



How do people perceive, understand, and anticipate responding to flash flood risks and warnings? Results from a public survey in Boulder, Colorado, USA



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SUMMARY

This study investigates flash flood forecast and warning communication, interpretation, and decision making, using data from a survey of 418 members of the public in Boulder, Colorado, USA. Respondents to the public survey varied in their perceptions and understandings of flash flood risks in Boulder, and some had misconceptions about flash flood risks, such as the safety of crossing fast-flowing water. About 6% of respondents indicated consistent reversals of US watch-warning alert terminology. However, more in-depth analysis illustrates the multi-dimensional, situationally dependent meanings of flash flood alerts, as well as the importance of evaluating interpretation and use of warning information along with alert terminology. Some public respondents estimated low likelihoods of flash flooding given a flash flood warning; these were associated with lower anticipated likelihood of taking protective action given a warning. Protective action intentions were also lower among respondents who had less trust in flash flood warnings, those who had not made prior preparations for flash flooding, and those who believed themselves to be safer from flash flooding. Additional analysis, using open-ended survey questions about responses to warnings, elucidates the complex, contextual nature of protective decision making during flash flood threats. These findings suggest that warnings can play an important role not only by notifying people that there is a threat and helping motivate people to take protective action, but also by helping people evaluate what actions to take given their situation.

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1. Introduction

Over the last few decades, flash flood detection, forecasting, and warning capabilities have improved dramatically. Yet flash floods are still one of the most deadly weather-related hazards (French et al., 1983; Jonkman and Vrijling, 2008). In the US, Europe, and Australia, a large portion of flash flood deaths occur when people enter or are swept into floodwaters, either in a vehicle or on foot, in part because they are unaware of or misjudge the risks (Gruntfest et al., 1978; Jonkman and Kelman, 2005; Ruin et al., 2007; Ashley and Ashley, 2008; Haynes et al., 2009; Kellar and Schmidlin, 2012; Diakakis and Deligiannakis, 2013; Sharif et al., 2015; Becker et al., 2015). Thus, it is important not only to issue timely flash flood forecasts and warnings, but also to understand how people perceive flash flood risks and what influences their

responses to warning information. This knowledge can then be used to develop evidence-based recommendations for improving communication about flash flood risks in ways that help people understand when, where, and how they are at risk and how to protect themselves when needed.

Although a number of studies have examined public risk perceptions and protective decisions for other hydrometeorological hazards, such as hurricanes and slower-onset floods (e.g., Dash and Gladwin, 2007; Lazo et al., 2015; Huang et al., in press; Bubeck et al., 2012; Kellens et al., 2013; Sherman-Morris, 2013), few studies have investigated these issues for flash floods (Gruntfest et al., 2002; Knocke and Kolivras, 2007; Wagner, 2007; Benight et al., 2007; Drobot et al., 2007; Ruin et al., 2007, 2008, 2014; Coles, 2008; League, 2009; Lazrus et al., in press). Flash floods evolve rapidly, often with significant variability and uncertainty in local conditions and impacts, and thus present distinct challenges for communicating and responding to threats. To help address these challenges, this study investigates people's perceptions,

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understandings, and interpretations of flash flood risks and alerts¹ and their anticipated responses to flash flood warnings. The analysis focuses on members of the public in the US, utilizing data from a survey of 418 residents of Boulder, Colorado, conducted in 2010.

The article examines four research questions: (1) How do members of the Boulder public perceive and understand flash flood risks? (2) How do they perceive and interpret flash flood warnings and other alerts? (3) How do they anticipate responding to flash flood alerts? (4) What influences their anticipated responses? This includes investigating people's knowledge, attitudes, and beliefs about flash flood risks and alerts and their anticipated decisions when a flash flood threatens. For time-sensitive hazards such as flash floods, people's interpretations and decision processes during a real threat are complex and difficult to measure, especially among people at high risk. By examining people's anticipated interpretations and behavior in hypothetical contexts, this study seeks to develop knowledge that can help researchers and practitioners interpret what people think and do during more complicated real-world flash flood situations.

The study area, Boulder, Colorado, is a community of approximately 100,000 people at the base of the foothills of the US Rocky Mountains, and more than 30,000 students are enrolled annually at the University of Colorado Boulder. To sample this population, members of the research team recruited survey respondents by mail, supplemented by convenience recruitment of students on the university campus. Flash flooding is a risk in the study region, and Boulder and nearby foothills and canyons experienced devastating and deadly flash flooding in September 2013. However, at the time of the survey, severe, widespread flooding had not occurred in Boulder in several decades (City of Boulder, 2012). Thus, the study examines a population with little or no direct local experience with flash flooding.

The article makes several novel contributions to the literature on public perceptions of and responses to flash flood (and other) risks. First, we examine respondents' perceptions and interpretations of flash flood risks and alerts in greater depth than previous studies and from new perspectives. For example, we build on previous work examining whether people can correctly differentiate the NWS alert terminology "watch" and "warning" by investigating people's understandings and interpretations of the alerts more broadly, using data from multiple survey questions. This includes utilizing new measures, such as perceived likelihood of flash flooding given a warning, that we anticipate may be related to how people respond to warnings. In addition, we aim to better understand how different aspects of people's flash-flood-related perceptions and interpretations influence their responses to flash flood warnings by quantitatively examining these relationships, using regression analysis. To help contextualize and interpret results from the quantitative analyses, we incorporate analysis of data from open-ended questions on flash flood warning decision making.

Another contribution of this research is that it was conducted as part of a larger, multi-method study, which included research using a mental models approach (e.g., Morgan et al., 2002) to examine how Boulder-area professionals and members of the public conceive of and make decisions about flash flood risks (Morss et al., 2015; Lazrus et al., in press). This related work found that some members of the Boulder public have misconceptions or incomplete understandings about several aspects of flash flood risks and risk reduction, which may influence their ability to avoid life-threatening situations when a flash flood threatens. The analysis presented here builds on this mental models research, first, by

examining the extent to which some of these types of misconceptions are present in the larger public survey sample, and second, by using regression analysis to quantitatively examine whether such misconceptions are associated with differences in anticipated responses to flash flood warnings. Further, as part of the larger study, a similar questionnaire to that examined here was implemented with 20 Boulder-area professionals with job responsibilities related to the Boulder-area flash flood warning system, including US National Weather Service (NWS) forecasters, local emergency managers and other public officials, and television and radio broadcasters (Morss et al., 2015). This allows us to compare, for some of the survey questions, public perceptions and interpretations with those of flash flood warning professionals.

Section 2 describes the study methodology, including the survey design, implementation, and data analysis. Sections 3 and 4 discuss how respondents perceive and understand flash flood risks and flash flood forecasts and alerts (including NWS watches and warnings). Section 5 examines whether and how respondents anticipate acting given a flash flood warning and how this varies with some of the factors discussed in Sections 3 and 4. Section 6 summarizes key results and discusses potential implications for improving flash flood alerts and risk communication.

2. Methodology

2.1. Survey questionnaire development

The survey questionnaire was initially developed as part of the flash flood mental models studies discussed in Morss et al. (2015) and Lazrus et al. (in press). The 20 Boulder-area professionals and 26 Boulder residents who participated in those studies were each asked to fill out a paper version of the questionnaire towards the end of their mental models interviews. In late fall–early winter 2009, the questionnaire was revised for a larger-scale public survey based on this initial implementation as well as ideas from members of the research team and collaborators.² Revisions included modifications to existing questions as well as development of several new questions.

The revised version of the questionnaire was pretested in person in January 2010 with five Boulder residents, using one-on-one interviews in which the participants were asked to think aloud while reading and responding to the survey (Ericsson and Simon, 1993). The findings from the pretest were used to revise and finalize the survey questionnaire.

2.2. Survey data collection and respondents

The survey data used in this article were collected using two sampling strategies: mailings to residents of Boulder zip codes (referred to as the "mail sample") and distribution to students on the University of Colorado Boulder campus ("university sample").

For the mail sample, surveys were mailed to 1000 addresses randomly sampled from Boulder zip codes, provided by a survey sampling company. Of the 1000, 750 were sent following Dillman's (2000) recommendations, with multiple mailings, using incentives ranging from none to \$5; the remaining 250 were sent in a single mailing with no incentive. All of the mail surveys were sent with a stamped and addressed return envelope. Of the

¹ In this article, we use the term "alerts" to encompass multiple types of forecast and warning communications, including (but not limited to) the flash flood "watch" and "warning" products issued by the US National Weather Service (NWS). The NWS watch and warning products are discussed further in Section 4.1.

² The survey data used in this article were gathered as part of a Senior Capstone project conducted by Kelsey Mulder and Curtis McDonald at the University of Oklahoma, under the mentorship of Jeffrey Lazo; Randy Peppler (Cooperative Institute for Mesoscale Meteorological Studies); and Kimberly Klockow and Gina Eosco (University of Oklahoma). Additional contributors to the survey design include the other co-authors of this article; Ann Bostrom and Rebecca Hudson (University of Washington); and Emily Laidlaw (National Center for Atmospheric Research).

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