreme cold warnings on the day freezing temperatures occurred (Figure 4). The day before, minimum temperatures were recorded in the 60s.

Figure 5 summarizes the proposed model. We expect that official alerts and trusted sources such as the NWS are important inputs, and we propose that localized information may increase protective action. Threat perception is expected to be high following Uri. The size of situational impediments, such as supply availability and plumbing condition, is an empirical question for the planned survey. The personal relevance gap sits between threat perception and protective action decision-making. This model emphasizes that the "Personal Relevance Gap" sits directly at the transition between Threat Perception and Protective Action Decision-Making.

Three main features are proposed to modify the original model, shown in the diagram as new or updated elements.

First, informal social influence may be attenuated, with neighbors having a smaller impact on household decisions. Post-Uri surveys show residents drew on a mix of local TV, weather channels, neighbors, and friends [28]. Whether neighbor cues carry less weight than official sources in recently settled, linguistically diverse communities is untested, so we propose it as a hypothesis.

Second, in regions with historically mild winters, residence alone may not translate into cold-weather risk knowledge. Research on risk perception shows that prior experience does not reliably produce preparedness [29], and Winter Storm Uri produced widespread home damage in Texas [30], including in South Texas communities. Another component 'geographic/cultural filter' at the exposure stage will also be included.

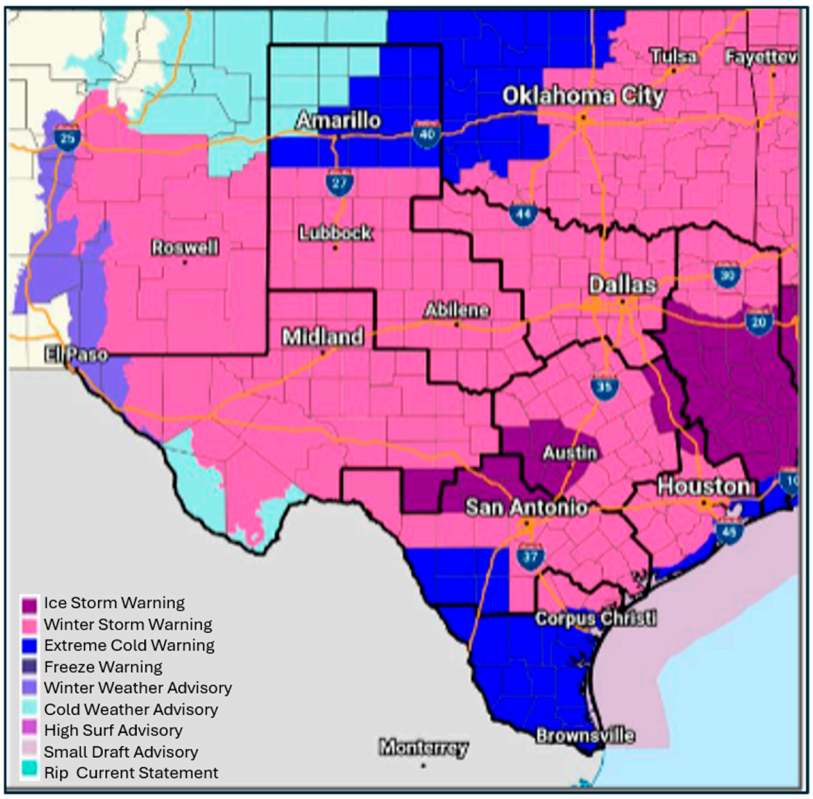


Figure 4. Radar image showing NWS Warnings, Watches, and Advisories on 25 January 2026. (Source: NWS-Fort Worth Southern Region ROC).

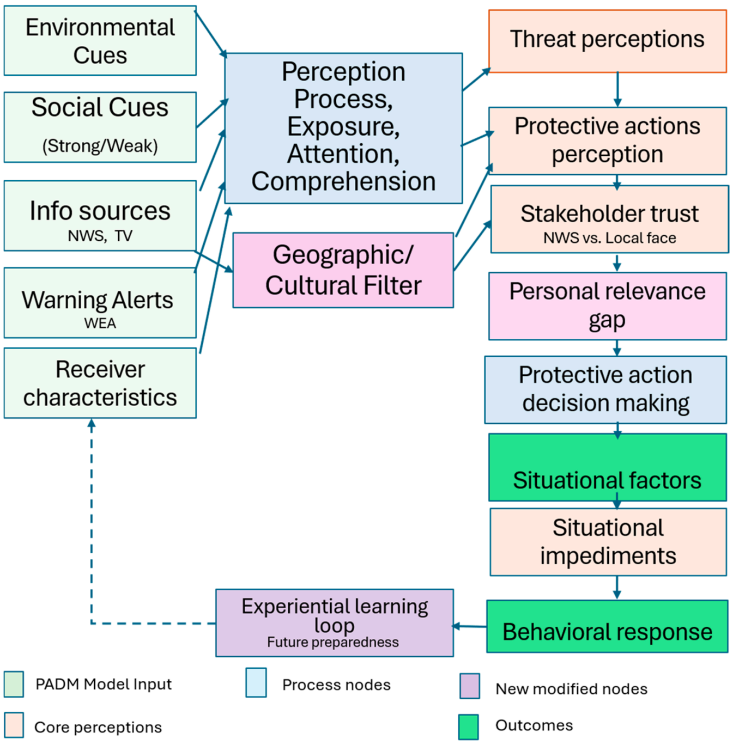


Figure 5. Proposed modifications in the PADM related to Winter Storm Fern over the South Texas region.

Finally, third, we included a "personal relevance gap" node directly under official trust. Even when residents trust the NWS and recognize the storm as dangerous, some may still

judge that the risk does not apply to their own home or neighborhood. Moving from general concern to personal action is where the model fits it cleanly and precisely where future warnings and research should be focused [31]. Our model includes a personal relevance node beneath official trust, consistent with the personalization stage of the Protective Action Decision Model [8,10]. This reflects evidence that trusting a warning does not ensure people judge it applies to their own home.

4.1. Warning Reception Under Geographic and Infrastructural Constraints

The PADM treats warning reception primarily as a function of exposure, attention, and comprehension. In the context of this hazard, reception of warning is also gated by a structural factor that sits upstream of an individual's cognition: the alignment between formal warning-polygon boundaries and household-level infrastructure vulnerability. These polygons are smaller than the county. For example, in Corpus Christi, Calallen, Northwest, Central City, Southside, Bay Area, Flour Bluff, and Padre Island are sub-sections of the city reflecting urban expansion from older to newer areas (City of Corpus Christi). Similarly, San Antonio also has 11 such subdivisions in the city. In historically warm regions, exposed or poorly insulated plumbing can create vulnerabilities not captured by county- or zone-level winter weather warnings [32]. Because WEA delivery should depend on these polygons [16], some at-risk households may never be eligible to receive a short-fuse alert at all. We propose adding a geographic/cultural filter to the PADM's initial stage to make this structural constraint explicit and analytically separable from downstream perceptual processes.

4.2. Attenuation of the Informal Social-Cues Pathway

The original PADM assigns social and neighbor cues a role roughly comparable to environmental cues and formal warnings, reflecting its origins in communities with dense local social networks and repeated hazard exposure. Every year during hurricane season, Gulf Coast neighborhoods remain cautious about boarding up windows against winds and protecting the house from water. We argue this pathway is likely attenuated for winter-storm hazards in transient, recently settled, and linguistically diverse South Texas communities (warmer region). Freeze events remain infrequent enough that even long-tenured residents may lack a shared local script for "what neighbors do" before a freeze, unlike more familiar regional hazards [33]. There are no official statistics quantifying the proportion of residents who take cold-weather precautions in South Texas. If this attenuation held, official channels including WEA, NWS products, and trusted local meteorologists would need to carry a disproportionate share of the warning-diffusion burden relative to what the standard model assumes.

4.3. The Personal Relevance Gap: Definition and Conceptual Position

We define the personal relevance gap as the shortfall between the scale at which a warning is issued and the scale at which a household judges its own risk. A regional or county-level warning describes a hazard for an area. A resident decides whether that hazard applies to a specific home, neighborhood, or situation. The gap arises when the resident accepts the hazard in general but doubts that the warning applies to them. It is a judgment about applicability, not about severity, capability, or cost.

The construct is related to several established concepts, but it is not the same as any of them. Risk perception and threat appraisal concern how likely and severe a hazard is. A resident can rate the regional threat as high and still see the warning as not about their own home. Risk personalization, as used in the warning response model and the PADM, is the closest concept. It describes recipients deciding that a warning is aimed at them [8,11]. Our

construct builds on it in two ways. First, we treat it as a gap with a measurable cause on the product side, namely polygon boundaries, county-level wording, and generic messaging. In the standard PADM, personalization is mainly an internal process of the receiver. Second, we argue it is especially likely to persist for infrastructure hazards in warm-climate regions. There, household vulnerability, such as exposed plumbing, is not visible in a regional forecast. Warning interpretation concerns whether the message is understood. It is found that participants understood and believed mock alerts [20], understanding therefore does not guarantee a judgment of relevance. Self-efficacy and response efficacy concern whether a person can act and whether the action works [12,13]. A resident may have both and still not act because they do not believe they are affected. Source trust is also separate. A resident can trust the NWS and still doubt that its warning covers their address. We summarized personal relevance and preferences in Table 1.

In the modified framework, the gap sits after threat perception, protective action perception, and source trust, and before protective action decision-making. It is linked to the geographic/cultural filter at the exposure stage. The filter shows whether a warning reached the household. The gap shows whether the household accepted it as relevant. The theoretical advancement is threefold. It separates a distinct judgment that existing measures often merge. It links a receiver-side judgment to a product-side cause. It generates testable predictions. H1 tests whether perceived relevance accounts for part of the link between threat perception and protective action. H3a tests whether more localized messages narrow the gap.

Table 1. Distinguishing the personal relevance gap from related constructs.

Construct	Core Question	Why It Is Not the Same
Risk perception/threat appraisal	How likely and severe is the hazard?	Can be high while the warning is judged not to apply to me
Risk personalization (PADM)	Is the warning aimed at me?	Closest concept. We treat it as a gap with product-side causes
Warning interpretation	Do I understand the message?	Understanding can be high without perceived relevance
Self-efficacy	Can I act?	Concerns capability, not applicability
Response efficacy/response cost	Will it work? Can I afford it?	Concerns the action, not the warning
Source trust	Do I trust the sender?	Trust in the sender does not ensure the warning applies to me
Personal relevance gap	Does this warning apply to my home and situation?	Gap between warning scale and household-level risk judgment

4.4. Localized, Probability-Based Messaging as a Behavioral Lever

Closing the personal relevance gap may require more than extending lead time. More specifically, location-based freeze risks paired with concrete guidance may be more effective. Gaps in government communication during Winter Storm Uri, including inconsistent use of the state's Emergency Alert System, show the need for more reliable communication strategies [34]. This is consistent with both the geotargeting literature, which links finer-grained targeting to greater recipient confidence that a message applies to them [16], and the actionable-risk literature, which emphasizes specifying what to do over restating that a risk exists [21]. We treat this as a testable proposition rather than an established finding and describe how it might be tested in Section 6.

4.5. Regionally Adapted Thresholds and Impact-Oriented Communication

The argument for localized, probability-based messaging connects to a wider body of work on regionally adapted and impact-oriented warning systems. Heat-health warning systems offer a useful comparison. How such systems have been developed and implemented across Europe were reviewed by [35]. As summarized in that review, effective systems do not rely on temperature forecasts alone. They combine meteorological forecasts with indicators that are relevant to health impacts. They also use thresholds that are specific to a region, because the same temperature can carry different risks in different climates and populations. Effective systems further depend on coordinated responses among stakeholders and on communication directed at the groups most at risk.

These principles are transferable to winter storms in South Texas, with an important caution. Heat-health warning systems address a different hazard, and they do not provide direct evidence of how the public responds to winter-storm warnings. We use them as comparative literature that illustrates general principles of warning-system design.

Three principles bear on our framework. First, thresholds should reflect local vulnerability. In historically warm regions, freezing temperatures can damage exposed plumbing even when conditions would not be considered severe elsewhere. A warning based on regional meteorological criteria may therefore understate household-level risk [36,37]. This supports our argument that county- or zone-level products can leave the personal relevance gap unaddressed. Second, warnings should state expected impacts, such as pipe freeze, ice on roads, or loss of services, and should not describe only the weather. This is consistent with the actionable-risk literature [21] and with the impact-based and people-centered approaches discussed in Section 2. Third, warnings need coordinated action beyond the forecast office. Utilities, municipalities, emergency managers, and local media each shape whether a warning becomes protective action. This reflects the response-capacity emphasis [25].

In the Fern case, these principles suggest that the main question is not only when warnings were issued. It is also whether thresholds and messages were matched to local conditions and household vulnerability. For example, a message that names the expected impact and the local risk, such as freezing pipes in a specific part of a city, may do more to establish personal relevance than a regional statement of cold weather. We treat this as a testable proposition. Hypotheses H3a and H3b in Section 5 examine geographic specificity and probability framing, and the survey could also examine whether respondents find impact-based wording more relevant than hazard-category wording.

4.6. Winter Storm Fern as a Communication and Response Capacity Problem

The Fern timeline suggests that forecasting was not the main weakness. The NWS issued a Winter Storm Watch and an Extreme Cold Watch by 20 January. It then issued warnings by 22 and 23 January, which gave several days of lead time (Figure 1). The more important weaknesses appear in communication and response capacity.

Communication: Warning boundaries did not match household vulnerability. Portions of the Corpus Christi area were not under a Winter Storm Warning, although freezing temperatures occurred nearby. Because WEA delivery depends on warning polygons, some residents could not receive an alert. Temperatures in the 60s on 24 January and in the 30s on 25 January may also have weakened perceived relevance. Although the cold front was forecast days in advance (Figure 1), a day-to-day drop from the 60s to the 30s may be hard for residents to believe, which could weaken perceived relevance. Limited multilingual information may add another barrier for some residents. These are failures in the dissemination and communication component. The personal relevance gap proposed

in this study sits at the same point. A resident may receive a warning and trust the source. The resident may still not believe that it applies to their own home.

Response capacity: Even when warnings reach people, response may be limited. Many residents in historically warm regions have little cold-weather experience. Homes may have exposed or poorly insulated plumbing. Supplies may be hard to find. Some workers face pressure to travel despite the risk. Transient residents may lack a shared local script for freeze events. These are response capability issues. They are different from message quality.

Implication for the framework: The EWS perspective suggests a refinement. The framework should treat response capacity as a distinct element. It should not be assumed to follow from risk perception. This is also a testable proposition. The planned survey could measure three things separately: receipt and understanding, perceived relevance, and practical ability to act. This would help show which link in the chain limits protective action.

4.7. The Experiential Learning Loop and False-Alarm Feedback

The PADM closes with a feedback loop in which the outcome of one hazard updates receiver characteristics ahead of the next. We propose making this loop explicit for short-fusing winter storms in historically warm-climate regions: post-event judgments of warning accuracy. Winter Storm Fern had more moderate local impacts compared to Uri. This may cause some residents to perceive the warning as overstated (Figure 3). This could reduce trust in future warnings, consistent with documented "cry wolf" effects [17]. We treat this feedback pathway as a distinct, testable addition to the learning loop rather than folding it into general receiver characteristics, because it is plausibly one of the more actionable targets for post-storm risk communication. Together, Sections 4.1–4.7 provide the theoretical justification for each added component described in Figure 5. Recently two winter storms over the South Texas region have remained in TV news and discussion among weather watchers. Table 2 shows a comparison of the threat, warning appropriateness, impacts, public perception, and damages. Because Fern was less intense, infrastructure damage was limited, though road conditions between San Antonio and Houston were hazardous [38]. Consequently, many students canceled their attendance at the 25th Annual AMS Student Conference (24–25 January) in Houston (personal observation).

Table 2. Comparison of two recent winter storms over South Texas region. (Partial Source NWS).

Comparison Factor	Winter Storm Fern (January 2026)	Winter Storm Uri (February 2021)
Forecast threat (documented, NWS)	Moderate ice, sleet, dangerous cold, and hazardous roads	Prolonged Arctic outbreak, snow, freezing rain, and extreme cold
Observed impacts (documented, NWS)	More localized winter-weather impacts in South Texas, with hazardous roads	Widespread and prolonged power, water, transportation, and infrastructure failures
Basis for issuing warnings (documented, NWS)	Forecast ice accumulation and dangerous travel conditions	Prolonged, severe winter-weather threats
Possible public perception (hypothesis, not measured)	Some residents may perceive warnings as exaggerated where local impacts were limited	Severe impacts may have reinforced the perceived seriousness of warnings
Possible explanation for differences in damage (interpretation, not tested)	Lower local exposure, geographic differences, and possibly protective actions	Extensive exposure and cascading infrastructure failures may have overwhelmed preparedness systems

We hypothesize that some residents may therefore judge the warnings to have been overstated. We have no direct evidence of how residents perceived the Fern warnings or how they behaved. The pathway is a proposition for testing, not a finding. We therefore

add it to the learning loop as a testable element, and we plan to examine it in the household survey described in Section 5.

5. Toward an Empirical Test: Proposed Survey and Hypotheses

The framework in Section 4 is intended to be tested, not merely asserted. Following institutional review, we plan to field a post-storm household survey across San Antonio (University of Incarnate Word). The survey will be structured around the sequential stages of the PADM: warning reception and response, threat perception and source credibility, preparation influences and barriers, behavioral response, and forward-looking preparedness priorities. Drawing directly on the conceptual modifications proposed here, we intend to test the following hypotheses:

H1. *Perceived personal relevance of a regional winter-storm warning will statistically account for part of the association between general threat perception and protective-action behavior, controlling for warning lead time.*

H2. *Among respondents in our South Texas sample, the standardized association between institutional source use and protective-action behavior might be larger than the association between informal social-cue exposure and protective-action behavior. This relationship will remain significant even after controlling demographics, housing characteristics, prior freeze experience, and warning lead time.*

H3a (geographic specificity)**.** *Respondents who receive a ZIP-code-level message will report higher intended protective action than those who receive a regional message, holding probability framing and lead time constant.*

H3b (probability framing)**.** *Respondents who receive a numeric probability will report higher intended protective action than those who receive qualitative wording, holding specificity and lead time constant.*

H3c (relative effect of message features vs. lead time)**.** *The effect of geographic specificity on intended protective action should be larger than the effect of extending lead time from 24 to 72 h. We will test this by comparing standardized effects from the same model.*

This survey will be submitted for prospective IRB (Institutional Review Board) review prior to any data collection, consistent with standard practice for research involving human subjects, and will report response rates, sampling frame, and informed-consent procedures in full once approved and fielded. The questionnaire will consist of approximately 20 multiple-choice items administered electronically via Microsoft Forms and distributed via email through the University of the Incarnate Word (UIW) Office of Institutional Research. We will be targeting a sample of $N > 100$ respondents. Because distribution relies on institutional email lists without quota sampling, participation will reflect a convenience sample of university-affiliated and local respondents.

6. Discussion

This section separates what the Fern reconstruction shows, what established literature supports, and what we propose as new hypotheses. It then considers which parts of the framework are specific to South Texas and which may apply more widely.

6.1. What the Fern Reconstruction Shows

The public record supports three descriptive observations. First, forecast lead time was not the main constraint. Watches were issued by 20 January and warnings by

22 and 23 January (Figure 1). Second, warning coverage was uneven. Parts of the Corpus Christi area were not under a Winter Storm Warning, although freezing temperatures occurred nearby, and Extreme Cold Warnings covered some coastal areas (Figure 4). Third, conditions changed abruptly. Temperatures were in the 60s on 24 January and in the 30s on 25 January (Figure 3). These observations come from NWS products and storm records. They do not show how residents perceived or responded to the warnings, because no household data were collected.

6.2. Interpretations Supported by Existing Literature

Several patterns in the record are consistent with earlier research. Because WEA delivery depends on warning polygons, residents outside them could not receive an alert, which is a known limit of geotargeting [16]. Coarse targeting and repeated over-alerting are associated with lower confidence that a message applies to the recipient and with warning fatigue [16,17]. Generic messages are less effective than messages that state the hazard, location, action, and timing [21]. Understanding and belief do not guarantee protective action. Bean et al. found high understanding and believability of mock alerts [20]. Warning failures often occur in communication and response capacity rather than in forecasting [25] and in the links between components [22]. Regionally adapted thresholds and impact-relevant content are also emphasized in heat-health warning research [35], which we use as comparative literature only. The Fern record is consistent with these findings. It does not test them.

6.3. New Propositions Introduced in This Study

The following are our own hypotheses, not established findings. (1) A personal relevance gap, in which residents accept a regional hazard but doubt that the warning applies to their home, lies between threat perception and protective action decision-making. (2) Informal social-cue pathways are weaker in transient, linguistically diverse, warm-climate communities. (3) Localized, probability-based messages narrow the personal relevance gap more than longer lead time does. (4) Perceived overstatement after a moderate storm such as Fern may reduce response to later warnings. These are tested in the planned survey (H1 to H3c). Until then, they remain conceptual.

6.4. Context-Specific and Transferable Elements

Some elements depend on South Texas conditions. These include the history of Winter Storm Uri, the housing and plumbing stock built for mild winters, the local warning polygons, and the large share of transient and Spanish-speaking residents. Other elements may apply more widely to regions facing infrequent or unfamiliar hydro-meteorological hazards. These include the gap between regional warning scale and household-level risk judgment, the gating of alerts by polygon boundaries, the limited shared experience that weakens social cues, and the risk that a moderate event reduces trust in future warnings. We expect the personal relevance gap and the geotargeting constraint to be the most transferable. The social-cue attenuation is the most context-dependent and the least supported so far. Testing in other regions, such as areas exposed to rare heat, flood, or snow events, would be needed to confirm this.

6.5. Practical Implications

If the propositions are supported, emergency managers may benefit from combining finer geotargeting with impact-specific wording, such as neighborhood pipe-freeze risk. They may also need to rely more on institutional channels, such as WEA, NWS apps, and local meteorologists, than on neighbor-to-neighbor communication. Explicit post-storm

explanations of why warnings were issued despite modest local impacts could help protect trust in future warnings.

7. Limitations

This study relies on a narrative reconstruction of public storm records rather than systematic content analysis. NWS archives and media reports may also contain gaps or inaccuracies in warning boundaries and timing. Because the authors' own expectations shaped which records were sought and how they were interpreted, some interpretive bias is possible in the absence of blinded or multi-coder review. The framework in Section 4 consists of testable propositions based on hazard-communication literature and the Fern timeline. Its specific claims, particularly the weakened social-cues pathway and personal relevance gap, remain hypotheses until tested with primary survey data. Finally, this paper focuses on a single storm and a single regional corridor. The degree to which these proposed modifications generalize to other warm-climate regions or short-fuse infrastructure hazards remains an open question.

The planned survey is cross-sectional and relies on retrospective self-report. Mediation analyses of the relationships among threat perception, personal relevance, and protective behavior will therefore indicate statistical consistency with the proposed pathway but cannot establish temporal order or causation.

Comparisons between our findings and prior PADM research on hurricanes and earthquakes are indirect. Differences in sampled populations, measurement of social and institutional sources, and study design may account for any divergence, and such differences should not be attributed to hazard type without a design that holds these factors constant.

The survey will try to measure *intended* action in response to hypothetical messages, and intentions do not always translate into behavior. Differences in effects across conditions therefore indicate message-format effects on stated intent, not on actual protective behavior during a storm. Lead-time effects are tested over a limited range (24 vs. 72 h), and conclusions about the relative value of lead time do not extend to other durations.

8. Conclusions

Winter Storm Fern arrived five years after Winter Storm Uri exposed the fragility of Texas's cold-weather infrastructure. This event offers an opportunity to reexamine how short-fuse, infrastructure-centered hazards are warned for and responded to in a historically warm-climate region. Using public records to reconstruct the storm timeline, we build on the Protective Action Decision Model and hazard-communication literature. We propose four modifications: a geographic/cultural filter at the exposure stage, an attenuated social-cues pathway, a personal relevance gap, and an explicit false-alarm feedback loop. We further propose localized, probability-based messaging as a lever for narrowing that gap. These propositions are deliberately framed as testable rather than demonstrated. The next phase of this research program is an IRB-reviewed household survey designed explicitly to evaluate these hypotheses. We will keep the possibility to cover the 'geographic/cultural filter at the exposure stage' in next study. We present this conceptual paper as the necessary theoretical and evidentiary groundwork for that empirical study.

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