

Assessing Public Interpretation of Original and Linguist-Suggested SPC Risk Categories in Spanish

ABBY BITTERMAN,^a MAKENZIE J. KROCAK,^{a,b,c} JOSEPH T. RIPBERGER,^a SEAN ERNST,^{a,b,c}
JOSEPH E. TRUJILLO-FALCÓN,^{b,c,d} AMÉRICA GAVIRIA PABÓN,^a CAROL SILVA,^a AND HANK JENKINS-SMITH^a

^a *Institute for Public Policy Research and Analysis, University of Oklahoma, Norman, Oklahoma*

^b *Cooperative Institute for Severe and High-Impact Weather Research and Operations, Norman, Oklahoma*

^c *NWS Storm Prediction Center, Norman, Oklahoma*

^d *NOAA/OAR/National Severe Storms Laboratory, Norman, Oklahoma*

(Manuscript received 17 June 2022, in final form 22 April 2023, accepted 25 April 2023)

ABSTRACT: Recent work has shown that the words used in the Storm Prediction Center's convective outlook are not easily understood by members of the public. Furthermore, Spanish translations of the outlook information have also been shown to have interpretation challenges. This study uses survey data collected from the Severe Weather and Society Spanish Survey, a survey of Spanish speakers across the United States, to evaluate how U.S. residents receive, understand, and respond to weather forecasts and warnings. For this experiment, respondents were tasked with ranking the words and colors used in the SPC's convective outlook. They were randomly assigned either 1) the words originally used by the SPC for Spanish translations or 2) a set of words suggested by linguistic experts familiar with Spanish dialects in the United States. We find Spanish speakers have similar challenges to English speakers when ordering the words the SPC uses. When using the translations proposed by the linguistic experts, we find the majority of Spanish speakers ranked the words in the intended order of associated risk. Spanish speakers also displayed similar ranking distributions for the colors in the outlook as English speakers, where both groups ranked red as the highest level of risk. These findings suggest the original translations used by the SPC convective outlook create barriers for Spanish speakers and that the expert translations more effectively communicate severe weather hazards to Spanish-speaking members of the public.

SIGNIFICANCE STATEMENT: The SPC's convective outlook provides important information about the risk posed by severe storms to members of the public. While the SPC had official Spanish translations for the categorical labels used in the outlook, it was believed anecdotally that there was a disconnect between the words the SPC was using and the way the translated outlook was being interpreted by Spanish-speaking members of the public. This work verifies previous beliefs about the original translation set and confirms the reliability of a new set of translations developed by linguistic experts among Spanish-speaking members of the public.

KEYWORDS: Social Science; Operational forecasting; Communications/decision making

1. Introduction and background

The Storm Prediction Center's convective outlook—which is derived from a probabilistic forecast of a severe weather event occurring within 25 miles of a point between one and eight days out—has undergone many changes since its inception in 1973 (Corfidi 1999; Ernst et al. 2021). The most significant change to the outlook was the addition of the Marginal and Enhanced categories in 2014 to expand the number of risk categories from three to five: Marginal, Slight, Enhanced, Moderate, and High (Edwards and Ostby 2015, Fig. 1). Recent work has shown that English-speaking members of the U.S. public have difficulty ranking the five categories by perceived risk in the official order used by the Storm Prediction Center (SPC), often switching Marginal with Slight and Enhanced with Moderate (Ernst et al. 2021). This same research also showed that

members of the public tend to rank the color red as conveying the highest level of risk when it is intended to indicate the second-highest risk level in the product (Ernst et al. 2021). Other recent work has aimed to offer more intuitive communication methods for the outlook, suggesting the use of numbered levels (e.g., Slight is a Level 2 of 5 risk), but these changes have yet to be officially adopted by the SPC (Krocak et al. 2022b).

The SPC risk categories were first introduced in the Spanish language in 2015. With the introduction of the five-category outlook in 2014, the SPC consulted with a bilingual meteorologist to translate the risk categories, which were operationalized a year later. The five risk categories were translated to *Mínimo*, *Leve*, *Elevado*, *Moderado*, and *Alto* (Fig. 2). The words became a part of the NWS Spanish to English dictionary and practiced across operations. As with the English words, many scientists and communicators have anecdotally suggested this set of Spanish translations of the categorical labels may be inadequate at communicating meteorologists' intent to members of the public (Trujillo-Falcón et al. 2021).

While the SPC already used a set of official translations for its risk categories—translating Marginal, Slight, Enhanced, Moderate, and High as *Mínimo*, *Leve*, *Elevado*, *Moderado*,

Denotes content that is immediately available upon publication as open access.

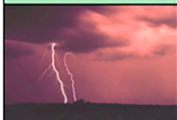




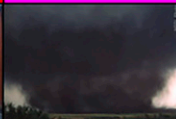
Corresponding author: Abby Bitterman, abbybitt@gmail.com

DOI: 10.1175/WAF-D-22-0110.1

© 2023 American Meteorological Society. This published article is licensed under the terms of the default AMS reuse license. For information regarding reuse of this content and general copyright information, consult the AMS Copyright Policy (www.ametsoc.org/PUBSReuseLicenses).

Brought to you by NOAA Central Library | Unauthenticated | Downloaded 08/02/23 02:01 PM UTC

Understanding Severe Thunderstorm Risk Categories

THUNDERSTORMS (no label)	1 - MARGINAL (MRGL)	2 - SLIGHT (SLGT)	3 - ENHANCED (ENH)	4 - MODERATE (MDT)	5 - HIGH (HIGH)
No severe* thunderstorms expected	Isolated severe thunderstorms possible	Scattered severe storms possible	Numerous severe storms possible	Widespread severe storms likely	Widespread severe storms expected
Lightning/flooding threats exist with <u>all</u> thunderstorms	Limited in duration and/or coverage and/or intensity	Short-lived and/or not widespread, isolated intense storms possible	More persistent and/or widespread, a few intense	Long-lived, widespread and intense	Long-lived, very widespread and particularly intense
					

* NWS defines a severe thunderstorm as measured wind gusts to at least 58 mph, and/or hail to at least one inch in diameter, and/or a tornado. All thunderstorm categories imply lightning and the potential for flooding. Categories are also tied to the probability of a severe weather event within 25 miles of your location.



National Weather Service

www.spc.noaa.gov



FIG. 1. The SPC risk categories for the convective outlook.

and *Alto*—research into how bilingual broadcasters presented the risk categories to their audiences showed inconsistencies, with some stations adding in *Ligero* and *Ampliado* as the second and third level risk words (Trujillo-Falcón et al. 2021). One station even moved *Elevado* from its intended position as the third category to the fifth, highest category. Inconsistencies occurred because 1) broadcasters did not know of the Spanish SPC risk categories and instead made up their own or

2) they disagreed with the official translation and created terms that best resonated with their community (and dialect). Although some stations used the then-official translations used by the SPC, this wide range of word scales created inconsistencies in how severe weather risk was communicated to the Spanish-speaking public.

Previous qualitative work has shown that television and radio broadcasts are a particular asset when it comes to communicating

Categorías de Riesgo de Tormentas Severas

Tormentas (sin categoría)	1 - MÍNIMO (MÍN)	2 - LEVE (LEVE)	3 - ELEVADO (ELEV)	4 - MODERADO (MOD)	5 - ALTO (ALTO)
Se esperan tormentas no severas*	Posibles tormentas severas aisladas	Posibles tormentas severas aisladas	Posibles tormentas severas numerosas	Probables tormentas severas de amplia cobertura	Se esperan tormentas severas de gran cobertura
Amenaza de rayos/inundaciones pueden existir en <u>todas</u> las tormentas	Limitadas en duración/cobertura/ intensidad	De corta duración/ no tan extensas, posiblemente alguna intensa aislada	Más persistentes/ de amplia cobertura, pocas intensas	Larga duración, amplia cobertura e intensas	Muy larga duración, gran cobertura y particularmente intensas
					

* El Servicio Nacional de Meteorología, NWS, define una tormenta severa como: ráfagas de vientos de por lo menos 58 MPH y/o granizo con 1 pulgada de diámetro y/o un tornado. Todas las categorías de tormentas implican rayos/descargas eléctricas y el potencial de inundaciones. Las categorías también están ligadas a la probabilidad de tiempo severa a 25 millas de su ubicación.



National Weather Service

www.spc.noaa.gov



FIG. 2. An example of the original Spanish translations used by the SPC for its risk categories.

messages about public health risks to Spanish-speaking communities (Arlkatti et al. 2014). Spanish-language media sources are important partners in communicating extreme weather threats as well, as some Spanish speakers prefer to receive warnings in Spanish (Benavides and Arlikatti 2010). Given the importance of television broadcasts for risk communication, Spanish-language TV stations need to be prepared to aid in the dissemination of weather warning information to local communities (Benavides and Arlikatti 2010). A lack of emergency communication resources in other languages, however, makes it difficult for bilingual practitioners to practice their profession. As of 2023, the United States does not have an “official” English to Spanish dictionary for weather and climate terminology (Trujillo-Falcón et al. 2021). There are some entities with local reference materials, such as the NWS and TV stations, but their translations at times do not match up and can lead to inconsistency in emergency messages (Trujillo-Falcón et al. 2022). The lack of a proper description of the hazard can lead to minority linguistic groups, like Spanish speakers, being forgotten in the emergency communication process (Abukhalaf and von Meding 2021; Tripathi et al. 2023; Uekusa 2019). This leaves subsets of these groups more vulnerable to disasters due to a lack of resources and trust (Méndez et al. 2020; Piller et al. 2020).

In addition to the importance of broadcast messaging described above, it is particularly important to study Spanish-speaking communities because disaster subcultures can lead to a potential lack of familiarity with a hazard. Living in a certain “disaster subculture” means the community one is from has developed strategies to address common recurring hazards which might impact that community (Chan and Huang 2012; Wenger and Weller 1973). For example, moving to an area regularly impacted by unfamiliar weather hazards can lead to a lack of background knowledge and familiarity with the impacts of an impending storm. Different regions in the United States are more familiar and aware of certain types of weather hazards—tornadoes in the Plains states and snowstorms in the Northeast—and thus they are more prepared to respond (e.g., Ripberger et al. 2020). The same is true for different Spanish-speaking countries, which can experience widely variable weather hazards. The country a person or their family comes from might not regularly experience the types of weather hazards typical of certain parts of the United States (Carter-Pokras et al. 2007). This leads to different disaster subcultures, meaning someone who has a background from Haiti might have a cultural understanding of hurricanes and be socialized to understand that type of hazard but not have the same context for tornadoes or snowstorms (Wenger and Weller 1973).

Risk communication barriers such as these have been addressed in fields outside of meteorology. Researchers have worked to develop methods to improve the quality of translations used for research and real-world application purposes. The concept of meaning-to-meaning translation is especially important when communicating (Esposito 2001), as it requires translators to not just translate words directly from one language to another, but cultural context and overall concepts trying to be delivered should also be taken into consideration when creating translations (Morales et al. 2023). It is also

important to test translated messages with the communities they are intended to be delivered to (Brelsford et al. 2019). Cultural context and comprehensibility both need to be considered when translating, especially when trying to communicate risk (Brelsford et al. 2019). While some previous work has suggested that the use of slang of regional dialects can improve comprehension of translations in local communities (Hendricson et al. 1989), the work presented below aims to be dialect neutral as it is intended for a national audience. Defined by Trujillo-Falcón et al. (2021), dialect neutral messages ensure that information can be understood by everyone in a language group, no matter what dialect they speak. Dialect neutrality is important because Spanish-speaking communities are not monolithic. Just as Spanish speakers come from different weather contexts, Hispanic heritage and location in the United States can also lead to different regional dialects that use the language differently. An example for English speakers would be the regional use of the words “coke,” “pop,” and “soda” to describe sugary carbonated beverages in different parts of the United States. Furthermore, risk tolerance is defined at an individual level, and people have their own concepts of uncertainty and risk (Joslyn and Savelli 2021). Therefore, it is especially important that the words used to communicate risk and uncertainty are evenly understood across languages and dialects.

Efforts to make translations more culturally relevant and dialect neutral have similarly been made in the medical field. Through decades of health communication research, Hsieh (2016) developed a translation framework for medical interpreters to use that incorporated the worldviews of diverse multilingual speakers. When translating health jargon that is not often practiced routinely in a community, translations needed to be 1) consistent among the medical field and 2) supplemented with educational campaigns to ensure everyone understood the message (Hsieh 2016). However, when considering risk terminology, medical interpreters need to work hand-in-hand with language experts to ensure that dialects and cultures do not get in the way of understanding and response. Trujillo-Falcón et al. (2021) adopted the health framework and applied it to the meteorological enterprise, suggesting that risk terminology needs to be dialect neutral so that all groups can equitably respond to weather warnings. This process, then, was applied to the SPC outlook by John Lipski’s Spanish Dialectology class at The Pennsylvania State University, who studied different dialects in Spanish and developed a set of translations for the SPC convective outlook risk categories in a dialect-neutral way (Trujillo-Falcón et al. 2021).

To evaluate the effectiveness of the linguist-suggested translations from Trujillo-Falcón et al. (2021)—*Mínimo, Bajo, Moderado, Alto, and Extremo*—this work tests the translations in a survey experiment with Spanish-speaking members of the U.S. public. Following the advice of established health and risk communication frameworks for translation (Hsieh 2016; Trujillo-Falcón et al. 2021), we first identify whether translations are dialect neutral. To help future educational campaigns, we also explore how effectively the translations resonate across levels of English proficiency. Throughout this

paper, the original set of translations from the SPC will be labeled as the “original SPC” translations because they were official translations at the time the survey was fielded, and the second set (from [Trujillo-Falc3n et al. 2021](#)) will be referred to as “linguist-suggested” translations.

Additionally, this paper looks at the colors associated with the SPC risk categories. While colors have been shown to express similar meanings across cultures, some variation has been observed in market research ([Adams and Osgood 1973](#); [Jacobs et al. 1991](#)). Furthermore, previous research has demonstrated the importance of testing graphics and visualizations with their target audience ([Braun and Silver 1995](#)). In some risk communication contexts, red has been shown to convey the highest level of risk ([Braun and Silver 1995](#)), though it was not being compared with magentas or purples, which are popular colors used by the National Weather Service to convey levels of risk higher than the level indicated by red. The use of color in graphics has also been shown to be an important factor for members of the public in their ability to discern information from weather graphics ([Hogan Carr et al. 2016](#); [Gulacsik et al. 2022](#)). However, for color scales to be effective at communicating risk, they must be intuitive, and a person’s intuition can be shaped by their cultural context ([Hogan Carr et al. 2016](#)). Challenges in interpreting the colors used by the SPC have been observed among English speakers ([Ernst et al. 2021](#)), so we wanted to evaluate whether or not similar challenges exist among Spanish speakers.

After discussion of the results of this study with SPC leadership, the SPC changed the words it uses to translate the convective outlook to the linguist-suggested set. The SPC now uses *M3nimo*, *Bajo*, *Moderado*, *Alto*, and *Extremo* for Spanish language communications of the outlook.

2. Data and methods

a. Survey

The data for this study come from the Severe Weather and Society Spanish Survey, a survey of Spanish speakers across the United States ([Krocak et al. 2022a](#)). This survey gathered data on respondents’ understanding of severe weather forecasts, warning systems, and preparedness actions, as well as a series of single-issue experiments. It was based off the Severe Weather and Society Survey that has been distributed in English by OU’s Institute for Public Policy Research and Analysis (IPPRA) for the past five years (see <https://dataverse.harvard.edu/dataverse/wxsurvey> for more information on the full Extreme Weather and Society Survey series). The Severe Weather and Society Spanish Survey was conducted using the Internet survey platform Qualtrics, which maintains an Internet panel of people who agree to take online surveys and garnered 1050 respondents in 2021. Due to the opt-in and fluent nature of the Qualtrics sampling process, it was not possible to calculate a response rate. In place of response rates, researchers using this type of sampling approach generally report completion rates, which indicate the proportion of respondents who complete the survey once

TABLE 1. Demographic representation of the Hispanic/Latinx respondents. The asterisk indicates that population estimates were obtained from the American Community Survey microdata records, made available by IPUMS USA (<http://www.ipums.org>) ([Ruggles et al. 2021](#)).

	U.S. Spanish speakers (Census 2020*)	Survey respondents
Age		
18–34	35%	46%
35–64	52%	50%
65+	13%	4%
Sex		
Female	50%	61%
Male	50%	39%
Origin (heritage)		
Not Hispanic	6%	22%
Mexican	55%	32%
Puerto Rican	8%	15%
Cuban	5%	5%
Other Hispanic	27%	26%
Speaks English		
No, not at all	8%	3%
Yes, but not well	16%	16%
Yes, well	19%	27%
Yes, very well	57%	54%
NWS region		
Eastern region	20%	28%
Southern region	37%	38%
Central region	9%	10%
Western region	34%	25%

they begin ([Callegaro and DiSogra 2008](#)). For this survey, the completion rate was 0.80 (1050/1307 = 0.80).

Respondents for the Severe Weather and Society Spanish Survey comprised a nationally representative sample of the Spanish-speaking public in the United States (Table 1). The survey slightly oversampled females, who made up 60.76% of respondents, as well as non-Hispanic Spanish speakers, who make up 6.4% of the population but were represented by 21.71% of respondents in the survey. To measure possible differences in dialect, respondents were asked to identify their Hispanic origin. In response to this question, 31.52% said they were of Mexican descent, 15.43% said Puerto Rican, 5.33% said Cuban and 26% said they were from another Hispanic or Spanish-speaking country. While many Spanish speakers in the United States are second- and third-generation residents and beyond, this survey did not ask respondents to provide this information.

The sample also roughly matches where U.S. Spanish speakers live when broken out by NWS region (see Table 1). It was important to this study to have diversity in Hispanic origin and U.S. region. As previously noted, different Spanish-speaking countries use different regional dialects, and regional dialects can also form in different parts of the United States. A driving factor in this study is finding a set of translations for the SPC convective outlook that is dialect neutral.

Spanish speakers in the United States also have varying levels of English proficiency. While the distribution of self-reported level of English proficiency in the sample of respondents was largely representative of the U.S. population as a whole (as

SPC risk words	Original SPC Translations	Linguist-suggested Translations
Marginal	Mínimo	Mínimo
Slight	Leve	Bajo
Enhanced	Elevado	Moderado
Moderate	Moderado	Alto
High	Alto	Extremo

Fig. 3. The SPC risk categories in English, the original Spanish translation set, and the linguist-suggested translation set.

seen in Table 1), we recognize the survey under sampled the most vulnerable populations (i.e., those who indicated they do not speak English at all). There were also variations between the survey sample and the Census in the distributions for age and gender. Only 4% of survey respondents were age 65 and older, compared to 13% of the Spanish-speaking U.S. public, which is likely due to the challenges of reaching older populations through online survey platforms. To overcome these potential limitations, poststratification weights were used in the data analysis to adjust for the differences in the sample and the population, thus allowing the results to reflect the population more closely.

b. Experimental design

Our first experiment was developed to address two research questions:

- 1) How do Spanish-speaking members of the U.S. public interpret the risk communicated by the original set of translations for the SPC risk categories?
- 2) How do Spanish-speaking members of the U.S. public interpret the risk communicated by the proposed linguist-suggested translations?

To compare the performance of the original translation set with the performance of the linguist-suggested set, respondents were randomly shown only one of the two sets of words, with 519 respondents given the original SPC set and 531 shown the linguist-suggested set (see Fig. 3). Depending on which set of words a respondent was assigned, those words appeared in a random order on the screen.

The question was phrased as follows:

The National Weather Service Storm Prediction Center uses the following phrases to describe the risk of severe thunderstorms and tornadoes. We want to know what these phrases mean to you. Can you rank them from one (lowest risk) to five (highest risk)?

Translation: *El Centro de Predicción de Tormentas del Servicio Nacional de Meteorología utiliza las siguientes frases para describir el riesgo de tormentas severas y tornados. Queremos saber que significan estas frases para usted. ¿Puede categorizarlas desde 1 (el riesgo es menor) hasta 5 (el riesgo es mayor)?*

In the second experiment, respondents were also asked to rank by perceived risk the colors associated with the risk categories. Since there are no translations related to color, the question was the same for all respondents. The question was phrased like this:

The Storm Prediction Center also uses colors to describe the risk of severe thunderstorms and tornadoes. We want to know what these colors mean to you. Can you rank these colors from one (lowest risk) to five (highest risk)?

Translation: *El Centro de Predicción de Tormentas también utiliza colores para describir el riesgo de tormentas severas y tornados. Queremos saber que significan estos colores para usted. ¿Puede categorizarlas desde 1 (el riesgo es menor) hasta 5 (el riesgo es mayor)?*

Just as with the words, the colors initially appeared in a random order on the screen. Colors were asked about independent of words, meaning the words and colors were not displayed together for either question, but the two questions were asked on the same page of the survey.

3. Results

a. Original SPC translation

These results are presented using three different methods: the proportions of respondents who chose each word at each place in the five-word order; the mean ranking, which shows the mean overall placement of each word on a 1–5 scale; and the common complete answers, which look at the full set of words submitted by the respondents. In this analysis, a lower ranking for a word indicates a lower level of perceived risk and a higher ranking indicates the word communicates a higher level of risk. For example, in the discussion of these results the “first word” refers to the word that is intended to communicate the lowest level of risk (i.e., *Mínimo*), and the fifth word refers to the word intended to communicate the highest level of risk (i.e., *Alto* in the original SPC translations and *Extremo* in the linguist-suggested translations).

For the original SPC translation set, the intended order from lowest to highest perceived risk is *Mínimo*, *Leve*, *Elevado*, *Moderado*, and *Alto*. Respondents who saw the original SPC translation set tended to put the intended first two words, *Mínimo* and *Leve*, in the intended order, but only *Mínimo* was placed in the intended position by a majority of respondents (Fig. 4). The greater challenge came with the final three categories, *Elevado*, *Moderado*, and *Alto*. These categories are used in the original SPC set to express a higher level of severe weather risk, so it is arguably even more important that the public interprets the same level of risk from these words as the SPC intends. Just under 62% of respondents who were shown the original SPC translations rated *Moderado* as the third word, while it occurs as the fourth word in the original SPC ordering. This means the SPC was using *Moderado* to communicate a higher level of risk of severe weather relative to how Spanish-speaking members of the public understood it, since respondents overwhelmingly favored using *Moderado* to express a 3 out of 5 risk level while the SPC was using it for a 4 out of 5 risk level. However, *Elevado* was intended to

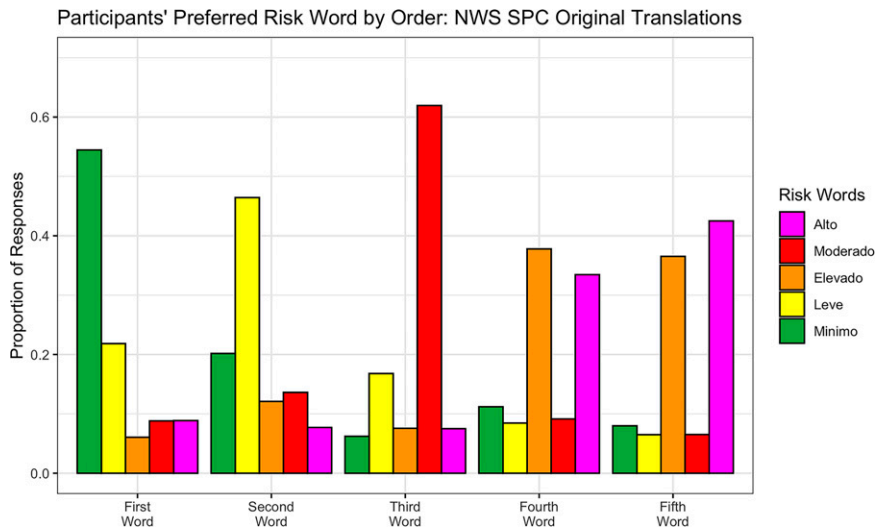


FIG. 4. The proportion of responses for each word at each potential placement in the order of the categories for the original SPC translation set.

convey this third level of risk, but only 7.5% of respondents placed it at 3 out of 5. Further confusion appeared in the rankings for the fourth and fifth word, where *Elevado* and *Alto* were closely ranked, with mean rankings of 3.87 for *Elevado* and 3.93 for *Alto* (Fig. 7). Respondents placed *Elevado* as a level four out of five risk when it was intended to represent the third level of risk, while *Alto* was the second most commonly chosen response for the fourth risk word. Conversely, over 42% of respondents ranked *Alto* fifth, but *Elevado* was chosen to express the highest level of risk by 36.5% of respondents. Again, *Elevado*, which was intended by the SPC to represent the middle level of risk from severe weather, seems to be interpreted by the Spanish-speaking public to express a higher level of risk.

While the mean rankings paint a telling picture, the most common complete rankings from respondents are even more revealing. The most common rankings, as shown in Fig. 5, list the number of respondents who submitted a particular order of words as their answer to the survey question. For example, the most commonly answered rank order for those who were shown the original SPC translation set was “*Mínimo, Leve, Moderado, Elevado, Alto*,” with 21.4% of respondents submitting this answer. The intended order of the original SPC translations—“*Mínimo, Leve, Elevado, Moderado, Alto*”—was submitted by 0.81% of respondents. This means the Spanish words the SPC was using were not interpreted by Spanish-speaking members of the public in the same way the SPC intended. This is problematic because it can lead to miscommunications

1st Word	2nd Word	3rd Word	4th Word	5th Word	Percent of Participants
SPC Original Translations (n = 519)					
Mínimo	Leve	Moderado	Elevado	Alto	21.40%
Mínimo	Leve	Moderado	Alto	Elevado	15.90%
...					
<i>Mínimo</i>	<i>Leve</i>	<i>Elevado</i>	<i>Moderado</i>	<i>Alto</i>	<i>00.81%</i>
Linguist Suggested Translations (n = 531)					
<i>Mínimo</i>	<i>Bajo</i>	<i>Moderado</i>	<i>Alto</i>	<i>Extremo</i>	<i>33.60%</i>
Bajo	Mínimo	Moderado	Alto	Extremo	9.43%
Bajo	Moderado	Mínimo	Alto	Extremo	5.86%

FIG. 5. The complete common responses to the survey questions broken down by translation set. The intended order of the words is indicated in red.

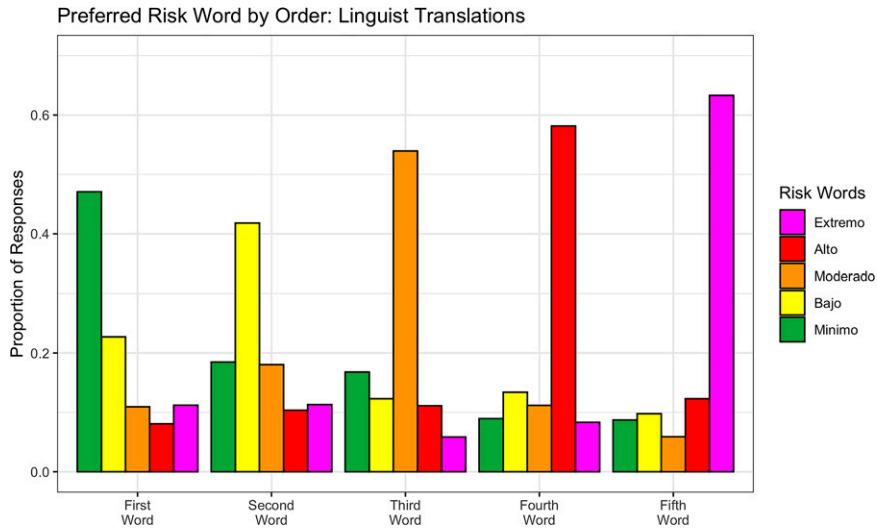


FIG. 6. The proportion of responses for each word at each potential placement in the order of the categories for the linguist-suggested translation set.

between the SPC and Spanish speakers when trying to convey the level of risk the public faces from a severe weather event.

b. Linguist-suggested translations

The set of translations suggested by the linguistic experts fared considerably better than the original SPC translations. As a reminder, the intended order of the linguist-suggested translations from lowest to highest perceived risk is *Minimo*, *Bajo*, *Moderado*, *Alto*, and *Extremo*. For this set, *Minimo* (the intended first word) and *Bajo* (the intended second word) were ranked consistent to the intended order, though at slightly lower rates—47.1% of people ranked *Minimo* first and

41.8% put *Bajo* second—as compared to *Minimo* (54.4% ranked first) and *Leve* (46.4% ranked second) in the SPC’s original translation set (Figs. 4 and 6). Unlike the original SPC translation, the linguists suggested the use of *Moderado* as the third highest risk word, and it was ranked third at a similar rate (62% of respondents placed it third in the original SPC set compared to 54% for respondents who saw the linguist-suggested set) and mean ranking (2.91 for the original SPC set and 2.83 for the linguist-suggested set out of 5) across both sets. In this case, however, the preference of the respondents matched the word order intended by the linguists (Fig. 7).

The words indicating the two highest levels of risk in the linguist-suggested translation set are *Alto* and *Extremo*, in

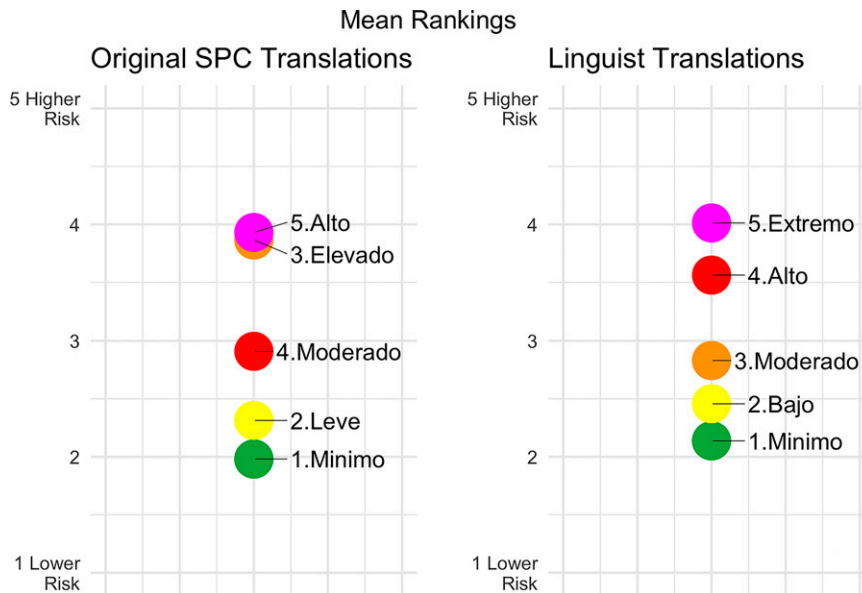


FIG. 7. The mean placement of each word in the given translation set is indicated by the dots in the above plot.

Mean Rankings by English Proficiency: Linguist Translations



FIG. 8. The mean ranking for each word in the linguist-suggested translation set is broken down by self-reported level of English proficiency.

that order. The proportion of respondents putting these two words in the intended order was higher than the other words in the set, with 58.2% of respondents ranking *Alto* in fourth and 63.3% putting *Extremo* in fifth (Fig. 6). There is also clear separation in their mean rankings. *Alto* had a mean ranking of 3.56 out of 5, and *Extremo*'s mean ranking was 4.01 out of 5 (Fig. 7), indicating that respondents had a clear preference to use *Alto* for the second highest level of risk and *Extremo* to communicate the highest level.

Looking again at the most common complete rankings, the intended order for the linguist-suggested translations—“*Mínimo*, *Bajo*, *Moderado*, *Alto*, and *Extremo*”—was also the most commonly submitted answer. Over 33% of people submitted this ranking (Fig. 5). This makes the linguist-suggested translations the most commonly submitted answer by proportion across both sets of translations. The second most common ranking, submitted by 9.43% of respondents, saw respondents flip *Bajo* and *Mínimo* but keep the next three words in the intended order. Again, in the linguist-suggested translation set, we see less disconnect between the intended order of the risk category words and the order most commonly preferred by respondents, resulting in more consistency in communicated and perceived risk. Given that a third of respondents submitted the complete intended order when shown the linguist-suggested translations, it appears this translation set is more intuitive for Spanish speakers and may allow the SPC and other agencies to better communicate the potential level of risk posed by severe weather.

c. Comparing the original and linguist-suggested SPC translations

Comparing these two translation sets, the linguist-suggested translations are interpreted in the intended order by respondents more often than the original SPC translations set. While the two lowest levels of risk, *Mínimo* and *Leve* or *Mínimo* and *Bajo*, are generally ranked in the intended order, there is a preference across both sets of respondents for *Moderado* to be associated with the third level of risk (Fig. 7). This

indicates Spanish speakers identify a “middle” level of risk with the meaning of the word *Moderado*. Finally, the words used for the two highest levels of risk are more widely understood by users for the linguist-suggested translations, as indicated by the separation between *Alto* and *Extremo* in the mean rankings (3.56 and 4.01, respectively, out of 5). By contrast, the mean rankings for the original SPC translation show the words *Elevado* and *Alto* were not as easily understood, as respondents preferred a different rank order than the SPC intended. This comparison further emphasizes the results communicated above. The respondents’ preference for communicating increasing levels of risk was more closely matched by the intended order developed in the linguist-suggested translations.

The results reported above are based on the entire pool of respondents who saw each set of translations, but we also tested both sets based on respondents’ self-reported Hispanic heritage and self-reported English proficiency. Results show that similar interpretation challenges exist for the original SPC translations across all respondents, regardless of Hispanic heritage or level of English proficiency. Across subgroups, respondents consistently indicated that *Moderado* (4 out of 5 in the original SPC set) conveyed a middle level of risk, while also showing no clear favorite between *Elevado* (3 out of 5) and *Alto* (5 out of 5) for which word should indicate the highest level of risk.

Conversely, the linguist-suggested translations performed well across all Hispanic heritage groups and English proficiency levels. Across all levels and groups, the only instance in which the linguist-suggested translations were not put in the intended order on average was among respondents who reported that they do not speak English at all (Fig. 8). This subset of respondents closely ranked the words used for the middle levels of risk, ordering *Moderado* second, *Bajo* third and *Alto* fourth, with 0.3 points separating the mean rankings of the three words. While it is important to note that those who spoke no English were the only group that did not, on average, produce a preference order that matched the order of



FIG. 9. The mean ranking for each word in the linguist-suggested translation set is broken down by self-reported Hispanic heritage.

the linguist-suggested set, it is also worth noting that this group also only made up 3% of survey respondents and only half of those respondents were shown the linguist-suggested translations, meaning some respondents may have an outsized influence on the results when using weighted data, thus altering the findings. Future work should specifically analyze interpretation of the SPC labels with Spanish-speakers who speak no English to see if this trend holds with a larger sample size.

All other subsets of respondents showed more clear separation in the mean rankings of the risk words. A driving factor behind working with linguists to develop this new translation set was to ensure the translated risk categories were dialect neutral, meaning they elicit the same understanding of associated risk across all Spanish speakers (Fig. 9). These results indicate this goal has largely been achieved.

d. Risk colors and culture

All 1050 respondents were asked to rank the colors used by the SPC in the convective outlook in order from lowest to highest perceived risk. Respondents consistently listed green as the

first color (indicating lowest risk), with many respondents ranking yellow and orange as the second and third colors, respectively, as they were intended. Magenta was the most common answer for the fourth color, even though it is intended to be the highest risk color, with orange chosen second most frequently for the fourth color. Red was the most frequent response by a large margin for the fifth color, with 67.4% of respondents ranking it in that position even though it is actually the intended fourth color (Fig. 10). These trends are almost identical to those previously observed among English speakers (Ernst et al. 2021), indicating similar perceptions of color and risk association among English and Spanish speakers in the United States. Much like the work done by Ernst et al. (2021), the findings presented here amount to further evidence that the SPC colors may need to be reconsidered, with red being the highest risk color.

4. Discussion and conclusions

Overall, this study finds the linguist-suggested translations of the SPC convective outlook category words communicate

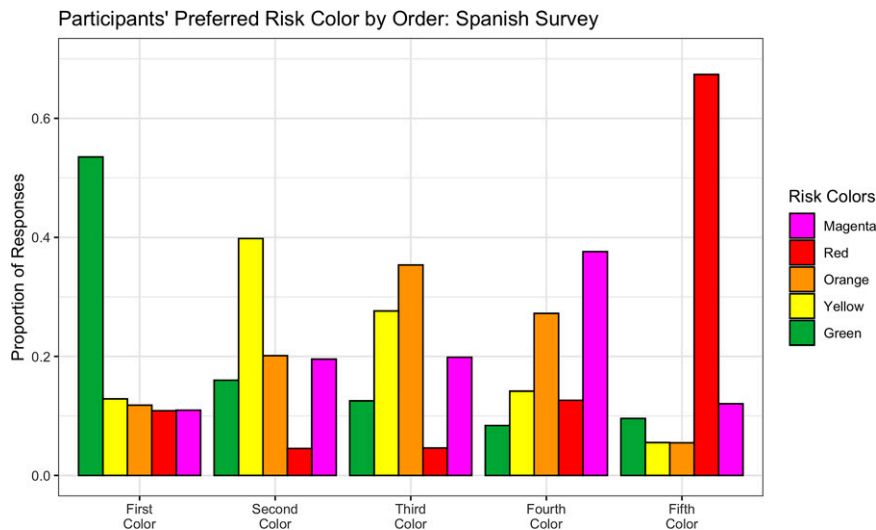


FIG. 10. The proportion of responses for each color at each potential placement in the order of the categories.

Comprensión de las Categorías del Pronóstico de Tormentas Severas						
NIVEL	CATEGORÍA	DETALLES	COBERTURA	¿Cuántas tormentas son posible?	¿Qué tan malas podrían ser las peores tormentas?	DEFINICIONES
	Tormentas	Las tormentas pueden producir relámpagos mortales, ráfagas de viento fuertes, y granizo.	N/A		Similar a las tormentas que su zona puede experimentar varias veces al año.	Tormenta Severa Tiene al menos una de las siguientes características:
1	Mínimo (MÍN)	Tormentas <u>aisladas</u> podrían producir vientos dañinos y granizo. Podría desarrollarse una amenaza localizada de tornado.	Aisladas	Nada Numerosas	Similar a las tormentas que su zona puede experimentar varias veces al año.	Ráfagas de viento de al menos 58 mph Granizo de al menos 1" de diámetro
2	Bajo (BAJO)	Aumenta la confianza que <u>unas que otras</u> tormentas pudieran producir vientos dañinos, granizo, y/o tornados. Algunas tormentas severas podrían ser significativas	Aisladas a dispersas	Nada Numerosas	Similar a las tormentas que su zona puede experimentar algunas veces al año.	Tornado
3	Moderado (MOD)	Incrementa la confianza que <u>varias</u> tormentas severas pudieran producir vientos dañinos, granizo, y/o tornados. Varias tormentas severas podrían ser significativas	Dispersas a numerosas	Nada Numerosas	Similar a las tormentas intensas que su zona puede experimentar sólo una o dos veces al año.	Tormenta Severa Significativa Tiene cualquiera de las siguientes características:
4	Alto (ALTO)	Alta confianza que <u>muchas</u> tormentas severas pudieran producir vientos dañinos, granizo, y/o tornados. Muchas tormentas severas podrían ser significativas	Dispersas a numerosas	Nada Numerosas	Similar a las tormentas intensas que su zona puede experimentar sólo una vez al año o menos.	Ráfagas de viento de al menos 75 mph Granizo de al menos 2" de diámetro
5	Extremo (EXTM)	Extrema confianza que un <u>brote de tormentas</u> pudiera producir tornados, vientos dañinos y/o granizo. Brote de tornados y/o vientos dañinos extensos.	Numerosas	Nada Numerosas	Tormentas muy intensas que su zona puede experimentar sólo una o dos veces cada siglo.	Tornado de al menos categoría EF-2

Note: Translations were developed through SPC research (Trujillo-Falcón et al. 2021). Some translations may not line up exactly with the English version. The meaning, not the words, is translated. [spc.noaa.gov](https://www.spc.noaa.gov) | [weather.gov](https://www.weather.gov)

FIG. 11. An example of a graphic with the new risk categories currently being used by the SPC, which highlights the change to the new translations as suggested by the linguists.

risk levels more intuitively to Spanish speakers than the original SPC translation set. The linguist-suggested translations perform well regardless of speakers’ Hispanic heritage or level of English proficiency. All respondent subgroups of Hispanic heritage and English proficiency had mean rankings for the risk words that matched the intended order of the categories except for respondents who indicated they speak no English at all, which had very similar rankings for the middle three words. Upon seeing this evidence, the SPC made the change from the original translation set to the linguist-suggested translation set, and now uses *Mínimo*, *Bajo*, *Moderado*, *Alto*, and *Extremo* in its risk communication graphics in Spanish (Fig. 11, <https://www.spc.noaa.gov/new/images/SPC-final-spanish.png>).

Prior to formally submitting this manuscript, the authors presented the data and findings to leadership at the SPC who were ultimately responsible for making this policy change. As with any change to a communication product, it is necessary to monitor public responses for any problems that may arise. One foreseeable challenge with the new set of translations, for example, is the fact that *Moderate* is still the word used for the fourth risk category in English and *High* is used for the fifth, but *Moderado* and *Alto*—direct Spanish translations of Moderate and High—have been moved to the third and fourth spots in the Spanish translation the SPC now uses, respectively. We do not yet know what the impact of this offset in the direct translations of these words could be, and it warrants further study as this change begins to take effect.

Other limitations to this study come from the way our data were collected. Online surveys use self-selection, meaning

those who participate choose to do so, and choosing to do so can often be influenced by a variety of factors such as age and socioeconomic status or interest in the topic (Jang and Vorderstrasse 2019). Younger people use the Internet more often than older people, and those with a higher socioeconomic status (SES) may have more time to spend taking long, online surveys than those in a lower SES (Jang and Vorderstrasse 2019). These same challenges exist among Spanish speakers. Additionally, Hispanics specifically have been shown to be more likely to refuse to participate in surveys, which may be caused by mistrust of the government or fears related to immigration and deportation, creating another limitation in attracting survey respondents (Brown 2015). To help mitigate some of these challenges, the survey was conducted completely online, the instrument assured respondents that their answers would be anonymous, and the entire survey was written in Spanish (Brown 2015). Additionally, the survey respondents were largely representative of Spanish speakers in the United States in levels of self-reported English proficiency overall, but it is important to note that only 3% of respondents self-reported as not speaking English at all, an under sample for this group, which is arguably the most vulnerable group to inconsistent translations. This was the only subgroup that did not rank the linguist-suggested translations in the intended order on average. Despite these challenges, the analysis presented in this paper used demographic quotas and survey weights to try to correct for some of these issues. Because of this, the findings presented in this study should be considered generalizable to the U.S. Spanish-speaking population, meaning the results are representative of most Spanish speakers.

Both health and risk communication research emphasize that finding dialect-neutral translations are a *first* step in engaging Spanish-speaking communities (Hsieh 2016; Trujillo-Falcón et al. 2021). To include *all* language groups (including those that do not speak English at all), educational campaigns are paramount to ensure that all the community resonates with risk messages (e.g., Trujillo-Falcón et al. 2022). We believe that, through future outreach by SPC and broadcast meteorologists, communities will be better equipped in contextualizing and understanding the new risk categories. Nevertheless, future testing with Spanish speakers who do not speak English should be kept in mind to ensure that life-saving information reaches even the most vulnerable groups.

While the data collected in this survey provided an important first step in understanding how Spanish speakers view the translations used in the SPC convective outlook, targeted qualitative interviews are another important research method to employ when trying to reach vulnerable Hispanic populations. Recently funded research that will be carried out over the next three years by some of the coauthors of this paper will continue to investigate how Hispanics understand and interpret current National Weather Service products, such as the convective outlook, using mixed methods approaches that will include interviews and follow-up surveys (Reedy et al. 2022).

The linguist-suggested translations appear to offer more consistent results in communicating the appropriate level of risk association to Spanish speakers compared to the original translations used by the SPC. Less than 1% of all Spanish-speaking survey respondents who were shown the original translation set ranked all five risk words in the original SPC order, compared to over 33% of respondents who identified the intended order for the linguist-suggested translations. Future work and educational campaigns should focus specifically on the most vulnerable members of the Spanish-speaking public (e.g., those with low English proficiency). It is imperative that translations resonate with the communities they are intended for and that weather products targeting vulnerable populations be tested on those groups to ensure improved clarity.

Acknowledgments. Special thanks to Dr. John Lipski and Dr. Estilita Cassiani Obeso for the translation of the Weather and Society Survey into Spanish. We would also like to express our gratitude to the Penn State Department of Spanish, Italian, and Portuguese; the NWS Multimedia Assistance in Spanish; and the NWS Spanish Outreach teams for their feedback and collaboration. Data collection for this project were funded by the OU Office of the Vice President for Research and Partnerships. Data analysis were funded by the NOAA Weather Program Office (Accelerating Development of the U.S. Extreme Weather and Society Survey Series, NA16OAR4320115).

Data availability statement. Data from the Severe Weather and Society: Spanish Survey can be found at <https://dataverse.harvard.edu/dataverse/wxsurvey>.

REFERENCES

- Abukhalaf, A. H. I., and J. von Meding, 2021: Psycholinguistics and emergency communication: A qualitative descriptive study. *Int. J. Disaster Risk Reduct.*, **55**, 102061, <https://doi.org/10.1016/j.ijdrr.2021.102061>.
- Adams, F. M., and C. E. Osgood, 1973: A cross-cultural study of the affective meanings of color. *J. Cross-Cultural Psychol.*, **4**, 135–156, <https://doi.org/10.1177/002202217300400201>.
- Arlkatti, S., H. A. Taibah, and S. A. Andrew, 2014: How do you warn them if they speak only Spanish? Challenges for organizations in communicating risk to Colonias residents in Texas, USA. *Disaster Prev. Manage.*, **23**, 533–550, <https://doi.org/10.1108/DPM-02-2014-0022>.
- Benavides, A., and S. Arlikatti, 2010: The role of the Spanish-language media in disaster warning dissemination: An examination of the emergency alert system. *J. Span. Lang. Media*, **3**, 41–58.
- Braun, C. C., and N. C. Silver, 1995: Interaction of signal word and colour on warning labels: Differences in perceived hazard and behavioural compliance. *Ergonomics*, **38**, 2207–2220, <https://doi.org/10.1080/00140139508925263>.
- Brelsford, K. M., E. Ruiz, C. M. Hammack, and L. M. Beskow, 2019: Improving translation and cultural appropriateness of Spanish-language consent materials for biobanks. *Ethics Hum. Res.*, **41**, 16–27, <https://doi.org/10.1002/eahr.500028>.
- Brown, A., 2015: The unique challenges of surveying U.S. Latinos. Pew Research Center Tech. Rep., 13 pp., <https://www.pewresearch.org/methods/2015/11/12/the-unique-challenges-of-surveying-u-s-latinos/>.
- Callegaro, M., and C. DiSogra, 2008: Computing response metrics for online panels. *Public Opin. Quart.*, **72**, 1008–1032, <https://doi.org/10.1093/poq/nfn065>.
- Carter-Pokras, O., R. E. Zambrana, S. E. Mora, and K. A. Aaby, 2007: Emergency preparedness: Knowledge and perceptions of Latin American immigrants. *J. Health Care Poor Underserved*, **18**, 465–481, <https://doi.org/10.1353/hpu.2007.0026>.
- Chan, S. E., and P. Huang, 2012: When disasters are a part of home: The Hakka community's rootedness and resilience to periodic landslides in Shenmu Village. *Landscape Rev.*, **14**, 34–47, <https://doi.org/10.34900/lr.v14i2.702>.
- Corfidi, S. F., 1999: The birth and early years of the Storm Prediction Center. *Wea. Forecasting*, **14**, 507–525, [https://doi.org/10.1175/1520-0434\(1999\)014<0507:TBAEYO>2.0.CO;2](https://doi.org/10.1175/1520-0434(1999)014<0507:TBAEYO>2.0.CO;2).
- Edwards, R., and F. Ostby, 2015: Time line of the SELS and SPC. Storm Prediction Center and NOAA, accessed 2 May 2022, <https://www.spc.noaa.gov/history/timeline.html>.
- Ernst, S., J. T. Ripberger, M. J. Krocak, H. Jenkins-Smith, and C. Silva, 2021: Colorful language: Investigating public interpretation of the Storm Prediction Center convective outlook. *Wea. Forecasting*, **36**, 1785–1797, <https://doi.org/10.1175/WAF-D-21-0001.1>.
- Esposito, N., 2001: From meaning to meaning: The influence of translation techniques on non-English focus group research. *Qual. Health Res.*, **11**, 568–579, <https://doi.org/10.1177/104973201129119217>.
- Gulacsik, G., S. L. Joslyn, J. Robinson, and C. Qin, 2022: Do advisories, warnings, or color coding matter to risk perception and precautionary decisions? *Wea. Climate Soc.*, **14**, 569–583, <https://doi.org/10.1175/WCAS-D-21-0070.1>.
- Hendricson, W. D., I. J. Russell, T. J. Prihoda, J. M. Jacobson, A. Rogan, and G. D. Bishop, 1989: An approach to developing a valid Spanish language translation of a health-status

- questionnaire. *Med. Care*, **27**, 959–966, <https://doi.org/10.1097/00005650-198910000-00006>.
- Hogan Carr, R., B. Montz, K. Maxfield, S. Hoekstra, K. Semmens, and E. Goldman, 2016: Effectively communicating risk and uncertainty to the public: Assessing the National Weather Service's flood forecast and warning tools. *Bull. Amer. Meteor. Soc.*, **97**, 1649–1665, <https://doi.org/10.1175/BAMS-D-14-00248.1>.
- Hsieh, E., 2016: *Bilingual Health Communication: Working with Interpreters in Cross-Cultural Care*. Routledge, 364 pp.
- Jacobs, L., C. Keown, R. Worthley, and K. Ghymn, 1991: Cross-cultural colour comparisons: Global marketers beware! *Int. Mark. Rev.*, **8** (3), <https://doi.org/10.1108/02651339110137279>.
- Jang, M., and A. Vorderstrasse, 2019: Socioeconomic status and racial or ethnic differences in participation: Web-based survey. *JMIR Res. Protoc.*, **8**, e11865, <https://doi.org/10.2196/11865>.
- Joslyn, S., and S. Savelli, 2021: Visualizing uncertainty for non-expert end users: The challenge of the deterministic construal error. *Front. Comput. Sci.*, **2**, 590232, <https://doi.org/10.3389/fcomp.2020.590232>.
- Krocak, M. J., J. T. Ripberger, A. Bitterman, C. Silva, H. Jenkins-Smith, J. Trujillo-Falcón, and A. Gaviria Pabón, 2022a: WXS21. Harvard Dataverse, accessed 25 April 2022, <https://doi.org/10.7910/DVN/IZNQVA>.
- , —, S. Ernst, C. L. Silva, and H. C. Jenkins-Smith, 2022b: Exploring the differences in SPC convective outlook interpretation using categorical and numeric information. *Wea. Forecasting*, **37**, 303–311, <https://doi.org/10.1175/WAF-D-21-0123.1>.
- Méndez, M., G. Flores-Haro, and L. Zucker, 2020: The (in)visible victims of disaster: Understanding the vulnerability of undocumented Latino/a and indigenous immigrants. *Geoforum*, **116**, 50–62, <https://doi.org/10.1016/j.geoforum.2020.07.007>.
- Morales, A., L. Medina Luna, D. W. Zietlow, J. E. LeBeau, and M. J. Molina, 2023: Testing the impact of culturally-relevant communication style on engagement with Hispanic and Latinx adults. *J. Geosci. Educ.*, <https://doi.org/10.1080/10899995.2022.2120701>, in press.
- Piller, I., J. Zhang, and J. Li, 2020: Linguistic diversity in a time of crisis: Language challenges of the COVID-19 pandemic. *Multilingua*, **39**, 503–515, <https://doi.org/10.1515/multi-2020-0136>.
- Reedy, J., J. Trujillo-Falcón, K. Klockow-McClain, and J. Ripberger, 2022: A Weather-Ready Nation Para Todos: Establishing Best Practices in Communicating Hazardous Weather Risks to Spanish Speakers. JTTI Grant Proposal.
- Ripberger, J. T., C. L. Silva, H. C. Jenkins-Smith, J. Allan, M. Krocak, W. Wehde, and S. Ernst, 2020: Exploring community differences in tornado warning reception, comprehension, and response across the United States. *Bull. Amer. Meteor. Soc.*, **101**, E936–E948, <https://doi.org/10.1175/BAMS-D-19-0064.1>.
- Ruggles, S., S. Flood, S. Foster, R. Goeken, J. Pacas, M. Schouweiler, and M. Sobek, 2021: IPUMS USA, version 11.0. IPUMS, accessed 17 May 2022, <https://doi.org/10.18128/D010.V11.0>.
- Tripathi, A., and Coauthors, 2023: Centering equity in the nation's weather, water, and climate services. *Environ. Justice*, <https://doi.org/10.1089/env.2022.0048>, in press.
- Trujillo-Falcón, J. E., O. Bermúdez, K. Negrón-Hernández, J. Lipski, E. Leitman, and K. Berry, 2021: Hazardous weather communication en Español: Challenges, current resources, and future practices. *Bull. Amer. Meteor. Soc.*, **102**, E765–E773, <https://doi.org/10.1175/BAMS-D-20-0249.1>.
- , and Coauthors, 2022: ¿Aviso o alerta? Developing effective, inclusive, and consistent warning translations for U.S. Spanish speakers. *Bull. Amer. Meteor. Soc.*, **103**, E2791–E2803, <https://doi.org/10.1175/BAMS-D-22-0050.1>.
- Uekusa, S., 2019: Disaster linguicism: Linguistic minorities in disasters. *Lang. Soc.*, **48**, 353–375, <https://doi.org/10.1017/S0047404519000150>.
- Wenger, D. E., and J. M. Weller, 1973: Disaster subcultures: The cultural residues of community disasters. University of Delaware Disaster Research Center Preliminary Paper 9, 20 pp., <https://udspace.udel.edu/server/api/core/bitstreams/8d48faff-ca32-45e0-8971-8d2f3ce12ca9/content>.