UNDERSTANDING LOCAL SEA LEVEL RISE RISK PERCEPTIONS AND THE POWER OF MAPS TO CHANGE THEM:

THE EFFECTS OF DISTANCE, DETAIL, AND DOUBT

A Dissertation in

Geography

by

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Abstract

Sea level rise poses a significant threat to people and property in many U.S. coastal communities. Because sea level rise adaptation depends in part on recognizing this threat, there is a need to communicate sea level rise risk. However, some audiences may not be receptive to information about local sea level rise risk, particularly if they see sea level rise as a distant hazard or hold doubtful or dismissive beliefs about climate change in general. By making visible the impacts of sea level rise on local communities, sea level rise maps may meet these challenges to sea level rise communication. This dissertation explores this potential. Using an interactive map of sea level rise in Sarasota, Florida and an accompanying online survey, it considers how college students from nearby and far away from Sarasota, and with different views about climate change, vary in: 1) their ability to read information about sea level rise flooding from the map; and 2) their risk perceptions for this flooding. Post-map risk perceptions for Sarasota sea level rise are compared with pre-map risk perceptions for: 1) Sarasota sea level rise; and 2) climate change and sea level rise in general. Results indicate that respondents’ read flood information from these maps accurately and in a way that is not biased by prior climate change beliefs. Results for risk perceptions show that while most respondents initially view Sarasota sea level rise as less risky than sea level rise in general, exposure to the sea level rise map raises Sarasota risk perceptions to levels equal to or above those for general sea level rise – particularly for respondents who are doubtful about climate change or are far from Sarasota, but also for many nearby respondents. These results confirm the potential of interactive maps for communicating sea level rise risk.
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For Frankie
Chapter I

GENERAL INTRODUCTION

1.1 Background

More than a decade of research suggests that the next century of sea level rise will prove costly and disruptive for many U.S. coastal communities. A review of the literature available in 2000 suggested that 50 cm of sea level rise along U.S. coasts by 2100 would result in cumulative costs of $20-200 billion, with costs of 1 m of sea level rise approximately twice as large (Boesch et al. 2000). More recent research has focused on the significant threat that sea level rise poses for coastal residents and infrastructure, particularly when coupled with flooding due to coastal storms. Significant percentages of coastal residents are directly exposed to coastal flooding: 1.2% of the U.S. population lives in coastal areas less than 1 m above high tide, and 7.4% live in areas less than 6 m above high tide; over 90% of both these populations live in urban areas (Strauss et al. 2012). While not directly at risk of inundation, a much larger percentage of the U.S. population could experience disruptive impacts of sea level rise in their communities: 30% of people in the U.S. live in counties that border the ocean or have at least a 1% annual risk of flooding due to coastal storms (Matson 2010). The threat to U.S. critical infrastructure may be even more significant: submerged roads, railways, and airports may disrupt transportation networks; schools, hospitals, and police and fire stations may need to be relocated to higher ground; and power and wastewater treatment plants may need to be protected with new sea walls, moved, or abandoned (Heberger et al. 2009, Larsen et al.)
2008, NRC 2008). With sea levels rising and 60% of land under 1 meter above spring high water on the U.S. Atlantic coast slated for development (Titus et al. 2009), the exposure of people and infrastructure to coastal flooding will likely increase.

Given the central role of risk perception in adaptation to climate change hazards (Grothmann and Patt 2005), effective communication of sea level rise risk is needed to address these significant threats to people and property. However, some audiences may not be receptive to information about local sea level rise risk, particularly if they see sea level rise as a distant hazard or hold doubtful or dismissive beliefs about climate change in general. Research shows that many individuals view climate change hazards – such as sea level rise – as distant threats (Nicholson-Cole 2005, Leiserowitz 2007, Lorenzoni et al. 2007, Swim et al. 2009), and tend to expect more severe sea level rise impacts in distant than in nearby places (Spence and Pidgeon 2010). This is consistent with spatial optimism bias: the tendency to view the impacts of environmental hazards more favorably at the level of one’s local community than at national or global levels (Schultz et al. 2014, Milfont et al. 2011, Gifford 2011, Gifford et al. 2009, Uzzell 2000). Such distancing of climate hazards can stymie adaptation, since moving the threat to a remote context or global level may reduce both the motivation to act and self-efficacy (Uzzell 2000, Spence et al. 2012). Additionally, motivated reasoning can lead audiences that are doubtful or dismissive about climate change to downplay or disregard new information about climate change hazards (Whitmarsh 2011, Kahan et al. 2012), particularly when these climate change beliefs are held as part of one’s political (Dunlap and McCright 2008) or cultural (Kahan et al. 2011) identity. Taken together, this evidence suggests that communicating sea level rise risk may
be particularly challenging at the local level and for audiences that are already doubtful about climate change.

Maps of local sea level rise may help meet these challenges. By making visible the local impacts of sea level rise, such maps may help audiences living nearby the hazard identify risks to everyday life in their local communities (Shaw et al. 2009, Monmonier 2008). Moreover, flood information like that shown on these maps may be effective in reaching audiences that are doubtful about global climate change, but are nonetheless concerned about local flooding (Kahan et al. 2013, Bruin et al. 2014). Research has yet to directly consider how exposure to sea level rise maps affects risk perceptions for such audiences: this dissertation addresses this gap. In so doing, it not only addresses the need for more effective means of communicating sea level rise risk, but also produces insights into role of spatial optimism bias and motivated reasoning in climate change communication. The following sections describe how this dissertation addresses this gap and these related contributions.

1.2 Goal, objectives, and research questions

The goal of this dissertation is to understand how individual differences in distance from the sea level rise hazard and beliefs about climate change affect risk perceptions – both before and after interacting with a map of local sea level rise. To consider the effect of distance, I present information about sea level rise in a specific place to audiences from both nearby and far away from that place. To evaluate differences in climate change beliefs, I use the Global Warming’s Six Americas framework (Maibach et al. 2009), which reflects broader differences in politics and worldview (Bliuc et al. 2015), but also provides a more
nuanced division into six audience segments – the Alarmed, Concerned, Cautious, Doubtful, Dismissive and Disengaged – each with distinct beliefs about the certainty and severity of climate impacts and the urgency of addressing them.

I address this goal through four objectives, one for each body chapter of this dissertation. My first objective is to review the literature on the advantages and challenges of using online, interactive maps to communicate sea level rise, including consideration of how different audiences may understand the many uncertainties communicated via these maps (Chapter 2). My next objective is to establish a pre-map baseline for the effect of audience distance and Six Americas group on sea level rise risk perceptions, for both general (global) and specific (local) geographic contexts, while also considering (and controlling for) possible effects of gender (Chapter 3). For my third objective, I evaluate whether participants understand the sea level rise information presented on the interactive map developed for this dissertation, and whether this understanding is affected by participants’ distance from the hazard or their Six Americas group (Chapter 4). My final objective considers whether exposure to this sea level rise map is associated with changes in risk perceptions for local sea level rise, and how these changes may vary for audiences from different distances and Six Americas groups (Chapter 5). Table 1.1 shows my research questions for each of these objectives.
Table 1.1: Objectives and related research questions

<table>
<thead>
<tr>
<th>Objective</th>
<th>Research questions</th>
</tr>
</thead>
</table>
| Review the literature on advantages and challenges of communicating sea level rise on online, interactive maps (Chapter 2) | • What are the possible advantages of online, interactive maps for communicating sea level rise?  
• What uncertainties do sea level rise maps communicate?  
• How can different audiences be expected to interpret maps of uncertain sea level rise?  
• What are the implications of this literature for the design of sea level rise maps? |
| Explore how spatial optimism bias and prior beliefs about climate change may affect risk perceptions for local and global sea level rise (Chapter 3) | • How does the specificity of the geographic context in which sea level rise is described affect risk perceptions?  
• How does distance from sea level rise affect risk perceptions?  
• How do audiences from different Six Americas groups and genders differ in their risk perceptions? |
| Determine whether map users understand the flood depth and probability information presented on a local sea level rise map, and whether motivated reasoning based on prior beliefs about climate change affects this understanding (Chapter 4) | • Does motivated reasoning based on prior beliefs about climate change affect the interpretation of flood depth and probability information on sea level rise maps?  
• Does motivated reasoning based on distance from the sea level rise hazard affect the interpretation of flood depth and probability information on sea level rise maps?  
• How does motivated reasoning vary with map task and associated uncertainty types?  
• Beyond motivated reasoning, do respondents’ subjective numeracy, map ability, and task-relevant map interactions correlate with their accuracy on map reading tasks? |
| Explore how exposure to a detailed and interactive map of local sea level rise may affect risk perceptions (Chapter 5) | • How does varying the level of detail with which a specific, local climate change hazard is depicted affect risk perceptions?  
• How does this effect on risk perceptions vary with distance and Six Americas group?  
• Is this effect on risk perceptions associated with more extensive or intensive interaction with the detailed hazard depiction? |
1.3 Contributions

These chapters make significant contributions to the literature on mapping and communicating local climate change impacts such as sea level rise. Unlike existing work on sea level rise map evaluation and design (e.g., Kostelnick et al. 2013, Roth et al. 2015), Chapter 2 advocates a user-centered approach, with a focus on how individual differences may shape understanding of cartographic depictions of sea level rise and its uncertainty. Chapter 3 follows existing studies in considering the role of spatial optimism bias in shaping risk perceptions for environmental hazards (Uzzell 2000, Gifford et al. 2009, Schultz et al. 2014), but extends these studies by applying them in the sea level rise context and by considering the effects of audience distance and geographic specificity separately (audience distance and geographic specificity were confounded in most earlier studies). Taking up the call for user-centered evaluation of sea level rise maps, Chapter 4 explores whether motivated reasoning based on beliefs about climate change affects how map users read information from a sea level rise map, and also considers whether some of the components of sea level rise uncertainty described in Kostelnick et al. (2013) are more likely to be associated with motivated reasoning than others. Chapter 5 builds on existing studies of the effects of messages about sea level rise and other local climate impacts on engagement (Scannell and Gifford 2013, Sheppard et al. 2011, Spence and Pidgeon 2010, O’Neill and Hulme 2009); while Chapter 5 follows these earlier studies in considering how audience distance may affect perceptions of sea level rise risk, it also considers how these risk perceptions may differ based on the level of detail in the message about local sea level rise. Chapters 3 and 5 also both take up calls to evaluate how environmental engagement and beliefs about climate change – evaluated here using the Global Warming’s Six Americas
framework – relate to spatial optimism bias (Schultz et al. 2014) and the interpretation of messages about local climate impacts (Spence and Pidgeon 2010). Collectively, these contributions may help climate change communicators design and deploy sea level rise maps in ways that account for individual differences and associated spatial optimism bias or motivated reasoning.

1.4 Structure of the dissertation

With the exception of this introduction and a concluding chapter, the chapters of this dissertation were prepared as stand-alone papers related to the common goal of exploring how local sea level rise messages and maps affect risk perceptions for different audiences. Chapter 2 has already been published in *Cartographic Perspectives*. Chapter 3 will be submitted to *Climatic Change*; Chapter 4 to the *Journal of Coastal Research*; and Chapter 5 to *Global Environmental Change*. Because I intend to publish these chapters separately, each includes separate sections for literature review, methods, results, discussion, and conclusions.

1.5 Research design

Although Chapters 3-5 each provide descriptions of the methods relevant to their respective research questions, this chapter contextualizes these more specific descriptions by providing an overview of the locations and survey structure used in this study. Additional information about specific survey questions and respondent characteristics are provided in the methods sections for Chapters 3-5.
1.5.1 Study area and survey recruitment

This study used an online survey of college and university students to evaluate the effect of an accompanying interactive map of sea level rise in the Sarasota, Florida area on risk perceptions for students from different distances and Six Americas groups. To evaluate the effects of distance from the sea level rise hazard, students were recruited from The Pennsylvania State University and three colleges and universities in the Sarasota, Florida area: New College of Florida, State College of Florida, and University of South Florida Sarasota-Manatee. Sarasota was chosen because it is exposed to sea level rise and related coastal hazards (Frazier et al. 2010) and is home to several colleges and universities from which I could recruit students to compare with the Penn State sample. I partnered with earth and environmental instructors and professors at these institutions, who then made the survey available to their students. Except at New College (where formal grades are not given), students were offered extra credit equivalent to 1% of their course grade for participating. Figure 1.1 shows the area covered by the sea level rise map (including all of Sarasota County and parts of neighboring Manatee County), as well as the locations of the four participating colleges and universities.

1.5.2 Survey design

The survey contained 53-55 total questions, and took respondents approximately a half hour to complete. Tables 1.2-1.4 summarize the survey structure. Questions in these tables are listed in the order in which they appeared in the survey and are matched with the chapter(s) in which they are discussed in this dissertation; questions with chapters marked “NA” are not discussed in this dissertation and are reserved for future research.
Figure 1.1: Map showing locations of participating colleges and universities and footprint of sea level rise map.
**Table 1.2:** Survey part 1: Six Americas self-classification and risk perceptions for climate change, sea level rise, and sea level rise in Sarasota

<table>
<thead>
<tr>
<th>Survey page</th>
<th>Questions</th>
<th>Chapter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beliefs and feelings about climate hazards</td>
<td>Six Americas self-classification (Swim in preparation)</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>Risk perceptions for climate change and sea level rise (2 questions, Kahan et al. 2013)</td>
<td>3,5</td>
</tr>
<tr>
<td></td>
<td>Familiarity with Sarasota (Thorndyke and Goldin 1981)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Risk perceptions for sea level rise in Sarasota (Kahan et al. 2013)</td>
<td>3,5</td>
</tr>
</tbody>
</table>

**Table 1.3:** Survey part 2: Sea level rise map, post-map risk perceptions for sea level rise in Sarasota, and related questions

<table>
<thead>
<tr>
<th>Survey pages</th>
<th>Questions</th>
<th>Chapter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tutorial for sea level rise map (2 pages)</td>
<td>Presentation of video and step-by-step instructions (no questions)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Check boxes for types of places affected by sea level rise in Sarasota</td>
<td>5</td>
</tr>
<tr>
<td>Sea level rise at one of four randomly assigned Sarasota locations</td>
<td>Estimate of average flood depth and probability for assigned location for 2050 and 2100 (4 questions)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Importance of protecting assigned location from sea level rise</td>
<td>NA</td>
</tr>
<tr>
<td>Where will sea level rise be most disruptive?</td>
<td>Drop pin on map to select most disrupted place</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Identify type of place for selection</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Estimate of average flood depth and probability for selected place for 2050 and 2100 (4 questions)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Importance of protecting selected place from sea level rise</td>
<td>NA</td>
</tr>
<tr>
<td>Beliefs and feelings about sea level rise in Sarasota</td>
<td>Post-map risk perceptions for sea level rise in Sarasota (Kahan et al. 2013)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Emotion experienced while interacting with sea level rise map (Scherer 2005)</td>
<td>NA</td>
</tr>
</tbody>
</table>
Table 1.4: Survey part 3: Respondent knowledge, abilities, worldviews, and demographics, with Chronbach’s alpha values for scale reliability

<table>
<thead>
<tr>
<th>Survey pages</th>
<th>Questions</th>
<th>Chapter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge about changing sea levels</td>
<td>Questions about causes, history, and future of sea level change (5 questions, NASA 2015)</td>
<td>NA</td>
</tr>
<tr>
<td>Map and math skills</td>
<td>Subjective map ability and comfort (2 questions, Thorndyke and Goldin 1981)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Subjective numerical ability (4 questions, Chronbach’s alpha=0.893, Fangerlin et al. 2007)</td>
<td>4</td>
</tr>
<tr>
<td>Your worldview</td>
<td>Individualist/Communitarian beliefs (6 questions, Chronbach’s alpha=0.694, Kahan 2012)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Hierarchical/Egalitarian beliefs (6 questions, Chronbach’s alpha=0.761, Kahan 2012)</td>
<td>3</td>
</tr>
<tr>
<td>More about you</td>
<td>Current residence type</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Distance of home, workplace, and school from ocean (4 questions)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Flood experience (2-4 questions)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Demographics (3 questions)</td>
<td>3</td>
</tr>
</tbody>
</table>

the first part of the survey (Table 1.2, Chapters 3 and 5), respondents chose a Six Americas group that best fit their beliefs and feelings about climate change, described their level of familiarity with the Sarasota area, and answered questions about their risk perceptions for climate change and sea level rise in general as well as for sea level rise in Sarasota. The second part of the survey (Table 1.3, Chapters 4 and 5) introduced the interactive sea level rise map and asked respondents to use this map to estimate the depth and probability of sea level rise flooding; following their interaction with the map, respondents completed a repeated measure of their risk perceptions for sea level rise in Sarasota. The third part of the survey (Table 1.4, Chapters 3 and 4) collected information about respondents’ sea level rise knowledge, map and math skills, worldviews, and demographics. The Appendix
provides a copy of the full survey, including screen captures of the interactive sea level rise map.

1.6 Summary

Recognizing both the need for communicating sea level rise and the potential benefits of cartographic approaches, this dissertation explores how exposure to a sea level rise map may interact with individual differences to affect understating of map information and associated risk perceptions. It considers the effects of individual differences in both distance from the sea level rise hazard and beliefs about climate change – two factors that have been shown to affect understanding and risk perceptions for information about climate change impacts. In so doing, it not only evaluates the potential of sea level rise maps to communicate risk, but also addresses more general concerns about spatial optimism bias and motivated reasoning in the perception of climate change hazards. In Chapter 2, I begin by reviewing the literature on how individual differences may affect the interpretation and use of sea level rise maps.
Chapter II

SEA LEVEL RISE MAPS: HOW INDIVIDUAL DIFFERENCES COMPLICATE THE CARTOGRAPHIC COMMUNICATION OF AN UNCERTAIN CLIMATE CHANGE HAZARD

2.1 Introduction

Maps have great potential for communicating climate change (Deitrick and Edsall 2009), and of the many ways of mapping climate change, maps of sea level rise may be one of the most powerful (Monmonier 2008) and popular (Preston et al. 2011) for reaching a general audience. Maps may be more familiar and comprehensible to novice users than graphs and other ways of visualizing climate change (Schnotz 2002), and have been shown to be more engaging than text alone for communicating climate change information (Retchless 2014a). Sea level rise is a popular topic on climate change maps. Preston et al. (2011) found that sea level rise was one of the more frequent topics on academic maps of climate change vulnerability, and of the 25 online, interactive water level visualization tools studied in Roth et al. (2015), 21 include depictions of sea level rise. Evidence suggests that these maps are not only widely available, but may also be one of the more sought after types of climate change map. According to a Google Trends analysis for 2007 to 2014, searches for “sea level rise map” have been almost as frequent as searches for the more general “climate change map,” and are becoming more common. (See Lang (2014) for a discussion of how Google Trends can be used to assess Internet users’ information seeking behavior.) During May 2014, the Trends analysis shows that searches for “sea level rise map” spiked to more than twice the highest previously recorded level for either search
term (Figure 1). This spike may have been driven by increased interest in sea level rise following widespread media coverage of a study predicting the collapse of part of the West Antarctic Ice Sheet (Joughin et al. 2014).

**Figure 2.1:** Weekly Google Trends comparison of the relative search volumes (as percentage of highest search volume in the dataset) for the terms “sea level rise map” and “climate change map”

With this increase in interest, sea level rise maps have gathered a diverse set of producers and users, potentially complicating the communication of this already complex and uncertain hazard. As described in Roth et al. (2015), government agencies, non-profits, universities, private-industries, and news organizations have all produced interactive, online sea level rise maps in recent years. Academics have also been active in the production of non-interactive maps of sea level rise vulnerability for at least 15 years (see
review in Preston et al. 2011). Audiences for sea level rise maps are similarly diverse, including scientists, policymakers, bureaucrats, educators, and increasingly members of the general public (Monmonier 2008, Kostelnick et al. 2013). Designing maps that clearly communicate both the sea level rise hazard and its uncertainty to users with multiple levels of domain and map-user expertise is a significant and important challenge (Kostelnick et al. 2013).

This chapter explores the advantages and challenges associated with using sea level rise maps for communicating climate change. It first discusses how, by displaying impacts that are local and tangible, such maps may make the sea level rise hazard seem less distant, and therefore more engaging. Next, it identifies the significant uncertainties associated with sea level rise mapping and describes how they can pose challenges to climate change communicators—particularly given the complex ways in which these uncertainties may interact with individual differences to affect how audiences understand and evaluate the sea level rise hazard. A final section offers general considerations for the design of sea level rise maps in light of these advantages and challenges.

2.2 Advantages of sea level rise maps: reducing psychological distance

The popularity of sea level rise maps may be related to their ability to make the global, complex, and chronic hazards of climate change local, tangible, and personally meaningful. The climate change communication literature suggests that such a transformation can be challenging. Surveys of US residents have found that while most are interested in learning more about climate change, they also believe it will affect others more than themselves, and therefore may not be inclined to take action to address the issue
Such distancing leads many to downplay the personal importance of climate change hazards, believing that any negative impacts will primarily be felt in the distant future, by people who live far away, or by non-human nature (Nicholson-Cole 2005, Leiserowitz 2007, Lorenzoni et al. 2007, Swim et al. 2009). Given the culturally and politically charged state of discussions about climate change, distancing may also be used (as part of motivated reasoning) to dismiss information about climate change hazards that is inconsistent with one’s worldviews or political brand (Kahan et al. 2011).

Several features of online sea level rise maps may diminish this distance. To illustrate these features, this paper uses two of examples of online sea level rise maps:

NOAA's Sea Level Rise and Coastal Flooding Impacts
(http://www.csc.noaa.gov/digitalcoast/tools/slrviewer, Figure 2) and Climate Central's Surging Seas (http://sealevel.climatecentral.org/). First, these maps make sea level rise local, displaying it at the level of neighborhoods and city blocks, and making clear that – at least for residents of coastal areas – the sea level rise hazard is one that will likely strike close to home. This perspective casts sea level rise as a potential threat to one’s identity as a member of the local community, potentially discouraging discounting and weakening the role of broader political and cultural commitments in shaping beliefs about climate change (Kahan et al. 2013). Monmonier (2008, 67) predicted the power of such a local perspective, claiming that large-scale maps that show sea level rise on top of local road networks “could be a powerful message for coastal residents,” particularly if published in an interactive, online format. Second, the maps make sea level rise tangible. For example, the NOAA map displays not only the extent of inundated land, but also provides clickable placemarks that use pictures to simulate what sea level rise flooding might look like at several local
landmarks. Similarly, the Climate Central map shows the locations of local schools, police stations, and other critical infrastructure that may be threatened by sea level rise. These depictions of flooding of well-known places make clearly visible the effects climate change, which are often diffuse, difficult to observe directly, and emerge only through analysis of trends and averages over large temporal and spatial scales (Hawkins and Sutton 2009, Moser 2010). Third, these online maps make sea level rise personally relevant. The pan-and-zoom interfaces encourage map users to explore and zoom in on locations that are personally meaningful, whether in their own hometowns, favorite vacation destinations, or places of symbolic importance. As argued in Bostrom et al. (2008), such interactive features can allow users to customize hazard maps to suit their needs and interests, facilitating personal engagement with the sea level rise information.

Figure 2.2: NOAA’s Sea Level Rise and Coastal Flooding Impacts Viewer
2.3 Challenges of sea level rise maps: three perspectives on sea level rise uncertainty

Although online interactive sea level rise maps may hold great potential for communicating climate change, at least one feature of these maps may prove challenging for some audiences: their depiction of the multiple, interacting uncertainties that are inherent to the sea level rise hazard. This section reviews three perspectives on sea level rise uncertainty – two from cartography and one from economics and decision sciences – and applies them to NOAA’s Sea Level Rise and Coastal Flooding Impacts Viewer. The next section then considers cartographic depictions of sea level rise uncertainty from the user perspective, concluding with examples of three ways in which individual differences may affect map users’ understanding of and responses to uncertain sea level rise information.

While authors from many different academic disciplines have considered sea level rise uncertainty, perspectives from two disciplines – cartography and GIScience, and the economic and decision sciences – are particularly relevant to this discussion of how maps can promote sea level rise awareness, engagement, and action. Perspectives from the cartographic and GIScience literature emphasize the components of sea level rise information that may be uncertain (Kostelnick et al. 2013) and the types of uncertainty that may be associated with these information components (Roth et al. 2015), while perspectives from the economic and decision sciences tend to emphasize the level of precision in the measurement or expression of these types of uncertainty (Willows et al. 2003). This list is not exhaustive. For example, from a modeling and prediction perspective, sources of uncertainty – such as unknowns concerning future economic development
pathways and associated greenhouse gas emissions – are often an important consideration (Dessai and Hulme 2004, Hawkins and Sutton 2009). Although the below discussion occasionally mentions sources of uncertainty, it focuses on how the three perspectives from cartography/GIScience and the economic and decision sciences have been used to study sea level rise communication.

2.3.1 First perspective: uncertainty in the components of sea level rise information

In the sea level rise context, the two cartographic/GIScience perspectives have generally been used to explore how elements of map design such as visual variables and map interaction can be used to communicate uncertainty. Kostelnick et al. (2013) consider how visual variables and map interaction are used on sea level rise maps to communicate uncertainty related to the spatial, temporal, and attribute (framed as “natural process”) components of geographic information, noting that MacEachren (1992) identified these three components as essential to uncertainty representation. These components of sea level rise information accrue uncertainty from several sources. Uncertainties about future emission pathways and oceanic/atmospheric response introduce significant attribute and temporal uncertainty: how much will sea levels rise, and when (Stocker et al. 2013)? Moreover, digital elevation models and tidal transformations introduce spatial uncertainty into any mapping of a specific amount of sea level rise (NOAA 2010). Kostelnick et al. (2013) describe how maps can communicate attribute and temporal uncertainty by presenting multiple scenarios for the amount of sea level rise at a specific time (e.g., small multiples depicting low, medium, and high sea level projections for 2100). For communicating spatial uncertainty, Kostelnick et al. (2013) suggest either: implying
uncertainty in future shoreline position using techniques such as vignettes (an example of the visual variable focus) or limits on the ability to zoom-in on interactive maps; or explicitly representing this uncertainty by using different raster fills to show areas that are slightly above or below the projected inundation level.

Additional research may be needed to explore which types of cartographic interaction are best suited to representing uncertainties in the spatial, temporal, and attribute components of sea level rise information. As noted in MacEachren et al. (2005) and detailed in Roth (2014), the effectiveness of visual variables for representing uncertainty has been widely explored, but comparable work matching interaction techniques to the communication of these uncertainties has been lacking.

2.3.2 Second perspective: uncertainty types associated with components

Deploying the second cartographic/GIScience perspective on sea level rise uncertainty, Roth (2009b, 2015) has considered how different types of uncertainty are used in inundation mapping. The uncertainty types considered in both studies are drawn from MacEachren et al. (2005), which presents nine ways in which geospatial information may be uncertain: accuracy/error, precision, completeness, consistency, lineage, currency, credibility, subjectivity, and interrelatedness. MacEachren et al. (2012) simplifies this list, retaining accuracy/error and precision as separate types but grouping the remaining seven, more “subjective” types of uncertainty into the collective type of “trustworthiness.” Roth (2009b) performed a qualitative assessment of the appropriateness and influence of all nine uncertainty types for floodplain mapping, which is similar to sea level rise mapping in its concern with delineating “hypothetical supplementary shorelines,” but differs in its
authoritativeness, audience, uses, and scale (Monmonier 2008, 49). He found that experts in floodplain mapping considered all nine types appropriate, with accuracy/error, precision, and currency considered particularly influential for decision making. Meanwhile, Roth et al. (2015) consider how the nine different types of uncertainty are communicated using visual variables in a collection of 25 interactive, online sea level rise maps. They find that only seven of the maps use the visual variables to represent one of the uncertainty types, that the only uncertainty types represented are completeness and “confidence” (which he considers similar to trustworthiness), and that only one map (the NOAA Viewer) represents both types. When these uncertainty types are represented, some combination of grain and color value are used to represent completeness, while the dimensions of color (hue, value, and saturation) are used for representing confidence.

While not dealing specifically with sea level rise, MacEachren et al. (2012) suggest that combining these two cartographic perspectives could inform the selection of visual variables for representing uncertainty. When combined, these two perspectives describe both what is uncertain (location, time, or attribute) and how or in what manner it is uncertain (in terms of accuracy, precision, or trustworthiness). MacEachren et al. (2012) show that visual metaphors for each combination of the “what” and the “how” of uncertainty can inform the design of iconic symbols for these combinations, and test the intuitiveness of these symbols in a user study. A similar study could extend this research by considering what symbols map users find most intuitive for the nine possible combinations of “what” and “how” of uncertainty on sea level rise maps.
2.3.3 Third perspective: level of precision in the measurement or expression of uncertainty types

From the perspective of the economic and decision sciences, uncertainty in sea level rise and climate change is often considered in terms of its level of precision in measurement or expression, which is seen as a key factor in decision making. In their exploration of climate adaptation under uncertainty, Willows et al. (2003) contrast the process of decision making under precise uncertainty – as in games of chance and other situations where outcomes and consequences can be assigned probabilities and considered quantitatively – with decision making under imprecise uncertainty, where these probabilities are unknown or unknowable and therefore more amenable to qualitative analysis. Following a distinction first made in the economics literature by Knight (1921), these two conditions are commonly referred to as decision making under risk and decision making under uncertainty, respectively. In the climate change context, such conditions where uncertainty is not quantified, bounded, or defined have also been referred to as “deep uncertainty” (Kandlikar et al. 2005, Moser 2005). (Bankes (2002) claims that this too has roots in economics, with the term “deep uncertainty” first used in this context by economist Kenneth Arrow in a talk on the Economics and Integrated Assessment of Climate Change offered at the Pew Center Workshop in 1999.) Willows et al. (2003) argue that when precise probabilities cannot be assigned to decision outcomes for climate adaptation, decision makers’ choice of adaptation strategy will be highly dependent on subjective factors such as the heuristics they deploy and their attitude towards the risk. Kandlikar et al. (2005) identify several such factors that may bias risk perception when probabilities are imprecise, including ambiguity aversion, conflict aversion, and ignorance aversion.
Similarly, Moser (2005, 364) suggests that sea level rise policymaking and management under deep uncertainty are sensitive to “values, cognitive processes, and attitudes.”

Much of this work has focused on how to describe and communicate these deep uncertainties to the public and decision makers. In an approach subsequently adopted by the Intergovernmental Panel on Climate Change (IPCC) for its Fifth Assessment Report (Mastrandrea et al. 2010), Kandlikar et al. (2005) suggest communicating uncertainties based on the precision with which they are known. They identify six levels of precision, with each matched to a different communication strategy. These levels range from situations where probabilities are well known and depiction using a full probability density function is appropriate; to less precisely known probabilities that are best described in terms of bounds, orders of magnitude, or the expected sign or trend direction; to states of effective ignorance, where quantitative descriptions are inappropriate and should be replaced with qualitative discussion of the available evidence and level of agreement (Kandlikar et al. 2005, Mastrandrea et al. 2010).

Researchers have yet to consider how these levels of precision might apply to the types of uncertainty identified by MacEachren et al. (2005). Of the nine types, accuracy/error and precision seem well suited to more precise levels of numeric expression, while the seven other types (grouped together as trustworthiness) seem likely to be more subjective, less precisely understood, and therefore communicated more qualitatively. Roth (2009a, 36) hints at this, noting that the level of precision for the map legends used in his study had to be adjusted so that “categories commonly reported at the ratio level (e.g., precision/resolution)...match[ed] uncertainty categories commonly reported at the ordinal level (e.g., credibility).” This adjustment suggests that each of the
uncertainty types may commonly be associated with a specific level of measurement or precision; however, less common combinations of type and precision level (such as highly precise reports of consistency based on a survey describing expert agreement and its margin of error, or low-precision reports of accuracy as within or beyond tolerance) are certainly possible. Interestingly, Roth (2009a, 36) grounds his discussion of precision levels not in literature describing a hierarchy of precision in uncertainty representation (e.g., Kandlikar et al. 2005), but in work by Beard and Mackaness (1993) describing a three-level hierarchy of precision (and difficulty) in geographic uncertainty assessment tasks: 1) notification that the geographic data are uncertain; 2) identification of the type and relative amount of uncertainty; and 3) quantification of the exact amount of uncertainty. This task hierarchy calls attention to the importance of the map user in determining the precision with which cartographic features communicate uncertainty. Uncertainty may be presented with great precision, but if map users lack expertise for reading probability density functions or other similarly precise uncertainty presentations, then they will probably understand such presentations only at the notification or identification level – if they recognize them as indicators of uncertainty at all. More studies are needed to consider this relationship between user expertise and levels of precision in uncertainty, both as expressed in representations and as understood through tasks.

2.3.4 Application of three perspectives to NOAA Viewer

An examination of the NOAA Viewer’s communication of uncertainty from all three perspectives suggests that they are compatible, and may be applied simultaneously to better understand how sea level rise maps communicate uncertainty. For the three
components of sea level rise information, the NOAA Viewer explicitly communicates the uncertainty about the attribute and spatial components cartographically: for uncertainty about how much sea levels will rise, an interactive slider allows the user to select different amounts of sea level rise and explore the extent of flooding they may cause using the dynamically updated inundation overlay; for uncertainty about the extent of inundation for a given scenario, a “confidence” overlay shows which areas have a high probability of flooding under the scenario, and which areas have a lower (but still significant) probability. Although temporal uncertainty is not explicitly represented on the NOAA map, its interactive slider for selecting sea level rise amounts may imply temporal uncertainty by presenting an ordered sequence of sea level rise scenarios that “suggests the passage of time” but does not assign specific dates (Kostelnick et al. 2013, 213).

The Viewer also communicates at least two different types of uncertainty information. As described in Roth et al. (2015), the Viewer shows completeness by applying a hatching texture to areas for which sea level rise was not mapped due to limitations in the NOAA model and data. Additionally, the confidence overlay may communicate trustworthiness, accuracy/error, or perhaps both. Roth et al. (2015) contends that this overlay uses different hues to identify areas where its depiction of sea level rise inundation is more or less trustworthy; however, supplementary documentation (NOAA 2010) states that this overlay is generated via a statistical calculation of the accuracy with which an area can be considered inundated, given the selected amount of sea level rise and the cumulative error from the DEM and tidal model.

The precision with which the Viewer represents these uncertainty types is generally low. Completeness of the sea level rise overlay is shown at the nominal level, with the
hatching showing areas not mapped. Despite being generated via a precise statistical calculation, confidence is shown at the ordinal level, using “high” and “low” categories. Since this tool is available to the public and does not require any training, these design decisions may reflect a desire on the part of NOAA to notify users of uncertainty without overwhelming them with highly precise information that would support more advanced uncertainty quantification tasks (Beard and Mackaness 1993). As discussed in the next section, user expertise is one of many individual differences that mapmakers may want to consider when deciding how to depict sea level rise and its uncertainty.

2.4 Challenges of sea level rise maps: effects of uncertainty and individual differences on risk perception and response

Because spatial reasoning about the sea level rise hazard – including decisions about the risks to one’s community, and whether landmarks within that community are worth protecting – often requires considering these uncertainties, it is important to understand how users of popular depictions of sea level rise (e.g., the NOAA Viewer) understand and act on them.

The available evidence suggests that including uncertainty information on sea level rise maps can be helpful to users. Several studies have suggested that including uncertainty on maps can improve decision outcomes (Deitrick and Edsall 2006, Brickner et al. 2007; review from Harrower 2003). In the climate change context, some authors have argued that including uncertainty in public communications may cut both ways, particularly when attempting to reach those who are doubtful or disengaged about climate change: while some map users may appreciate an honest depiction of uncertainty, this uncertainty may
also lead others to underestimate risk or justify delaying adaptive action (Swim et al. 2009, Moser 2010). However, governments and public officials often need this uncertainty information to successfully assess climate change risks and prioritize the implementation of mitigation and adaptation to high-risk areas. Model means and consensus estimates may fail to capture outliers with important policy implications (Oppenheimer et al. 2007, Brown and Wilby 2012); for this reason, models that do not account for uncertainty have been found to significantly underestimate the protective response needed to cope with sea level rise (Lewandowsky et al. 2014). For a more general audience, including uncertainty information in climate change materials may promote public trust in climate science, since a range of possible futures may be seen as more credible than a single, worst case scenario (Sheppard 2005).

Authors have also considered both whether and how individual differences can affect map users’ understanding of uncertainty information, and ultimately their decision making process. From the limited literature addressing the mapping of uncertain hazards, authors have stressed the importance of designing for different user groups (Hagemeier-Klose and Wagner 2009), including those with different “culture or knowledge” (Fuchs et al. 2009) and those who perform different types of tasks, with varying levels of data complexity (Pang 2008). These considerations may be even more important when the map is interactive, since “interactive visualization has the potential to allow users to tailor displays to reflect their individual differences” (Bostrom et al. 2008, 34).

Beyond these general insights, several authors have also considered specific ways in which one particularly important type of individual difference – map users’ expertise – may affect their interpretation of uncertainty information about flood hazards. Roth (2009a)
found that when shown a map with uncertain floodplain boundaries, map users with expertise – both in map use and especially in floodplain mapping – had higher risk assessments and assessment confidence than novices. He also noted a potentially dangerous combination of expertise: users who were map-use experts but flood-mapping novices had high confidence in their assessments, but significantly underestimated the risk relative to the domain experts, suggesting that they did not fully appreciate the potential for unfortunate surprises that the domain experts recognized in the uncertain data. In the sea level rise context, Kostelnick et al. (2013) describes a similar fear that novice users of sea level rise maps will not appreciate their significant spatial uncertainty, and will zoom in to levels not appropriate given the resolution of the data. Monmonier (2008) relates that, when faced with a similar concern regarding novice users’ ability to interpret sea level rise maps, the U.S. Environmental Protection Agency opted to produce versions with different descriptions of uncertainty for research papers, the popular press, and the public. Roth (2009a) suggests that while such user-aware design approaches are desirable, uncertainty should not be relegated to marginalia, but should be represented explicitly on the map, where it will be difficult for novices to ignore. Deitrick and Edsall (2009) argue that such an approach is particularly important in the context of climate change media, where seemingly authoritative graphics in news reports communicate possible futures but generally not their own uncertainty.

This literature suggests two lessons: 1) including uncertainty information on sea level rise maps may promote more informed risk assessment and decision making; and 2) individual differences (particularly user expertise) will likely affect both how map users interpret these sea level rise uncertainties and how they act on them. However, mapmakers
who heed these lessons will likely face additional, largely unanswered questions: which other individual differences are likely to have significant effects on the interpretation of uncertainties, and what will these effects be? The next three sections explore these questions, examining three examples of cases where individual differences may shape how map users understand and act on uncertainty in general, and sea level rise uncertainty in particular. These sections consider situations where aspects of each of the three perspectives on uncertainty described above have been suggested to dictate (or at least strongly influence) adaptive or mitigative action in the context of sea level rise or similarly uncertain hazards. They sketch out the reasons why these expected relationships are at least somewhat justified, and then problematize these accounts by showing how context and individual differences mediate (and in some cases reverse) these expected relationships. A concluding section discusses how these effects of individual differences on the interpretation of uncertainty may inform the design of sea level rise maps.

2.4.1 Certainty in the spatial, temporal, and attribute components of damaging sea level rise encourages more adaptive and mitigative action.

Several authors have suggested that when people perceive a threat as more likely – e.g., when spatial and temporal certainty of a damaging amount of sea level rise is seen as high – they are more likely to take action to respond to the threat. Thus, in the model of climate change adaptation proposed by Grothmann and Patt (2005), risk appraisal (a combination of perceived probability and severity) is an important driver of adaptation intentions. Working with a similar model, Grothmann and Reusswig (2006) confirmed that risk appraisal was a significant predictor of protective responses for flooding. Moreover,
while not studying the effect on protective responses, Severtson and Myers (2012) found that study participants assigned to higher risk zones on a map of cancer risk generally had stronger risk beliefs.

For sea level rise, this suggests that people in areas where inundation is more likely should also be more likely to take adaptive or mitigative action. But this willingness to take action will likely also depend on the characteristics of the hazard and individual differences. If the sea level rise threat is seen as so great that it overwhelms an individual’s perceived adaptive capacity, then being located in a high-risk zone might lead to a fatalistic response. For example, Howe (2011) proposes that fatalism may explain why businesses at the highest risk of storm surge flooding took the fewest adaptive actions. Grothmann and Patt’s (2005) model acknowledges that such maladaptive responses (also including denial and wishful thinking) will often dampen the response to climate threats.

Beyond such “maladaptive” responses, people may also differ on what they feel is an acceptable risk (Nicholson et al. 2005). Thus, there is unlikely to be an objective way to determine a single probability value for sea level rise above which it would be logical to take personal action (such as moving away from the risky location). Some people may value the immediate amenities of living near the ocean highly enough to bear an almost certain risk of inundation in 2050 or 2100, especially since they are likely to significantly discount the inundation risk at these times several decades in the future. This is supported by a series of studies of home values and risk perception in the Houston area, which found that proximity to the ocean was seen as both an amenity and a hazard, with conflicting affects on home value (Zhang et al. 2010, Lindell and Hwang 2008).
2.4.2 Some types of uncertainty are given greater weight than others in decision making.

The type of uncertainty presented to map users may also affect their decision making. For example, uncertainty may be used quite differently in decision making when it is communicated as consistency in opinion among a panel of experts rather than as a model-based expression of accuracy or precision. For example, Patt (2007) found that students’ subjective estimates for the likelihood of a certain amount of sea level rise were closer to 50/50 if the probability of the sea level rise was presented as a level of agreement among experts, rather than as a model-based probability estimate. This suggests a significant effect of the type of uncertainty (and possibly the message source) on how uncertainty information is weighted in the decision process.

However, it cannot be assumed that everyone will ascribe the same uncertainty types to information about sea level rise. In an example from Patt (2007), a person who does not trust climate modelers may believe that a modeled probability of sea level rise is also highly subjective and discount it accordingly. This is in line with Wachinger et al.’s (2010) finding that trust in experts and authorities was one of the most frequently cited factors associated with higher risk perceptions and more protective actions for natural hazards. While there is probably no objectively correct way to weight disagreement among expert predictions, engaging with residents and stakeholders through participatory exercises may build trust (Wachinger et al. 2010). This could help to fight the perception among the disengaged and dismissive that scientists remain divided on whether climate change is happening and will have harmful effects.
Additional research is needed to explore the comparative weight given to uncertainty types other than consistency/subjectivity and accuracy/precision in the sea level risk assessment context. The results of such studies could help mapmakers' choose uncertainty types that users are less likely to interpret in ways that run counter to the accepted science.

2.4.3 When uncertainties are expressed imprecisely, risk perceptions are higher.

Economists and decision theorists have found that, when people are presented with a low to moderate – but imprecise – probability of a hazardous event (such as sea level rise flooding), they are likely to skew their perception of the risk towards the worst possible outcome (e.g., the highest probability of flooding possible given the imprecise specification) (Einhorn and Hogarth 1985, Kuhn 2000, Rustichini 2005). This finding is based on researchers’ observation that people generally prefer to bet on outcomes with known, precisely specified probabilities rather than outcomes with vague or imprecisely defined probabilities (Ellsberg 1961), and will pay a premium to avoid or remove such vagueness or imprecision (Becker and Brownson 1964). Although generally referred to as “ambiguity aversion” in the economic and decision science literature (Ellsberg 1961, Becker and Brownson 1964), this tendency may be more properly termed “vagueness aversion,” since imprecisely specified probabilities suggest a range of possible values, rather than the small set of distinct possibilities implied by ambiguity (Kuhn 1997).

This finding of greater risk perception under vagueness would seem to be readily applicable to sea level rise and climate change, where epistemic (limited knowledge about climate processes), natural stochastic (irreducible complexity of the climate response), and
human reflexive (unknowns in the future socioeconomic system) elements all limit our ability to provide well defined probability estimates for specific climate outcomes (Dessai and Hulme 2004). Given the large uncertainties and the potential for highly disruptive impacts, the application of the first element of the precautionary principle – “taking preventive action in the face of uncertainty” (Kriebel et al. 2001, 871) – to climate change would appear to be an example of a response to uncertainty that would be in line with the expected increase in risk perception under vagueness. In line with this expectation, several authors have suggested that more should be done to communicate high-impact sea level rise scenarios (Oppenheimer et al. 2007, Nicholls and Cazenave 2010, Brysse et al. 2013), the apparent expectation being that the possibility (with small but unknown probability) of such a highly disruptive future should lead to adaptive or mitigative action.

However, as argued in Kuhn (2000), vagueness may not always increase risk perception, particularly for environmental problems and related hazards, where motivated reasoning may interact with vagueness to increase or decrease perceived risk. Kuhn (2000) found that prior environmental attitudes determined whether risk perceptions skewed towards the top or bottom of a range of probabilities given for an environmental hazard; this effect increased when the high and low ends of the range were associated with sources with a known bias. In a cartographic context, Severtson and Myers (2012) similarly found that when assessing risk in a high-risk zone on a map, participants in a study were more likely to have lower risk beliefs if the boundaries of this high-risk zone were blurred in a way suggesting vagueness. Thus, rather than an unambiguously positive relationship between vagueness and risk perception that might suggest a clear role for the
precautionary principle in the response to climate change, uncertainties in climate change impacts may also lead some people to lower their risk perceptions.

Individual differences in comfort and perceived competence with climate data may also affect vagueness aversion. While early attempts to model vagueness aversion focused on the effect of imprecise probabilities on decision making (e.g., Einhorn and Hogarth 1985), later work suggested that the preference for precisely defined probabilities in such situations may be an example of a broader inclination towards choices that are well known (and about which one has some level of expertise, or a general “feeling of competence”) over choices which are poorly understood (Heath and Tversky 1991). As a product of both imprecision in the underlying data and individuals’ recognition and interpretation of this imprecision, vagueness aversion will thus be felt most strongly when these two factors (data and expertise) combine in ways that lead to a perceived lack of competence. Hope and Hunter (2007) have explored this interaction between expertise and vagueness aversion in a cartographic context; future work could consider this interaction as it applies specifically to sea level rise mapping.

2.5 Conclusions: lessons for mapping sea level rise and other uncertain climate futures

What lessons does this literature hold for the communication of uncertainty on online, interactive sea level rise maps like the NOAA Viewer and Climate Central’s Surging Seas? Perhaps most importantly, sea level rise map design demands a user-centered perspective. As a popular and powerful medium for communicating one of the more dramatic impacts of climate change on coastal communities, these maps appeal to many
audiences, ranging from scientists and policymakers to members of the public (Monmonier 2008, Kostelnick et al. 2013). Because sea level rise is a highly uncertain hazard, communicating this uncertainty to all of these diverse map users is likely necessary and important: for scientists and policymakers, it may improve decision outcomes (Deitrick and Edsall 2006, Brickner et al. 2007; review from Harrower 2003); and for members of the public more interested in general exploration of the sea level rise hazard, it may dissuade anchoring on a single scenario (Deitrick and Edsall 2009) and establish credibility by clearly indicating limitations in the data and models (Sheppard 2005, Spiegelhalter et al. 2011). Despite these general benefits of showing uncertainty on sea level rise maps, each of the many audiences these maps serve is likely to interpret these uncertainties somewhat differently (as shown for other hazard maps in Roth (2009a) and Severtson and Myers (2012)), suggesting the need for designs that are customized (or interactive and customizable) to address these differences. This may be particularly true in cases where individual differences can lead users to interpret uncertainties in ways that significantly underestimate risks (relative to expert assessments) or encourage maladaptive responses (see, e.g., Roth 2009a).

The examples reviewed in this chapter suggest at least two types of individual differences that may contribute to such dangerous distortions in map users’ risk perception and response: user expertise and trust. Compared to domain and map-use experts, novices have been shown to have lower risk perceptions after studying a map of an uncertain flood plain (Roth 2009a); novices may similarly discount the possibility of high-end impacts on maps of sea level rise uncertainty. This possibility is supported by work in the vagueness aversion literature, which has found that expertise can shape interpretation of imprecisely
defined probabilities for hazardous events (Heath and Tversky 1991). Roth (2009a) suggests that despite novices’ underestimation of flood risk, they may still take appropriate precautions because they also have lower confidence in their risk assessments, and may therefore be more likely to consult an expert. However, if the novice map users do not trust the relevant experts, then they may not seek or value their opinion. This devaluation of expert opinion may be particularly true for politically charged climate hazards such as sea level rise, where considerations such as the message source and type of uncertainty (Patt 2007) and users’ prior environmental beliefs (Kuhn 2000) may affect their trust in the uncertainty shown on hazard maps (and experts’ assessments of it). Prior beliefs about the environment in general and climate change in particular are therefore another individual difference that may shape sea level rise risk perceptions; others introduced in this chapter include hazard proximity and perceived adaptive capacity. More studies are needed to explore these in the cartographic context, and to identify additional individual differences that may also affect map users’ interpretation of uncertainties on hazard maps. The remaining chapters of this dissertation focus on two of these individual differences: prior beliefs about climate change and hazard proximity. The affects of these differences on the interpretation of sea level rise information are discussed in greater detail in the literature review sections of Chapters 3-5. Map use expertise is also considered briefly in Chapter 4, but warrants additional research.

In addition to identifying which individual differences are most likely to affect the interpretation of uncertainty, mapmakers must also decide whether and how to design for these differences. At the most basic level, this may include decisions about which components of geographical uncertainty should be shown, using which types of uncertainty,
and at what level of precision; it may also include considerations of which representational techniques (e.g., visual variables and map interaction) should be used to communicate these uncertainties. The following list presents some general guidance on how mapmakers might approach these decisions in light of the literature considered in this chapter.

- Brysse et al. (2013, 327) argue that the scientific commitment to restraint, objectivity, skepticism, rationality, dispassion, and moderation has actually led climate scientists to generally err “on the side of least drama.” Mapmakers should not shy away from dramatic presentations: visualizations showing projected impacts of sea level rise on local landscapes can drive home the personal relevance of rising seas (Nicholson-Cole 2005, Sheppard 2005), and when made engaging and interactive they may also encourage deeper understanding of complex scientific information (Rapp 2005). However, because such visualizations can be so convincing, they must be used with great care, and employ what Sheppard (2005) calls “permissible drama” – the idea that the map or visualization should remain grounded in a scientifically plausible (e.g., not exaggerated) future, and that goals of the visualization should be made explicit (e.g., raising awareness about the possible future impacts of sea level rise).

- Multiple authors (Deitrick and Edsall 2009, Roth 2009a, Spiegelhalter et al. 2011) have stressed that maps and other depictions of uncertain hazards such as sea level rise should clearly and prominently communicate their limitations. For interactive, online sea level rise maps, this suggests that mapmakers should strongly consider explicitly communicating uncertainties associated with all
three components of sea level rise information: space, time, and attribute. While spatial and attribute uncertainty are already represented on some of these maps (including the NOAA Viewer and Climate Central’s Surging Seas), mapmakers should consider representing temporal uncertainty more explicitly (rather than implying it using sliders and animation).

• Following the lead of MacEachren et al. (2012), mapmakers and researchers could explore the use of visual metaphors to represent possible combinations of uncertainty components and types on sea level rise maps. To extend this work, researchers could consider how adjusting the visual variables used to construct these metaphors might communicate uncertainty with different levels of precision.

• As discussed in Kostelnick et al. (2013), mapmakers should consider communicating uncertainty using map interaction as well as visual variables. This is an active area of research. For example, recent work by Roth (2012 and 2014) explores a possible typology for map interaction primitives, and speculates about the use of map interaction to communicate uncertainty.

• The potential parallel between levels of precision in the expression of uncertainty (as described in the IPCC uncertainty guidance, Mastrandrea et al. 2010) and the hierarchy of precision (and difficulty) for uncertainty assessment (Beard and Mackaness 1993) may warrant further exploration. If user expertise can be matched with an appropriate level of assessment task, then perhaps this task level can be further paired with a corresponding level of precision in the cartographic presentation of uncertainty. This could perhaps lead to a better fit
between map design and user expertise. However, as discussed in the above section on vagueness aversion, other individual differences (such as prior environmental beliefs) can also affect users’ interpretation of imprecisely defined uncertainties, potentially complicating mapmakers’ decisions about which level of precision is most appropriate.

- Mapmakers may also consider adjusting the production and presentation of their maps to help earn the trust of their audiences. Seeking these audiences’ active participation in the design of sea level rise maps may help build trust in their depictions of sea level rise and its uncertainty (Patt 2007). Mapmakers should also consider which types of uncertainty might be considered most or least trustworthy for the map’s intended audience, perhaps based in part on its predominant political or environmental beliefs.

Much of this guidance is preliminary. In particular, additional studies are needed to assess: which visual variables and forms of map interaction most effectively communicate different combinations of uncertainty types and precision in the sea level rise context; which individual differences most strongly affect interpretation of these uncertainties; and how the types, precision, and presentation of uncertainty might be adjusted to limit the effect of any individual differences that may strongly bias its interpretation. It is hoped that by raising these questions and beginning to explore possible answers, this chapter will prove valuable both to researchers in the field of cartographic uncertainty representation and to designers of maps of sea level rise and other similarly uncertain environmental hazards.
In Chapter 4, I explore these questions further. Heeding the calls of Deitrick and Edsall (2009), Roth (2009a), and Spiegelhalter et al. (2011) to communicate uncertainty on hazard maps, Chapter 4 discusses the development of a map of local sea level rise and its uncertainty. It also evaluates how many of the individual differences discussed in this chapter – including hazard proximity, climate change beliefs, and map use expertise – affect performance on a map reading task. However, to better understand how different audiences interpret local sea level rise messages, I first consider how local context alone (without a map) affects risk perceptions. I take up this discussion in Chapter 3.
Chapter III

Spatial Optimism Bias and Local Climate Impacts: Effects of Audience Distance and Message Specificity

3.1 Introduction

Climate change is often seen as a spatially distant problem (Uzzell 2000, Pidgeon and Fischhoff 2011, Spence et al. 2012, Scannell and Gifford 2013). Such distancing of climate change may frustrate engagement by reducing overall concern and moving the threat to a remote context or global level, where one may feel powerless to take action (Uzzell 2000, Spence et al. 2012). Motivated in part by this threat to engagement, several researchers have considered why this distancing occurs (e.g., Uzzell 2000, Schultz et al. 2014), and ways to prevent it (e.g., Spence et al. 2012, Moser 2010, Swim et al. 2009, Lorenzoni et al. 2007, Leiserowitz 2007, Rayner and Malone 1997). These studies have generally considered distance in terms of nested spatial levels – ranging from the local, to the national, to the global – and have shown that individual concern about environmental hazards increases with this distance (Uzzell 2000, Gifford et al. 2009, Schultz et al. 2014). However, as these levels also range from the general (e.g., global climate change) to the specific (e.g., climate change in your community), another explanation would be that individual concern decreases with specificity. Hatfield and Job (2001) found some support for the role of specificity in spatial optimism for environmental hazards, but this topic

1 Engagement is defined here as “a personal state of connection with the issue of climate change,” including cognitive, affective, and behavioral aspects (Lorenzoni et al. 2007, 446).

2 Because my hypotheses are for the effects of female gender, I compare respondents who
remains largely unstudied. Most existing studies have to some extent confounded specificity and distance, as they have not considered how individuals will perceive climate change risk for specific far away places, or how individuals close to or far away from a climate change hazard (such as sea level rise) might differ in their general risk perceptions for this hazard.

To address this gap, this study offers a preliminary examination of how individuals’ distance from climate hazards may interact with the specificity of hazard framing to affect risk perceptions. I begin with a brief review of the literature on one of the more popular explanations for the distancing of climate change risk – spatial optimism bias – and discuss its consequences and possible causes. I then complicate this account by pointing to theoretical considerations and survey results suggesting that variations in the specificity of the message frame may be responsible for some of the effect attributed to distance. After reviewing this literature and introducing research questions and hypotheses, a methods section describes the survey design and implementation for the study. Sections for results, discussion, and conclusions follow.

3.2 Literature review

3.2.1 Spatial optimism bias: what it is and why it matters

Public concern about climate change and related environmental hazards often exhibits spatial optimism bias: in the environmental context, this is the tendency, often grounded in positive feelings for one’s self and community (Schultz et al. 2014), to view proximal environmental conditions more favorably than distal conditions (Schultz et al. 2014, Gifford 2011, Gifford et al. 2009, Uzzell 2000). Consistent with spatial optimism bias,
surveys in the U.S. (Leiserowitz 2005, Maibach et al. 2009) and UK (Lorenzoni et al. 2007) have found that residents of these countries tend to be more concerned about the effects of climate change on people who live far away than they are about effects on themselves, their families, or their communities.

This distancing of climate change impacts is in line with results from surveys about environmental problems in general, which have found that, in the vast majority of countries surveyed, residents believe that environmental conditions are better at lower spatial levels (e.g., the level of the respondent and their local community) and worse at higher spatial levels (e.g., the national or global level), within which the lower levels are nested (Uzzell 2000, Gifford et al. 2009, Milfont et al. 2011, Schultz et al. 2014). In one of the more extensive studies to address this issue, Schultz et al. (2014) report results from a series of cross-cultural surveys of university students from 26 developed and developing countries. They find that spatial optimism for environmental conditions is nearly universal (observed in all but one country), and that such optimism is likely biased, i.e., greater than would be expected given an objective assessment of local environmental conditions relative to the global average. By deploying questions similar to those used by Gifford et al. (2009) to assess spatial optimism in 18 countries, Milfont et al. (2011) confirmed that, for New Zealand residents, spatial optimism applied to climate change in a similar way as to the other environmental hazards considered in Gifford et al. (2009) and Schultz et al. (2014).

Research suggests when climate change impacts are perceptually distant, personal engagement many decrease. Specifically, distancing has been associated with lower overall concern about climate change, and may discourage individuals from taking action to
mitigate its causes or adapt to its effects. In his assessment of the results of a U.S. public opinion survey, Leiserowitz (2005) attributed respondents’ “moderate” level of overall concern about climate change to the fact that they were most concerned about impacts on geographically distant people and places. Similarly, a survey of a nationally representative British sample (Spence et al. 2012) found that respondents who perceived climate change as more distant also tended to have lower overall levels of concern.

Research on environmental hazards generally has also implicated spatial optimism in reducing pro-environmental behavior through what Hatfield and Job (2001) term the “environmental paradox.” This is the observation that, with the move to higher spatial levels, concern about environmental problems increases, but the sense of personal responsibility and self-efficacy needed to address them decreases (see, e.g., results to this effect from a four-nation study in Uzzell 2000). In apparent contrast with the environmental paradox, more recent research suggests that concern about distant climate impacts can sometimes provide an impetus to action by creating an “abstract mindset” in which core environmental beliefs are more easily accessible (Spence et al. 2012). However, this same study finds that, consistent with the environmental paradox, this impetus will likely go unheeded unless it is also connected to concern about more local impacts, which can be addressed through a concrete plan of action.

### 3.2.2 Causes of spatial optimism bias

To explain why spatial optimism bias occurs and how it may affect engagement, researchers have proposed several theories:
• **Media messages.** Uzzell (2000) claims that because climate change is difficult to perceive directly, it is often understood through media messages. Both Uzzell (2000) and Gifford et al. (2009) speculate that to the extent that media depictions of environmental hazards are predominately global, this could contribute to spatial optimism. Schultz et al. (2014) found that environmental knowledge did not have an effect on spatial optimism, but did not test directly for the role of media exposure. Contrary to these claims for the role of media messages, studies of how climate change has actually been depicted in the U.S. media have shown that while its uncertainty is often overemphasized relative to the scientific consensus, climate change is more frequently presented through dramatization and personalization than through messages that are abstract, global, or distant (Boykoff and Boykoff 2007).

• **Perceived control.** According to Uzzell (2000), lack of control over a threatening hazard can lead to increased distant concern as compensation for local denial. This is consistent with findings that uncontrollable, dread risk is associated with both higher risk perceptions (Slovic 1987) and optimism bias relative to others who are similarly exposed (Weinstein 1988). In more evidence for the association of perceived control with optimism bias, Hatfield and Job (2001) not only found that students rated environmental hazards in their own local area as less threatening than hazards in the local areas of their peers, but also that when descriptions of these hazards were made more specific, students both displayed more optimism bias and called to mind more personally effective precautions for reducing their risk.
• **Motivated reasoning.** Several authors have argued that at spatial levels where people have perceived control, they will deploy motivated reasoning to protect elements of place and self that are important to their identity (Schultz et al. 2014, Gifford et al. 2009). Schultz et al. (2014) point to evidence that people generally expect to experience more positive futures (Weinstein 1980) and less risk (Weinstein 1989) than their peers, and have been shown to use identity-protective reasoning to maintain a positive view of places they inhabit and value when faced with environmental hazards (Hugh-Jones & Madill, 2009). Gifford et al. (2009) similarly note that some cases of spatial optimism may be driven by a need to maintain a positive national identity. In support of these claims for the role of “self serving” and “place serving” sources of spatial bias, Schultz et al. (2014) found that respondents in their study who were happier or from smaller communities also tended to exhibit more spatial optimism.

• **Environmental engagement.** To explain an unexpected association between age and spatial bias in their study, Schultz et al. (2014) suggest that younger individuals might demonstrate more spatial bias because they tend to be more environmentally engaged (Fransson and Garling 1999). They support this conjecture by noting that such a relationship would be in line with the positive relationship between spatial bias and a country-level measure of environmental sustainability observed in their study (Schultz et al. 2104). In the climate change context, this possible relationship between environmental engagement and spatial bias could be explored by using the Global Warming's Six Americas framework (Maibach et al. 2009) – an audience segmentation analysis developed
using a representative sample of U.S. residents – to compare spatial bias in
survey respondents based on their engagement with, and pre-existing beliefs
about, climate change. As described below, I adopt this approach in this study.

Construal level theory may serve as a unifying framework for explaining spatial
optimism in climate change and other environmental hazards (Swim et al. 2009, Milfont et
that are experienced as more distant (in time, space, social connection, or deviation from
what is known, i.e., uncertainty) tend to also be construed as more abstract, and that more
abstract (higher level) construal also increases perceived distance (Liberman et al. 2007).
Spence et al. (2012) found that for climate change, many of the four dimensions of
perceived distance are highly correlated, suggesting, in line with arguments in Milfont et al.
(2011), that when climate change is perceived as distant on one of these dimensions, it is
likely to also be construed more abstractly, leading it to be perceived as distant on the
other dimensions as well. This may provide some support for the media-messages theory
of spatial optimism: even if the media only presents climate change as distant in one way
(e.g., in terms of its uncertainty), such presentations may lead media consumers to perceive
it as distant on the other dimensions as well.

Construal level theory may also inform accounts related to control and motivated
reasoning. To the extent that climate change risk is construed abstractly, it will be most
easily applied to distal targets (Liberman et al. 2007, Milfont et al. 2011). For proximal
targets, where specificity and “noise” resists generalization, these abstract ideas about
climate change risk must be translated into a more concrete and detailed representation of
what climate change risk will mean in that specific context (Liberman et al. 2007, Spence et al. 2012). To the extent that one feels that they have control over this translation process, one may be expected to exercise motivated, self- and place-serving reasoning by selecting details in ways that reduce perceived risk and are protective of self and valued places (Kunda 1990). This is in line with the finding of Hatfield and Job (2001) that optimism bias for environmental hazards was not only evident spatially, but also increased when descriptions of the hazard were made more detailed and specific in other ways.

This account suggests a role for specificity as well as distance in explaining spatial optimism bias for climate change hazards. Notably, however, apart from the work of Hatfield and Job (2001) for environmental hazards generally, research has not considered how the specificity of the climate change context may affect risk perceptions, independent of distance. While these factors are usually combined – the global is both less specific and farther away than the local – they need not be. For example, local climate change in a particular place will always be a more specific context than climate change in general; however, for people living far away from and unfamiliar with that place, such “local” climate change may be seen as quite distant. Because coverage of climate change in the popular press, assessment reports (such as those from the IPCC), and scientific journals uses “local” frames that may be distant to readers not from that place, it may be important to understand how distance interacts with specificity to shape readers’ responses to these frames.
3.3 Research questions and hypotheses

As a step towards better understanding the effects of this interaction between distance and specificity on the perception of climate change hazards, this study explores how the risk perceptions of students at two distances from a climate change hazard – sea level rise – vary with the specificity of the hazard frame (Table 3.1).

Table 3.1: Study design (respondent distance crossed with frame specificity)

<table>
<thead>
<tr>
<th>Frame specificity</th>
<th>Near &amp; Specific</th>
<th>Near &amp; General</th>
<th>Distant &amp; Specific</th>
<th>Distant &amp; General*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific</td>
<td>Near</td>
<td>General</td>
<td>Distant</td>
<td>General*</td>
</tr>
<tr>
<td>General</td>
<td>General*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Combinations widely studied in the spatial optimism bias literature

To evaluate the effects of distance and specificity, I explore three research questions:

- How does the specificity of the climate-impact stimulus affect risk perceptions?
- How does distance from the climate-impact stimulus affect risk perceptions?
- How do audiences differ in their risk perceptions?

As described in the Methods section, I evaluate hypotheses for these questions using a survey of college and university students from both nearby and far away from a local climate change hazard: sea level rise in Sarasota, Florida. Below, I briefly discuss the research design and hypotheses for each question.

How does the specificity of the climate-impact stimulus affect risk perceptions? The effect of the specificity of climate change stimuli on risk perceptions is
evaluated using three frames, each more topically or spatiotemporally specific than the last: 1) climate change in general, 2) sea level rise in general, 3) sea level rise in Sarasota over the next century.

In line with Hatfield and Job (2001), I predict that risk perceptions will decrease with increasing specificity of the climate-impact frame. For the two most general frames (climate change and sea level rise) this expectation is in line with their objective relationship: the risks posed by sea level rise should fall within the more general category of climate change risk. Therefore, the absolute risk posed by sea level rise should be less than that posed by climate change as a whole. For the most specific frame (Sarasota sea level rise), the objective relationship is less clear. Since it is subsumed spatiotemporally, rather than topically, within the sea level rise frame, risk for the Sarasota frame may reasonably be seen as higher or lower than that for sea level rise in general, depending on how one expects the local amount of sea level rise and the damage it causes to compare with global averages.

How does distance from the climate-impact stimulus affect risk perceptions?

To evaluate the effect of distance from the local climate-impact stimulus (sea level rise), students were recruited from two locations: colleges and universities in the Sarasota, Florida metro-area (nearby hazard) and the University Park campus of The Pennsylvania State University (far away from hazard).

Consistent with previous studies that have found that climate change risk perceptions are higher among coastal residents than among persons living inland (e.g., Brody et al. 2008), I predict that, overall, risk perceptions for participants from the Sarasota area will be higher overall than those for participants from Penn State. However,
consistent with spatial optimism, I also expect Sarasota-area students to: 1) have lower risk perceptions for Sarasota sea level rise than for sea level rise in general; and 2) be more likely than Penn State students to decrease their risk perceptions when moving from the general to the local sea level rise frame.

**How do audiences differ in their risk perceptions?** For audience effects, I consider how participants’ risk perceptions vary with their Six Americas audience segment and gender. Because differences among the Six Americas are based in large part in differences in political identity and worldview (Bliuc et al. 2015) that have been associated with motivated reasoning (Hart and Nisbet 2011), I predict that participants’ risk perceptions will generally mirror their Six Americas classification, with risk perceptions trending from higher to lower with membership in the Alarmed, Concerned, Cautious, Doubtful, or Dismissive segments. I further predict that, consistent with the speculation of Schultz et al. (2014), segments with the highest levels of positive engagement with climate change (the Alarmed and Concerned) will be most likely to decrease their risk perceptions when shifting to the frame for sea level rise in Sarasota. Moreover, since members of the Disengaged segment generally devote little attention to climate change, I expect that their risk perceptions will, on average, be close to the middle of the risk perception scale, and will also be little changed by shifts in framing.

For gender, I expect women to have higher risk perceptions than men. Compared to men, women are generally more concerned about the environment (Davidson and Fredudenburg 1996), tend to be more worried about climate change (Maibach et al. 2009), and may find depictions of climate impacts more engaging (Scannel and Gifford 2013).
3.4 Methods

To test these research questions, the survey was structured to evaluate risk perceptions across different climate impact stimuli and audiences, and implemented using participants from nearby and far away from the sea level rise hazard. The next sections describe this survey structure and implementation in more detail.

3.4.1 Survey structure

The full survey contained 53-55 total questions, and took respondents approximately a half hour to complete. This chapter primarily discusses results from the first page of the survey (5 questions), which included a Six Americas self-classification and several risk perception questions. However, it also considers the relationship between these results and information about respondents’ worldviews and demographics collected in the final two pages (22-24 questions) of the survey.

The first part of the survey opened by asking respondents to choose which of the Six Americas segments best fits their beliefs and feelings about climate change. To avoid burdening respondents with the full 15 item instrument required to implement the formal Global Warming’s Six Americas audience segmentation typology (Maibach et al. 2011), respondents were asked to self-identify their Six Americas segment. In studies with Penn State psychology students, Swim (in preparation) has shown that when selecting from among the segments and descriptions shown in Box 2.1, students’ selected segments that generally matched the Six Americas segments to which they were assigned based on the formal segmentation typology.
Box 3.1: Six Americas self-identification question

Which of the following best describes your beliefs and feelings about climate change?

**Alarmed:** "I am very concerned about climate change and think the government and individuals need to act now."

**Concerned:** "I am concerned and think we need to take action but we have time to decide what the appropriate responses should be."

**Cautious:** "I suspect that climate change is happening but I am not certain. We have time to make careful decisions about when and whether to respond."

**Disengaged:** "I have not really thought much about it."

**Doubtful:** "I suspect that climate change is NOT happening but I am not certain. I am concerned more about overreacting to climate change."

**Dismissive:** "I do not believe climate change is occurring and certainly do not think humans have caused it. So, I’m not motivated to take or support action to address it."

The dependent variables for the first part of the survey – respondents’ risk perceptions for climate change, sea level rise, and sea level rise in Sarasota – were measured using variations on a question used in Kahan et al. (2013) to measure the public’s “latent disposition toward climate change.” As originally developed, this question asked respondents to answer “How much risk do you believe climate change poses to human health, safety, or prosperity?” on a 0-10 scale, with 0 indicating “no risk” and 10 indicating “extreme risk.” Because responses to this item are highly correlated with answers to many questions about public concern about climate change, Kahan et al. (2013) proposed that this is a good “single-item indicator” for climate change risk perceptions. In this dissertation, I first ask this question for climate change and then adapt it to the more specific sea level rise context (Box 3.2).
Box 3.2: General climate change and sea level rise risk questions

How much risk do you believe that each of the following hazards poses to human health, safety, or prosperity? Answer on a scale from 0 (no risk) to 10 (extreme risk).

- Climate change
- Sea level rise

Before evaluating risk perceptions for sea level rise in Sarasota, all respondents were shown a brief textual description of the location of Sarasota and its exposure to sea level rise: “This survey focuses on the effects of sea level rise flooding on the Sarasota metro area. Located on the coast of southwest Florida, the Sarasota metro area (including the cities of Bradenton, Sarasota, Venice, and Northport and surrounding suburbs) is home to over 700,000 people.” Respondents then indicated how familiar they were with the Sarasota area on an eight-point scale, from “totally unfamiliar” to “currently living in Sarasota.” I intended this description and question to provide needed context for those unfamiliar with Sarasota, and to call to mind any knowledge about Sarasota and its sea level rise exposure that those who were more familiar with the area might posses. I then asked respondents to draw on this knowledge when assessing sea level rise risk for Sarasota, as shown in Box 3.3.

Box 3.3: Sarasota sea level rise risk question

Please use any knowledge you may have about the Sarasota area to answer the following question. How much risk do you believe that sea level rise poses to human health, safety, or prosperity in the Sarasota metro area during this century? Answer on a scale from 0 (no risk) to 10 (extreme risk).
3.4.2 Survey implementation

To compare responses from students based on their physical proximity to the sea level rise hazard, the survey was offered to undergraduate students from both Penn State and three colleges and universities in Sarasota, Florida. Undergraduate students were chosen for this study because of their availability at locations both nearby and far away from the sea level rise hazard. Moreover, the Six America’s self identification has been shown to be appropriate for use with undergraduates, since it was piloted and validated with this group. Sarasota was chosen in part because, as a city on Florida’s Gulf Coast, it is exposed to sea level rise and related coastal hazards, such as hurricane storm surge (Frazier et al. 2010); sea level rise was therefore expected to be of interest to area students. Additionally, unlike many other areas on the U.S. Gulf Coast, Sarasota County has not suffered a direct hit from a hurricane since 1944, a streak of good luck that many residents (incorrectly) attribute to a “blessing” putatively offered by American Indians who once lived in the area; Sarasota residents may therefore be particularly susceptible to spatial optimism bias for coastal hazards, making them good candidates for evaluating how the specificity of messages about local sea level rise may affect spatial optimism. Sarasota is also home to several colleges and universities from which I could recruit students to compare with the Penn State sample.

Students were offered extra credit equivalent to 1% of their course grade for participating. Because this extra credit was the primary incentive to participate, I generally restricted my recruitment to earth and environmental science courses, where the sea level rise information presented in the survey would be relevant to in-class instruction. To reach students in these courses, I developed relationships with their instructors, who agreed to
send invitation emails to their students. The one exception to this approach was at New College of Florida, a small honors college where formal grades are not offered and many students are environmentally active; in this case, the professor with whom I partnered offered the survey to all College students, but also specifically encouraged students in his courses to participate. Table 3.2 shows a break down of respondents by institutions and courses.

**Table 3.2:** Survey responses by institution and course

<table>
<thead>
<tr>
<th>Proximity to SLR hazard</th>
<th>Institution</th>
<th>Course name, dates offered</th>
<th>Group code</th>
<th>Respondents (actual/possible)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far</td>
<td>Pennsylvania State University</td>
<td>Landforms of the World, Spring 2014</td>
<td>GEOG 115   SP14</td>
<td>28/56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Introduction to Physical Geography, Spring 2014</td>
<td>GEOG 10    SP14</td>
<td>68/97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Introduction to Physical Geography, Fall 2014</td>
<td>GEOG 10    FA14</td>
<td>61/119</td>
</tr>
<tr>
<td>Near</td>
<td>New College of Florida</td>
<td>Campus-wide email list, Spring 2014</td>
<td>NC         SP14</td>
<td>49/800</td>
</tr>
<tr>
<td></td>
<td>State College of Florida</td>
<td>Intro to environmental science, Fall 2014</td>
<td>SCF        PLUTA</td>
<td>9/23</td>
</tr>
<tr>
<td></td>
<td>University of South Florida</td>
<td>Environmental Science, Summer 2014</td>
<td>USF        SU14</td>
<td>30/51</td>
</tr>
<tr>
<td></td>
<td>Sarasota-Manatee</td>
<td>Environmental Ethics &amp; Environmental Science, Fall 2014</td>
<td>USF        FA14</td>
<td>53/85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TOTAL</td>
<td>298/1231*</td>
<td></td>
</tr>
</tbody>
</table>

*Overall response rate was 24.2%. Excluding New College students, it was 57.8%.
The survey was administered from late spring to early fall of 2014, and remained open for approximately two weeks for students in each course/institution. The invitation email that respondents received from their instructors contained a brief description of the survey and a link to participate. These survey links contained the group codes shown in Table 3.2, enabling responses to be tied to a specific group and, in most cases, instructor. Access to the survey was not possible without a valid group code. To consent to participating in the survey, respondents were required to enter their full name on the consent form. After the survey closed for a given group, these names were sent to the instructors so that they could award extra credit and verify that the respondents in question were students from their courses/institutions.

3.4.3 General sample characteristics

From 571 initial responses, 273 were eliminated because they were: entirely blank (241 responses); an earlier, incomplete response from a respondent who had not yet seen the sea level rise map but later completed the survey (26 responses); or a second response from a respondent who had already seen the sea level rise map (6 responses). (I eliminated responses based on exposure to the sea level rise map because I expected such exposure to affect respondents’ risk perceptions for sea level rise in Sarasota, and wished to evaluate respondents’ risk perceptions pre-map.) This left 298 valid responses (a 24.2% response rate). Of these, 157 were from Penn State students and 141 were from Sarasota-area students. More of these students identified as female (131), than as male (115) or other (2); however, 50 students (16.8%) did not indicate their gender, either because they skipped the question (2) or because they did not complete part 3 of the survey (48).
Compared to Penn State respondents, Sarasota respondents were more likely to be female and were also more age-diverse (Table 3.3). Among Sarasota respondents who indicated their gender, nearly twice as many identified as female than as male; in contrast, more Penn State respondents identified as male than as female. For age, only one Penn State respondent was 25 or older, while 28.3% of Sarasota respondents indicated that they were this old. As expected, Sarasota respondents were much more likely than Penn State respondents to indicate that they had lived in or visited Sarasota (88.7% versus 7.6%), or lived within 10 miles of the ocean (72.5% versus 9.2%). Compared to Penn State students, Sarasota students were also more likely (24.1% versus 8.9%) to drop out before completing part 3 of the survey.

Compared to a Six Americas segmentation analysis conducted for the U.S. in October, 2014 (Roser-Renouf et al. 2014), student respondents were more likely to be Alarmed about climate change, and less likely to be Doubtful; no respondents identified as Dismissive (Figure 3.1). The lack of Dismissive respondents may be due in part to the tendency toward greater environmental concern among younger individuals (see review from Fransson and Garling 1999). Selection bias may have also played a role: students who are Doubtful or Dismissive may have been less interested than other students in participating in the survey, or may not have enrolled in the earth and environmental science courses from which I recruited. I group the small number of Doubtful respondents with the Cautious for analysis. This combination is theoretically justified because both groups are uncertain about both whether climate change is happening and the urgency with which we should respond to it.
Table 3.3: Gender and age of survey respondents by location

<table>
<thead>
<tr>
<th>Demographic variable</th>
<th>Sarasota students (n=141)</th>
<th>Penn State students (n=157)</th>
<th>Overall (n=298)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>50.4% (71)</td>
<td>38.2% (60)</td>
<td>44.0% (131)</td>
</tr>
<tr>
<td>Male</td>
<td>24.1% (34)</td>
<td>51.6% (81)</td>
<td>38.6% (115)</td>
</tr>
<tr>
<td>Other</td>
<td>1.4% (2)</td>
<td>-</td>
<td>0.7% (2)</td>
</tr>
<tr>
<td>NA</td>
<td>24.1% (34)</td>
<td>10.2% (16)</td>
<td>16.8% (50)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-24</td>
<td>47.5% (67)</td>
<td>89.8% (141)</td>
<td>69.8% (208)</td>
</tr>
<tr>
<td>25-34</td>
<td>16.3% (23)</td>
<td>0.6% (1)</td>
<td>8.1% (24)</td>
</tr>
<tr>
<td>35-54</td>
<td>11.3% (16)</td>
<td>-</td>
<td>5.4% (16)</td>
</tr>
<tr>
<td>55+</td>
<td>0.7% (1)</td>
<td>-</td>
<td>0.3% (1)</td>
</tr>
<tr>
<td>NA</td>
<td>24.1% (34)</td>
<td>9.6% (15)</td>
<td>16.4% (49)</td>
</tr>
</tbody>
</table>

Figure 3.1: Percentage of survey respondents in each Six Americas segment, compared to representative U.S. sample from October, 2014 (Roser-Renouf et al. 2014)
Comparing the Six Americas segments of respondents by location, Sarasota respondents were more likely to be Alarmed, while Penn State respondents were more likely to be Cautious or Disengaged. Because Sarasota respondents were predominately female, their tendency towards greater concern about climate change is consistent with studies showing greater concern about climate change among both women (Maibach et al. 2009) and U.S. residents living close to the ocean (Brody et al. 2008).

Although the distribution of respondents across Six Americas groups was different from that observed for the U.S. as a whole, many characteristics of student respondents within each segment were consistent with those observed for the national sample. Consistent with the finding that, nationally, the Alarmed are more likely to be women (Maibach et al. 2009, Roser-Renouf et al. 2014), 70.1% of the Alarmed respondents identified as female, compared to 45% for all other respondents and 39.1% for Cautious and Doubtful respondents (percentages are among respondents who selected a gender from choices of male, female, or other). The worldviews of students (measured using 6-item scales from Kahan 2012, with Cronbach's alpha values near 0.7 for my student sample) were also consistent with their chosen Six Americas group. In line with the tendency of the Alarmed to hold stronger egalitarian values than other segments (Maibach et al. 2009), 45.5% of the Alarmed students fell in the highest quartile for a measure of egalitarian beliefs, compared to 19.3% of all other respondents and 14.5% of the Cautious and Doubtful. Similarly, consistent with the tendency of less concerned segments to hold individualistic values (Maibach et al. 2009), 40% of the Cautious and Doubtful fell in the highest quartile for a measure of individualistic beliefs, compared to 17.5% of all other respondents and 13.5% of the Alarmed.
3.5 Results

To evaluate the possible effects of specificity of risk framing and spatial optimism bias, risk perceptions were compared across the three frames (climate change, sea level rise, and sea level rise in Sarasota) for students both nearby (Sarasota-area students) and far away from (Penn State students) the Sarasota area. I first consider differences in risk perceptions across frames for all students. Next, I evaluate differences in overall levels of perceived risk for students of different distances, climate change beliefs (based on the Six Americas segmentation), and genders. Finally, I consider whether the direction of change in risk perceptions with the move to the Sarasota frame depends on student distance, climate change belief, or gender.

In each case, I begin with nonparametric methods appropriate to the ordinal measure of students’ risk perceptions. These nonparametric methods are used here and in subsequent chapters because responses to the risk perception items in the survey are not continuous, are not assumed to fall on an equal interval scale, and are non-normal (left-skewed) due to the generally high risk perceptions among respondents. Bonferroni-corrected p-values are used to correct for the family-wise error rate within each set of comparisons for these non-parametric tests. However, the non-parametric tests are unable to address possible confounds among between-subject variables. I therefore supplement the non-parametric tests in this chapter and Chapter 4 with mixed ANOVA analyses that

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2 Because my hypotheses are for the effects of female gender, I compare respondents who identified as female to respondents who identified as not female, i.e., male or other. Notably, 50 respondents did not indicate a gender and are not included in this portion of the analysis; nearly all of these omissions were from respondents who had dropped out of the survey before they were asked to identify their gender. Missing values are discussed in more detail in Chapter 5.
make more assumptions about the data but are able to consider the simultaneous effects of several between-subjects variables (e.g., evaluating the effect of audience distance given simultaneous variation in Six Americas group and gender). In Chapter 5, I introduce a non-parametric method that is also able to account for these possible confounds.

3.5.1 Effect of specificity of climate-impact stimulus on risk perceptions

As the specificity of the climate-impact stimulus increased (from climate change, to sea level rise, to sea level rise in Sarasota), respondents generally decreased their risk perceptions (Figures 3.2 and 3.3). Results from a Friedman test – a non-parametric equivalent of repeated measures analysis of variance that is based on the comparison of ranks and is therefore suitable for ordinal data (Sheldon et al. 1996) – identified a significant difference in risk perceptions across climate-impact stimuli (n=293, Chi-Square=24.897, df=2, p<0.001). Post-hoc sign tests at the two change points suggest that much of this difference is due to the significantly higher likelihood of decreased (rather than increased) risk perceptions following the move to the Sarasota-specific frame (n=293, Bonferroni-corrected p=0.002). The sign test for the change from climate change to sea level rise frames was not significant (n=293, Bonferroni-corrected p=0.478). I use sign tests rather than paired-sample t-tests because, consistent with the ordinal nature of the risk perception variables, sign tests compare the direction, but not the magnitude, of change from frame to frame (Dixon and Mood 1946).

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3 Note that responses in Figures 3.2 and 3.4-3.6 are centered on the overall median value of 7 so that instances where stimuli or audience groups are associated with deviations from the median are more apparent.
Figure 3.2: Students’ risk perceptions across climate change stimuli, with percentages below (tan), equal to (gray), and above (green) overall median (7)

Figure 3.3: Direction of change in students’ risk perceptions across climate change stimuli, with percentages in each category.
Sign test for change in risk perceptions: ** Bonferroni-corrected p<0.01
3.5.2 Effect of distance and other audience characteristics on overall risk perceptions

Across all three frames, risk perceptions were higher for: nearby students (Figure 3.4); students who identified as Alarmed or Concerned about climate change (Figure 3.5); and students who identified as female (Figure 3.6). Comparison of the median risk scores across frames by location, Six Americas segment, and gender (female compared with not female, including male and other) confirm that there were significant differences (Bonferroni-corrected p<0.003) in risk perceptions among respondents in different categories for each of these variables (Table 3.4). To test for differences in distribution of median risk scores between categories of distance and gender, I used Mann-Whitney U tests, which are appropriate for comparing ordinal scores between two independently sampled groups, and make no assumption about the shape of their statistical distribution (McKnight and Najab 2010). For comparing distributions within my four-category, condensed Six Americas variable, I used Kruskal-Wallis one-way analysis of variance, an extension of Mann-Whitney U to variables with more than two categories that is similarly appropriate for ordinal data (Feir-Walsh and Toothaker 1974).

3.5.3 Effect of distance and audience characteristics on change in risk perceptions

To test whether distance, Six Americas segment, or female gender were related to the significant change in risk perceptions observed between the frame for sea level rise in general and the frame for sea level rise in Sarasota, I conducted Chi-Square tests of independence (Pearson 1900). These tests considered whether, when the direction of the change in risk perceptions (decrease, no change, increase) was crossed with each of these
**Figure 3.4:** Students’ risk perceptions across climate change stimuli by distance, with percentages below (tan), equal to (gray), and above (green) overall median (7)

**Figure 3.5:** Students’ risk perceptions across climate change stimuli by Six Americas group, with percentages below, equal to, and above overall median (7)
**Figure 3.6:** Students' risk perceptions across climate change stimuli by gender, with percentages below (tan), equal to (gray), and above (green) overall median (7).

**Table 3.4:** Tests for differences in distributions of global median risk scores within categories for distance, gender, and Six Americas segment, with values for first through third quartiles.

**Distance**

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Q₁</th>
<th>Q₂</th>
<th>Q₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near</td>
<td>140</td>
<td>6</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Far</td>
<td>153</td>
<td>5</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Mann-Whitney U=7340, Bonferroni-corrected p<0.003

**Gender**

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Q₁</th>
<th>Q₂</th>
<th>Q₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>130</td>
<td>6</td>
<td>7.5</td>
<td>9</td>
</tr>
<tr>
<td>Not female (male/other)</td>
<td>113</td>
<td>5</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

Mann-Whitney U=5231.5, Bonferroni-corrected p<0.003

**Six Americas segment**

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Q₁</th>
<th>Q₂</th>
<th>Q₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarmed</td>
<td>97</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Concerned</td>
<td>98</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Cautious/Doubtful</td>
<td>78</td>
<td>4</td>
<td>5</td>
<td>6.25</td>
</tr>
<tr>
<td>Disengaged</td>
<td>17</td>
<td>4</td>
<td>5</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Kruskal-Wallis Chi-Square=53.890, df=3, Bonferroni-corrected p<0.003
three variables, the resulting cell counts were different from those expected by chance. For distance, results suggested that there may be a weak relationship but were not conclusive.

Results (n=293, Chi-Square=6.145, df=2, p=0.046) initially showed that the null hypothesis of independence should be rejected; however, once Bonferroni corrected for the three Chi-Square tests performed in this family of hypotheses, this result was no longer significant (p=0.138). Inspection of a plot of the direction of change in risk perceptions by student distance (Figure 3.7) indicated that any difference in change in risk perceptions with distance would likely be due to the tendency of Sarasota students to decrease or not change their risk perceptions more frequently (79%) than Penn State students (66%). Post-hoc sign tests did show a significant (n=140, Bonferroni-corrected p<0.002) difference between the number of Sarasota students who decreased their risk perceptions (66) and the number of Sarasota students who increased their risk perceptions (44); a sign test comparing increases and decreases for Penn State students was not significant (n=153, Bonferroni-corrected p=0.534).

For Six Americas segments, the presence of two cells with counts less than 5 required the use of Fisher’s Exact test in place of the Chi-Square test for independence (Fisher 1922). Results initially showed some evidence for rejecting the null hypothesis (n=290, Fisher's Exact test=10.827, p=0.090), but were clearly beyond significance once Bonferroni corrected (p=0.270). Sign tests and plots (Figure 3.8) showed that if there were a significant difference in change in risk perceptions with Six Americas segment, it would likely be among the Alarmed (n=97, Bonferroni-corrected p=0.112) or Concerned (n=98, p=0.028), both of which were more likely to show a decrease than an increase in risk perceptions. Results did not permit rejection of the null hypothesis of independence for
**Figure 3.7:** Direction of change in students’ risk perceptions across climate change stimuli by student distance, with percentages in each category. Sign test for change in risk perceptions: ** Bonferroni-corrected p<0.01

**Figure 3.8:** Direction of change in students’ risk perceptions across climate change stimuli by Six Americas group, with percentages in each category. Sign test for change in risk perceptions: * Bonferroni-corrected p<0.05
female versus non-female gender (n=243, Chi-Square = 3.974, df=2, Bonferroni-corrected p=0.411).

3.5.4 Mixed ANOVA considering simultaneous effects of distance and audience characteristics across risk perception frames

To complement these non-parametric analyses and address the possibility of confounding factors, I also conducted a mixed ANOVA analysis considering variation in risk perceptions by audience distance, Six Americas group, and gender (between-subjects factors) and across three levels of frame specificity (within-subject factors). Between-subject results were generally consistent with the non-parametric results presented above. Six Americas group was the strongest predictor of overall risk perceptions (F(3, 235)=44.255, p<0.001). The effects of distance (F(1, 235)=2.530, p=0.113) and female gender (F(1, 235)=0.750,p=0.387) were weaker than reported in the non-parametric results, likely because these variables are partially confounded with Six Americas group in my sample. For within-subject factors, I found that, when holding constant the effects of the between-subject factors, risk perceptions did not vary significantly with specificity (Greenhouse-Geisser sphericity-adjusted F(1.754, 4.12.103)=2.381, p=0.101). However, the interaction of specificity with Six Americas group did have a significant effect on risk perceptions (Greenhouse-Geisser sphericity-adjusted F(5.261, 4.12.103)=2.765, p=0.016). This is consistent with my earlier finding that the Concerned and possibly the Alarmed Six Americas groups were more likely than other Six Americas groups to decrease their risk perceptions when moving to the most specific frame (Sarasota-area sea level rise). Interactions between specificity and student distance (Greenhouse-Geisser sphericity-
adjusted $F(1.754, 4.12.103)=0.934$, p=0.383) and female gender (Greenhouse-Geisser sphericity-adjusted $F(1.754, 4.12.103)=2.245$, p=0.114) were not significant.

### 3.6 Discussion

Support for my hypotheses was mixed. In line with my predictions for specificity and distance, I found that risk perceptions for frames that were more specific or for students that were farther from the hazard were generally lower than those for less specific frames or nearby students. Variation in results for the shift to the most specific frame (Sarasota sea level rise) by student distance was consistent with spatial optimism, with students from nearby the sea level rise hazard more likely than distant students to decrease their risk perceptions when shifting to this local frame. Notably, while students from both distances decreased their risk perceptions at this change point – suggesting that specificity may affect risk perceptions independent of distance – students were only significantly more likely to decrease than increase their risk perceptions if they were also from nearby the hazard. However, ANOVA results suggest that this increased likelihood of decreased risk perceptions among nearby students can mostly be explained by the confounding effects of their higher levels of concern about climate change in general (as measured by their Six Americas group).

Additional studies are needed to explore whether distance acts with specificity to decrease risk perceptions for nearby climate hazards, or whether the effects of distance are largely explained by confounding variation in climate change beliefs, as in this study. To the extent that distance does effect risk perceptions, construal level theory suggests a likely story for response patterns. The high-specificity frame may prompt students to translate
their high-level, abstract models of sea level rise risk into a concrete and detailed, place-based account of local sea level rise risk. For students far away from and unfamiliar with this place, the specificity of the frame prompts recognition that concrete details are required to perform this translation; since distant students lack the details needed to assemble this account, they cannot confidently apply their less specific, global sense of sea level rise risk in this frame. Distant students’ raw scores for Sarasota risk (Figure 3.4) support this, as they selected the middle risk category (5) for Sarasota risk more frequently than did students for any other distance-specificity combination, suggesting that they may have been satisficing when answering this question. Nearby students would likewise be expected to look for concrete specific details to assemble an account of Sarasota risk. However, instead of finding none, they may find reasons why the specifics of the nearby place do not match their global image of what makes a place vulnerable to sea level rise; because they know and value this nearby place, self- and place-serving biases may motivate this selection process. Additional research is needed to confirm the details of this “likely story,” particularly given the confounding effect of climate change beliefs (as assessed using Six Americas groups).

My hypotheses for the effects of other audience characteristics were supported. For gender, women had higher risk perceptions than men; however, their change in risk perceptions with the introduction of the Sarasota frame did not significantly differ from that of other genders. Risk perceptions were also in line with my hypotheses for respondents’ Six Americas segments, with higher risk perceptions among the Alarmed and Concerned, and lower risk perceptions among the Cautious and Doubtful. As expected, risk perceptions for the Disengaged fell near the middle of the scale (median value of 5 across
risk frames, Table 3.4) and were less likely than those of other respondents to increase or decrease with a shift in framing (Figure 3.8). The results also support (but do not confirm) my hypotheses regarding the effect of Six Americas segments on change in risk perceptions. Although my non-parametric analysis showed that the relationship between Six Americas segments and shift in risk perceptions with the introduction of the Sarasota frame was not significant once Bonferroni corrected, the Concerned were significantly more likely to decrease than increase their risk perceptions with this shift (and the Alarmed approached significance at the 0.1 level), while changes in risk perceptions for other segments were not significant. This result is also consistent with the ANOVA results, which showed evidence for a significant interaction between specificity and Six Americas group. Some of this decrease in risk perceptions among the Alarmed and Concerned may be attributable to the higher baseline risk scores for these segments, which may have made a decrease in scores more likely. Consistent with self- and place-serving biases, these most concerned groups may also have been most motivated to find reasons why local sea level rise will not be as bad as sea level rise in general.

3.7 Limitations and conclusions

Several limitations of this study should be considered when interpreting its results. Comparisons between nearby and far away students based on student distance will only hold to the extent to which differences in risk perceptions between these groups are due to this difference in distance and not differences on another confounding factor. One such factor in this study could be age: while, as expected, students from both distances were most likely to fall in the 18-24 age group, students from the Sarasota area were somewhat
older and more age-diverse. Because of the low variation in age among Penn State students, I was not able to control for possible age effects in this study. It is also not certain that the results obtained for this student sample would generalize to other populations, such as U.S. residents as a whole, particularly since this study only tested risk perceptions for one specific place (Sarasota) and type of climate change hazard (sea level rise). However, the fact that the results were consistent with both theory and results from previous studies increases confidence that they may hold more generally. Additional research should test this by extending the methods used here to new audiences and places. Future research could also consider the extent to which spatial optimism bias is evident at regional as well as local scales by evaluating risk perceptions for sea level rise at multiple distances and levels of specificity.

Despite these limitations, this study offers important lessons for communicating climate change. Consistent with existing literature on spatial optimism bias, my results suggest that merely framing climate change as “local” may not increase engagement with the issue. For audiences nearby such a local framing, it is likely that even (or perhaps especially) those who are very concerned about climate change in general will deploy motivated reasoning to establish why these concerns are not as applicable to themselves and their local communities. And, for distant audiences that know little about the chosen place, the local framing may be too specific for audience members to apply their general understanding of climate change risk.

This suggests that passing mentions of climate impacts in local places – whether nearby or distant – are unlikely to be engaging for many audiences. However, in real-world climate change communication, descriptions of local impacts are rarely limited to such
passing mentions, but are instead imbued with concrete details and social context. In the study described here, the effects of framing were evaluated without providing any such concrete information about possible climate change or sea level rise impacts. This was done so that results can be compared with those from public opinion surveys asking respondents to rate their concern about climate change at different spatial levels. A second portion of this study, described in Chapter 5, considers how concrete information about sea level rise impacts (using an interactive map) may affect risk perceptions, providing more applied guidance for climate change communicators.
Chapter IV

DO CLIMATE CHANGE BELIEFS BIAS INTERPRETATION OF INFORMATION FROM SEA LEVEL RISE MAPS? A STUDY OF THE EFFECTS OF MOTIVATED REASONING ON MAP-READING TASKS

4.1 Introduction

Maps of sea level rise may be one of the more popular (Preston et al. 2011, Roth et al. 2015) and powerful (Monmonier 2008) ways to communicate climate change to the public. By showing tangible impacts of global climate change at the local level, these maps may help to reduce the tendency to view climate change as spatially, temporally, or socially remote (Nicholson-Cole 2005, Leiserowitz 2007, Lorenzoni et al. 2007). Many of these maps are also interactive (see review from Roth et al. 2015), enabling users to customize the map to suit their needs and interests, potentially facilitating engagement (Bostrom et al. 2008). Importantly, authors have found that flood information like that shown on these maps may be particularly effective in reaching audiences that are doubtful about global climate change, but are nonetheless concerned about changes in flooding in their local communities (Kahan et al. 2013, Bruin et al. 2014). Taken together, this evidence suggests that sea level rise maps should be one of the preferred strategies for communicating the risks of climate change to the public.

However, as discussed in Chapter 2, there are many unanswered questions about how different audiences understand the information on these maps. In particular, because the information presented on these maps is uncertain in at least three ways – in amount,
timing, and spatial extent – communicators may benefit from understanding how 
audiences with different opinions about climate change interpret these uncertainties. 
While communicators may hope that audiences will adopt the precautionary principle by 
considering the high end of possible impacts under these uncertainties (Oppenheimer et al. 
2007, Nicholls and Cazenave 2010, Brysse et al. 2013), evidence suggests that some 
audiences may instead use motivated reasoning to interpret them in line with existing 
beliefs (e.g., Kuhn 2000, Whitmarsh 2011). Thus, instead of using the maps to inform their 
beliefs and behavior, audiences who are doubtful about climate change may use the 
uncertainties on the map to justify downplaying the possible impacts of sea level rise.

To explore these issues, this study presents results from a survey designed to assess 
how respondents with different opinions about climate change understand and interact 
with a map of sea level rise in Sarasota, Florida. I begin with a brief review of the literature 
on how motivated reasoning may affect the interpretation of uncertain climate change 
information such as that presented on the sea level rise map. I then introduce research 
questions and summarize the map design and survey methods used to carry out this study, 
present my results, and reflect on their implications for the design and dissemination of sea 
level rise maps as a climate change communication tool.

4.2 Literature review: motivated reasoning and climate change 
communication

Kunda (1990, 480) defines motivated reasoning as the selection of cognitive 
strategies for “accessing, constructing, and evaluating beliefs” based on their ability to yield 
outcomes that are consistent with pre-existing motives or goals. Several studies have
suggested that such motivated reasoning may shape the interpretation of climate change information for many audiences – particularly for those with strongly held beliefs about the topic. Consistent with results that have shown that opinions about climate change are closely tied to broader worldviews and political party identification (e.g., Bliuc et al. 2015, Dunlap and McCright 2008), Whitmarsh (2011), found that climate skepticism between 2003 and 2008 in the UK was most strongly associated with political orientation and environmental values. She also found that, despite increasingly certain scientific and media messages about climate change and its risks over this period, skepticism remained nearly unchanged; to explain this contradiction, she suggests that individuals may demonstrate motivated reasoning and assimilation bias (Lord et al. 1979) by selectively filtering and interpreting these messages to support their existing views (Whitmarsh 2011). Studies by Dan Kahan and his colleagues support this conclusion, finding that individuals generally form and maintain beliefs about climate change risk based on their values and worldviews (Kahan et al. 2011), and use their capacity for technical and scientific reasoning to interpret information about climate change in ways that are consistent with these cultural commitments (Kahan et al. 2012). In a survey designed to assess how U.S. residents’ perceived experience of climate change related to their belief in its certainty, Myers et al. (2013) add nuance to this account, finding that while motivated reasoning shaped how those who were already alarmed or dismissive interpreted climate experience, less engaged audiences showed evidence of adjusting their existing beliefs based on “experiential learning.” Finally, messages about climate change may not only fail to reach individuals with more extreme political views, but can also cause what Hart and Nisbet (2011) call a “boomerang effect”: in their study, Republicans who were exposed to
simulated news stories about health impacts were significantly less supportive of climate mitigation policies than a control that saw no message.

Additional research suggests that motivated reasoning about climate change messages may be particularly likely when the messages are uncertain or when audiences are not strongly motivated to understand them accurately. For uncertainty, Kuhn (2000) found that when an environmental hazard was described using a range of probabilities, prior environmental attitudes determined whether risk perceptions skewed towards the top or bottom of the range; this effect increased when the high and low ends of the range were associated with sources with a known bias. For the effects of accuracy goals, Kunda (1990) reviewed a number of studies showing that when participants were more motivated to be more accurate – generally by increasing the stakes of being wrong – their information processing demonstrated fewer cognitive shortcuts and biases. This is consistent with the suggestions of Kahan et al. (2013) for reducing motivated reasoning: focus messages on local adaptation to climate hazards – such as sea level rise – where the clear and tangible consequences of getting the science wrong raise the stakes high enough to overcome political commitments and motivate informed communal action to protect lives and property.

The distance of audiences from climate change impacts may also affect their level of motivated reasoning. Messages that present climate impacts on spatially and socially distant people may encourage motivated reasoning about adaptive or mitigative action: for example, Hart and Nisbet (2011) found that Republicans had significantly lower support for climate mitigation policies after viewing messages showing impacts in distant countries than after viewing messages showing identical impacts on compatriots, whereas
Democrats saw no significant difference in support for nearby and distant frames. However, consistent with spatial optimism bias, messages depicting nearby climate impacts may trigger self- and place-protective motivated reasoning about the severity of these local impacts. Thus, Schultz et al. (2014) found that individuals from many different countries expected environmental problems to be worse in other countries than in their own, an effect the authors associated with higher self regard and pride of place among some study participants. Spence and Pidgeon (2010) showed that varying the distance of a message about climate change flood impacts had both of these expected effects: impacts in the distant frame were expected to be more severe, but the local frame produced more positive attitudes towards climate change mitigation. These authors did not consider how individual differences in opinions about climate change and associated motivated reasoning may have affected their results.

4.3 Research questions and hypotheses

The literature cited above suggests that audiences with strong pre-existing beliefs about climate change may engage in motivated reasoning when processing information about sea level rise flooding on interactive maps. To explore whether such motivated reasoning does take place and to assess the role of other factors that may affect map reading accuracy, I use an online survey of college and university students to address the following questions:

• Does motivated reasoning based on prior beliefs about climate change affect the interpretation of flood depth and probability information on sea level rise maps?
• Does motivated reasoning based on distance from the sea level rise hazard affect the interpretation of flood depth and probability information on sea level rise maps?
• How does motivated reasoning vary with map task and associated uncertainty types?
• Beyond motivated reasoning, do respondents’ subjective numeracy, map ability, and task-relevant map interactions correlate with their accuracy on map reading tasks?

Below, I briefly discuss the research design and hypotheses for each research question.

**Does motivated reasoning based on prior beliefs about climate change affect the interpretation of sea level rise maps?** To consider how survey respondents’ existing beliefs about climate change would affect their understanding of information on sea level rise maps, I first had respondents self-identify with one of the groups in Global Warming’s Six Americas – an audience segmentation analysis of a representative sample of U.S. residents based on their climate change beliefs and related demographic characteristics (Maibach et al. 2009). As described in more detail in Chapter 3, these six groups are the Alarmed, Concerned, Cautious, Doubtful, Dismissive, and Disengaged. I then asked respondents to use an interactive sea level rise map to select the amount of sea level rise they expected by a given year (2050 or 2100). Making a selection updated the map of sea level rise flooding, which respondents then used to estimate the resulting flood depth and probability in one of four randomly assigned areas. In addition to presenting the expected depth of sea level rise flooding for the selected sea level rise amount, the map also showed information about associated temporal, attribute, and spatial uncertainty.

Given the many studies suggesting that those with strong opinions about climate change will interpret climate change messages in line with those beliefs – particularly when
the messages themselves are uncertain – I expect to find that respondents who feel most strongly about climate change (e.g., the Alarmed or Dismissive) will show evidence of motivated reasoning. Specifically, in both their selection of an expected amount of sea level rise and their map reading tasks, I expect those with greater concern about climate change to choose higher values (more sea level rise, higher flood depth and probability) compared to those who are less concerned about sea level rise. Moreover, I expect those respondents with more extreme beliefs to deviate further from the suggested “most likely” sea level rise amounts, and to be less accurate (more biased) in their estimates of flood depth and probability.

**Does motivated reasoning based on distance from the sea level rise hazard affect the interpretation of sea level rise maps?** To evaluate the effect of distance from the chosen sea level rise location (Sarasota, Florida) on motivated reasoning, I surveyed students from colleges and universities in Sarasota (near the map location) and from The Pennsylvania State University (far from the map location). Because this study measures respondents’ assessments of the magnitude or severity of sea level rise impacts (rather than their support for mitigation or adaptation measures), I expect to find that – consistent with spatial optimism bias – distant students will select higher sea level rise amounts, flood depths, and flood probabilities than nearby students.

**How does motivated reasoning vary with map task and associated uncertainty types?** My design permits exploration of how different components of uncertainty – attribute, temporal, or spatial – in a message may combine with map tasks to affect motivated reasoning. As described in the map design section below, the slider that respondents used to select an amount of sea level rise communicates temporal and
attribute uncertainty, while the flood probability estimation task involves using a spatial
uncertainty overlay. Accordingly, by considering whether motivated reasoning is observed
more frequently in the slider selection (attribute and temporal uncertainty) or probability
estimation (spatial uncertainty) tasks, I hope to gain insight into which of these task and
uncertainty combinations is most strongly associated with motivated reasoning.

Do respondents’ subjective numeracy, map ability, and map interactions
correlate with their accuracy on map reading tasks? While respondents’ Six Americas
group or distance from the map location may lead to motivated reasoning and biased flood
estimates, several other factors may influence the magnitude but not direction of errors in
these estimates. In this study I consider several such factors, including subjective numeracy
(Fagerlin et al. 2007), map reading ability and enjoyment (Thorndyke and Goldin 1981),
number of interactions with interface elements relevant to the map estimation tasks (i.e.,
the slider for selecting sea level rise amounts and the buttons for switching between both
flood depth and probability views and scenarios for different years), and total amount of
time spent on the survey page containing the map estimation tasks. In line with Severtson
and Myers (2012), I expect higher numeracy to be associated with more accurate map
reading. I also expect respondents who are more competent and comfortable with maps in
general and who spend more time interacting with the map or perform more task-relevant
interactions to have higher accuracy.

4.4 Methods

To test these research questions, I developed an interactive map of sea level rise in
the Sarasota area and used a survey to compare performance on map reading tasks across
respondents with different views about climate change, distances from Sarasota, and levels of ability with maps and math. The next sections describe the map design and survey structure and implementation in more detail.

4.4.1 Map design

The design of my map was based on that of the NOAA Sea Level Rise Viewer (see description from Chapter 2). Like the NOAA Viewer, my map includes a slider to select a sea level rise amount; moving the slider updates the map to show the corresponding amount of sea level rise flooding. Also like the NOAA Viewer, my map contains views to show this flooding in terms of either its depth or its probability (Figure 4.1). The probability views on both my map and the NOAA Viewer depict the spatial uncertainty in the extent of inundation for the selected sea level rise amount. More specifically, they show the probability of inundation at high tide (mean higher high water) given the selected amount of sea level rise and the combined uncertainties in the digital elevation model and tidal datum (NOAA CSC 2010).

However, my design differs from the NOAA Viewer in its presentation of uncertainty. In addition to the two spatial uncertainty categories on the NOAA Viewer (flood probabilities of >80% and 50-80%), I show two categories of lower flood probability (20-50% and 5-20%); these were added to balance the high probability categories and to make the probability estimation task more challenging for respondents. My map also displays information about the uncertainties in the magnitude and timing of sea level rise that are not included in the NOAA Viewer. I designed the map to communicate attribute and
Figure 4.1: Interactive map of sea level rise flooding, showing depth (A) and probability (B) views for Sarasota, Florida
temporal uncertainty so that I could consider how these uncertainty components (Kostelnick et al. 2013) affect respondents’ selection of sea level rise amounts. Because it is not yet possible to assign probabilities to sea level rise amounts for a given date, I developed sea level rise scenarios using a risk-based approach (Hinkel et al. 2015). Using this approach, I identified likely scenarios based on IPCC process-model projections (Stocker et al. 2013) but also included a broader range of physically possible scenarios derived from semi-empirical models (e.g., Parris et al. 2012, Rahmstorf et al. 2012). Because rates of sea level rise in Sarasota have been similar to those observed globally (Merrifield et al. 2009), these scenarios are based on a combination of regional (e.g., Beever III et al. 2009) and global (e.g., Stocker et al. 2013) projections.

To communicate these likely and possible sea level rise scenarios, my map adds annotations to the slider for selecting a sea level rise amount (Figure 4.2). Clicking on the buttons for the years 2050 or 2100 updates these likely and possible scenarios for the chosen year and also moves the slider to a suggested sea level rise amount: for 2050, 1 foot; and for 2100, 3 feet. I hoped that respondents would start with these suggested amounts for each year and then adjust the slider position within the likely and possible ranges to suit their beliefs about how much sea level rise would occur by the selected date. When respondents first viewed the map, it was set to show scenarios for 2100, with the slider in the 3-foot position (Figure 4.2 B).
Figure 4.2: Up-close view of slider tool, showing likely and possible ranges and default slider positions for 2050 (A) and 2100 (B)

To accommodate the map reading tasks that respondents’ performed as part of the survey, my map also added several other elements not found on the NOAA Viewer. Unlike the single default view of the NOAA Viewer, my map randomly assigned respondents to one of four Sarasota-area map locations: Dolphin Fountain (a landmark in a popular bay-side park near downtown), Siesta Beach (a heavily touristed white sand beach on a barrier island), St. Armand’s Circle (an upscale shopping and recreation area on a barrier island), and Tamiami Trail (a heavily trafficked road in downtown). Multiple locations were used to ensure that respondents’ accuracy on map reading tasks was not an artifact of a particular map location or place type. To familiarize respondents with their assigned map location, a popup showing a brief description of the place and a Google Street View window opened automatically when respondents first viewed the map. A bold, white outline was added to the map to demarcate the boundary of the assigned location for the depth and probability estimation tasks (Figure 4.3). These boundaries were also used to calculate mean flood depths and median probability categories for each combination of map location and sea level rise amount (Table 4.1). These values were compared with respondents’ estimates for average depth and probability to determine the estimates’ error.
Figure 4.3: Example of map for flood depth and probability estimation task
Table 4.1: Table of average flood depths and probabilities for all possible combinations of assigned map location and sea level rise amount

<table>
<thead>
<tr>
<th>Selected sea level rise amount</th>
<th>0 ft</th>
<th>1 ft</th>
<th>2 ft</th>
<th>3 ft</th>
<th>4 ft</th>
<th>5 ft</th>
<th>6 ft</th>
<th>7 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assigned map</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dolphin</strong></td>
<td>0 ft</td>
<td>0-1 ft</td>
<td>0-1 ft</td>
<td>1-2 ft</td>
<td>2-3 ft</td>
<td>3-4 ft</td>
<td>4-5 ft</td>
<td>5-6 ft</td>
</tr>
<tr>
<td><strong>Siesta</strong></td>
<td>0 ft</td>
<td>0-1 ft</td>
<td>0-1 ft</td>
<td>0-1 ft</td>
<td>1-2 ft</td>
<td>2-3 ft</td>
<td>3-4 ft</td>
<td>4-5 ft</td>
</tr>
<tr>
<td><strong>St. Armand’s</strong></td>
<td>0 ft</td>
<td>0 ft</td>
<td>0-1 ft</td>
<td>1-2 ft</td>
<td>2-3 ft</td>
<td>3-4 ft</td>
<td>4-5 ft</td>
<td>5-6 ft</td>
</tr>
<tr>
<td><strong>Tamiami</strong></td>
<td>0 ft</td>
<td>0 ft</td>
<td>0-1 ft</td>
<td>0-1 ft</td>
<td>1-2 ft</td>
<td>2-3 ft</td>
<td>3-4 ft</td>
<td>4-5 ft</td>
</tr>
</tbody>
</table>

Mean depth

| **Assigned map**              |      |      |      |      |      |      |      |      |
| **Dolphin**                   | Very low | Low | High | Very high | Very high | Very high | Very high | Very high |
| **Siesta**                    | Very low | Very low | Moderate | High | Very high | Very high | Very high | Very high |
| **St. Armand’s**              | Very low | Low | High | Very high | Very high | Very high | Very high | Very high |
| **Tamiami**                   | Very low | Very low | Moderate | Very high | Very high | Very high | Very high | Very high |

Median probability

| **Assigned map**              |      |      |      |      |      |      |      |      |
| **Dolphin**                   | Very low | Low | High | Very high | Very high | Very high | Very high | Very high |
| **Siesta**                    | Very low | Very low | Moderate | High | Very high | Very high | Very high | Very high |
| **St. Armand’s**              | Very low | Low | High | Very high | Very high | Very high | Very high | Very high |
| **Tamiami**                   | Very low | Very low | Moderate | Very high | Very high | Very high | Very high | Very high |

Very low: <5% chance; Low: 5-20% chance; Moderate: 20-50% chance; High: 50-80% chance; Very high: >80% chance

4.4.2 Survey structure

The survey contained 53-55 questions and took approximately a half hour to complete; for a copy of the survey, see the Appendix. Respondents first chose a Six Americas group that best fit their beliefs and feelings about climate change (Swim in preparation). They then answered questions about their risk perceptions for climate change, sea level rise, and sea level rise in Sarasota; responses to these risk perception questions are evaluated in Chapters 3 and 5. To familiarize respondents with the sea level rise map, they were then asked to watch a tutorial video and complete a map exploration task.

Respondents were then shown the sea level rise map for their assigned location (e.g., Figure 4.3 for St. Armand’s Circle) and asked to use the map and slider tool to estimate sea
level rise depth and probability for 2050 and 2100 (Box 4.1). For flood depth, answer
categories included 0-7 feet of flooding in 1-foot increments, with an additional option for
“no flooding” (0 ft). For flood probability, answer categories were very low, low, moderate,
high, and very high (including associated percentages). When respondents made an
estimate for flood depth or probability for a given year, the position of the sea level rise
slider was also recorded, providing a record of the sea level rise amount for which the
estimate was made. Table 4.1 shows the correct response categories for all possible
combinations of assigned map location and selected sea level rise amount.

<table>
<thead>
<tr>
<th>Box 4.1: Flood depth and probability estimation question</th>
</tr>
</thead>
<tbody>
<tr>
<td>For St. Armand’s Circle (location indicated by the white outline), what is the average depth [probability] of sea level rise flooding within the outlined area most likely to be by:</td>
</tr>
<tr>
<td>• 2050?</td>
</tr>
<tr>
<td>• 2100?</td>
</tr>
</tbody>
</table>

After completing additional map tasks, respondents answered questions about their
sea level rise knowledge, worldviews, demographics, and flood experience. In this final
section, they also completed questions about their numerical ability and map reading
ability and enjoyment. These were measured using subjective assessments that have been
shown to be correlated with objective measures of numeracy (Fagerlin et al. 2007) and
map reading ability (Thorndyke and Goldin 1981). In particular, subjective numeracy was
measured using the four-item subjective numerical ability subscale, which includes items
for ability with fractions, percentages, and calculating tips and discounts (Fagerlin et al.
2007). In my sample these four items were found to form a reliable scale (Cronbach’s
alpha=0.893, n=250) and were therefore averaged to form a single measure of subjective
numeracy. Subjective map reading ability and enjoyment were measured using single
questions, as shown in Box 4.2. Answers to these questions were recorded on five-point Likert scales.

**Box 4.2: Subjective map reading ability and enjoyment questions**

- How comfortable and competent do you feel in general when using maps?
- How much do you enjoy using or looking at maps?

### 4.4.3 Survey implementation

To enable comparison of responses on their physical proximity to the sea level rise hazard, the survey was offered to undergraduate students from both The Pennsylvania State University and three colleges and universities in Sarasota, Florida: New College of Florida, State College of Florida, and University of South Florida Sarasota-Manatee. Sarasota was chosen in part because, as a city on Florida's Gulf Coast, it is exposed to sea level rise and related coastal hazards, such as hurricane storm surge (Frazier et al. 2010). Sarasota is also home to several colleges and universities from which I could recruit students to compare with the Penn State sample. Students from earth and environmental science courses were offered extra credit equivalent to 1% of their course grade for participating; the survey was also made available to all students at New College of Florida, a small honors college where formal grades are not offered and many students are environmentally active. The survey was administered from late spring to early fall of 2014, and remained open for approximately two weeks for students in each course or institution.

### 4.4.4 General sample characteristics

Of 571 submitted responses, 298 were considered valid and used for analysis. Responses were eliminated because they were entirely blank (241 responses) or were one
of multiple responses from the same respondent (32 responses). For multiple responses, the most complete response was generally used, except where this response came after an earlier response in which the respondent had already been exposed to the sea level rise map. Of valid responses, 157 were from Penn State students and 141 were from Sarasota-area students (49 from New College, 9 from State College of Florida, and 83 from USF Sarasota-Manatee). More of these students identified as female (131), than as male (115) or other (2); however, 50 students (16.8%) did not indicate their gender, either because they skipped the question (2) or because they did not complete the last part of the survey (48).

Sarasota students were more likely (23.4% versus 8.9%) than Penn State students to drop out before completing the survey. Much of this difference may be explained by the higher drop out rate for New College students than for students from other Sarasota schools (46.9% versus 10.9%), likely due to the lack of a formal extra credit incentive for New College students. For all students, dropout was most likely to occur either on the map tutorial page (7.7%) or while using the map (7.4%); only two respondents (0.7%) dropped out later in the survey.

Based on their Six Americas groups, students participating in the survey were generally more concerned about climate change than were respondents from a nationally representative survey of U.S. residents conducted in October 2014 (Roser-Renouf et al. 2014). Compared to this national sample, student respondents were more likely to be Alarmed about climate change, and less likely to be Doubtful; no student respondents identified as Dismissive (Figure 4.4). Dismissive respondents may be missing from the sample in part because younger individuals tend to show greater environmental concern
Figure 4.4: Percentage of survey respondents in each Six Americas segment, compared to representative U.S. sample from October, 2014 (Roser-Renouf et al. 2014)

(see review from Fransson and Garling 1999); students who were Dismissive may also have been less interested in participating in the survey, or may not have enrolled in the earth and environmental science courses from which I recruited. Because few respondents identified as Doubtful, they are grouped with the Cautious for analysis; combining these groups is also theoretically justified, since they are similarly uncertain about both whether climate change is happening and the urgency with which we should respond to it.

Although the distribution of respondents across Six Americas groups in my sample was not representative of that for the U.S., the characteristics of respondents that I observed within each segment were consistent with those that have been observed for national samples. Specifically, survey response patterns were consistent with national findings that the Alarmed are more likely to be women (Maibach et al. 2009, Roser-Renouf et al. 2014) and to hold stronger egalitarian values (Maibach et al. 2009) than other
segments, while less concerned segments are more likely to hold individualistic values (Maibach et al. 2009). These results are discussed in more detail in Chapter 3.

4.5 Results

To evaluate whether respondents engaged in motivated reasoning when selecting a sea level rise amount or estimating flood depth or probability for their assigned map location, responses to these items are compared based on students’ Six Americas group and distance from Sarasota. I first consider differences in the amount of sea level rise selected using the slider tool. Next, I evaluate differences in the raw flood depth and probability estimates. I then consider whether the error in these estimates depends on students’ Six Americas group or distance from Sarasota. In each case, I use Kruskal-Wallis one-way analysis of variance to test for differences in mean ranks based on students’ Six Americas group or distance from Sarasota. The Kruskal-Wallis test is used to compare ordinal scores across multiple independently sampled groups, and is therefore appropriate for comparing the ordinal response categories for sea level rise amount and flood depth and probability across groups for Six Americas and distance (McDonald 2009). Significance is assessed based on the chi-squared distribution, which is generally equivalent to the probability distribution of the Kruskal-Wallis test statistic (Feir-Walsh and Toothaker 1974). To address the possibility of confounds among explanatory variables, I also includes mixed ANOVA analyses for selected sea level rise amounts, flood depth and probability estimates, and the errors in these estimates.

I also consider whether other individual differences (such as subjective numeracy and map reading ability) are correlated with differences in respondent accuracy on depth
and probability estimation tasks. Because many of these individual differences are measured on ordinal scales, I use Spearman’s rho correlation on ranks, which is appropriate for use with ordinal data and measures the statistical dependence between variables (Spearman 1904, Zou et al. 2003). Values for rho are generally similar to those for the Pearson correlation, and like Pearson coefficients range from 1 (perfect positive correlation) to -1 (perfect negative correlation). Throughout the analysis, p-values are Bonferroni adjusted based on the number of explanatory variables evaluated in each comparison.

4.5.1 Selected sea level rise amount

Mean ranks for sea level rise amounts selected using the slider tool did not differ significantly with respondent distance or Six Americas group for either the 2050 or 2100 estimation points (Table 4.2). Most respondents chose the suggested amount of sea level rise for each time point (1 foot for 2050, 3 feet for 2100); however, about a third of respondents kept the slider in the default, 3 foot position when making estimates for 2050 (Figure 4.5). Respondents assigned to the Siesta Beach and Dolphin Fountain map locations were somewhat more likely than respondents assigned to other locations to select sea level rise amounts over three feet (Figure 4.5); these differences were marginally significant (Bonferroni-corrected p<0.1) at 2100 but not at 2050 (Table 4.2). Mixed ANOVA results confirmed that distance (F(1, 232)<0.001, p=0.983) and Six Americas group (F(3, 232)=0.596, p=0.618) were not significant predictors of selected sea level rise amount; assigned map location was again found marginally significant (F(3, 232)=2.108, p=0.100).
Table 4.2: Kruskal-Wallis test results for relationships between respondents’ distance, Six Americas group, or assigned map and their selected sea level rise amounts for 2050 and 2100

<table>
<thead>
<tr>
<th></th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(df=1)</td>
<td>$\chi^2 = 0.021$</td>
<td>$\chi^2 = 0.357$</td>
</tr>
<tr>
<td>Six Americas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(df=3)</td>
<td>$\chi^2 = 2.341$</td>
<td>$\chi^2 = 1.529$</td>
</tr>
<tr>
<td>Assigned map</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(df=3)</td>
<td>$\chi^2 = 0.807$</td>
<td>$\chi^2 = 10.109^*$</td>
</tr>
</tbody>
</table>

* p < 0.1 (Bonferroni corrected)

Figure 4.5: Amount of sea level rise selected using slider tool by assigned map, with percentages below (tan), equal to (gray), and above (green) default selection (3 ft)
4.5.2 Estimated flood depth and probability

Mean ranks for the depth and probability of sea level rise flooding within the assigned map areas did not differ significantly across Six Americas groups (Table 4.3). However, mean ranks for depth estimates did differ significantly by distance at 2100, with distant (Penn State) students estimating slightly higher average flood depths than nearby (Sarasota) students (Table 4.3, Figure 4.6). Most respondents expected sea level rise flooding to average from 0-1 feet by 2050; by 2100, most expected it to average from 1-3 feet (Figure 4.7 A). For flood probability, most respondents expected a low to moderate probability of flooding within their assigned areas by 2050, and a very high probability of flooding within these areas by 2100 (Figure 4.7 B). As expected given the objectively different flood depths and probabilities for each assigned location (Table 4.1), the mean rank of respondents’ estimates also varied significantly with flood depth at both time points and with flood probability in 2050 (Table 4.3). Mixed ANOVA analyses were generally consistent with these results. Six Americas group was not a significant predictor of depth (F(3, 240)=0.324, p=0.808) or probability (F(3, 236)=2.070, p=0.105) estimates. Distance was a significant predictor of depth (F(1, 240)=3.991, p=0.047) but not probability (F(1, 236)=0.131, p=0.718) estimates. Assigned map was also predictive of depth (F(3, 240)=3.300, p=0.021) but not probability (F(3, 236)=1.533, p=0.207).

4.5.3 Error in estimates of flood depth and probability

Errors in these estimates of flood depth and probability were calculated by subtracting actual from estimated values. As shown in Table 4.1, these actual values were
Table 4.3: Kruskal-Wallis test results for relationships between respondents’ distance, Six Americas group, or assigned map and their estimated flood depth and probability for 2050 and 2100

<table>
<thead>
<tr>
<th>Distance</th>
<th>Depth 2050</th>
<th>Depth 2100</th>
<th>Probability 2050</th>
<th>Probability 2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>(df=1)</td>
<td>$\chi^2 = 4.251$</td>
<td>$\chi^2 = 5.366^*$</td>
<td>$\chi^2 = 0.006$</td>
<td>$\chi^2 = 0.402$</td>
</tr>
<tr>
<td>Six Americas (df=3)</td>
<td>$\chi^2 = 2.490$</td>
<td>$\chi^2 = 2.721$</td>
<td>$\chi^2 = 4.054$</td>
<td>$\chi^2 = 6.009$</td>
</tr>
<tr>
<td>Assigned map (df=3)</td>
<td>$\chi^2 = 9.911^*$</td>
<td>$\chi^2 = 16.186^{**}$</td>
<td>$\chi^2 = 20.519^{**}$</td>
<td>$\chi^2 = 3.014$</td>
</tr>
</tbody>
</table>

* $p < 0.1$  ** $p < 0.01$  (Bonferroni corrected)

Figure 4.6: Estimated flood depth for 2050 and 2100 by distance
Figure 4.7: Estimated flood depth (A) and probability (B) for 2050 and 2100 by assigned map
calculated based on the sea level rise amounts selected using the slider tool at the time of
the estimate for a given year. The resulting errors indicate the direction and magnitude of
the deviation of the estimates from the actual, objective values that would have been
expected given the selected sea level rise amount.

Mean ranks for these errors did not differ by Six Americas group for either flood
depth or flood probability (Table 4.4). Mean ranks did differ significantly for flood depth
(Table 4.4); compared to distant (Penn State) respondents, nearby (Sarasota) respondents
were less likely to overestimate flood depth (55% versus 60%) and were more likely to
have no error in their estimate (35% versus 31%) (Figure 4.8). Respondents were more
likely to overestimate than to underestimate flood depth (although generally not by more
than 1-2 feet); flood probability estimates were about equally likely to be above or below
actual values (Figure 4.9). Mean ranks for errors in flood and probability estimates also
differed significantly by assigned map (Table 4.4). Compared to other locations, flood depth
for Dolphin Fountain was somewhat more likely to have no error, more likely to be
underestimated, and less likely to be overestimated (Figure 4.9 A). Flood probability
estimates for Siesta Beach were generally higher and less accurate than those for other
locations (Figure 4.9 B). Mixed ANOVA analyses for the error in estimates of flood depth
and probability produced similar results. For error in depth estimates, distance (F(1,
240)=5.000, p=0.026) and assigned map (F(3, 240)=8.398, p<0.001) were significant
predictors; Six Americas group (F(3, 240)=0.101, p=0.959) was not. For probability
estimates, assigned map was a significant predictor (F(3, 236)=12.920, p<0.001), but
distance (F(1, 236)=0.021, p=0.886) and Six Americas group (F(3, 236)=0.657, p=0.579)
were not.
Table 4.4: Kruskal-Wallis test results for relationships between respondents’ distance, Six Americas group, or assigned map and the error in their estimates for flood depth and probability

<table>
<thead>
<tr>
<th>Distance</th>
<th>Depth</th>
<th>Probability</th>
<th>$\chi^2$</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(df=1)</td>
<td>$\chi^2 = 4.725$</td>
<td>$\chi^2 = 0.078$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Six Americas (df=3)</td>
<td>$\chi^2 = 0.889$</td>
<td>$\chi^2 = 3.418$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assigned map (df=3)</td>
<td>$\chi^2 = 34.080^{**}$</td>
<td>$\chi^2 = 49.497^{**}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$p < 0.01$  ** $p < 0.01$  (Bonferroni corrected)

Figure 4.8: Error in estimated flood depth by distance
Figure 4.9: Error in estimated flood depth (A) and probability (B) by assigned map
4.5.4 Mean absolute error in estimates of flood depth and probability

To consider the magnitude of these errors independent of their direction, mean absolute errors (MAEs) were calculated. The MAE is frequently used as a measure of average error magnitude (Willmott and Matsuura 2005), particularly in applications comparing predictions with actual values (Hyndman and Koehler 2006). For each estimation task (depth and probability), the MAE is equal to the sum of the absolute values of the errors for the 2050 and 2100 estimates, divided by the number of estimates (two, one each at 2050 and 2100). As plots of the MAE for depth and probability show (Figure 4.10), most respondents’ estimates were within one category of the actual expected value; however, in both cases long right tails indicate that some respondents were much less accurate in their estimates than others.

Spearman’s rho correlations between MAEs and individual differences in respondents’ abilities and map use (Table 4.5) suggest several factors that may contribute to this variation in respondents’ accuracy. In line with earlier results, respondents from Penn State had tended to have higher MAEs for their flood depth estimates than respondents from Sarasota, although this result was not significant (p>0.1) once Bonferroni adjusted. Respondents’ depth-estimation MAEs were also significantly lower if they felt more able working with maps, enjoyed working with maps, or had higher subjective numeracy; higher self-assessed map ability was also associated with lower MAEs on the probability estimation task, but this correlation was not significant (p>0.1) once Bonferroni adjusted. More time on the survey page and more interactions with task-relevant map tools also showed significant negative correlations with MAEs for both depth and probability estimates.
Figure 4.10: Mean absolute error (MAE) for depth (A) and probability (B) estimates
Table 4.5: Spearman’s rho correlations between mean absolute error (MAE) for depth and probability estimates and individual differences

<table>
<thead>
<tr>
<th></th>
<th>Depth MAE Correlation Coefficient</th>
<th>Probability MAE Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spearman’s rho</strong></td>
<td>1.000</td>
<td>0.173*</td>
</tr>
<tr>
<td><strong>Depth MAE</strong></td>
<td>N</td>
<td></td>
</tr>
<tr>
<td><strong>Probability MAE</strong></td>
<td>0.173*</td>
<td>1.000</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>250</td>
<td>242</td>
</tr>
<tr>
<td><strong>Distance</strong></td>
<td>0.138</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>250</td>
<td>246</td>
</tr>
<tr>
<td><strong>Map ability</strong></td>
<td>-0.168*</td>
<td>-0.147</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>241</td>
<td>238</td>
</tr>
<tr>
<td><strong>Map enjoyment</strong></td>
<td>-0.210**</td>
<td>-0.095</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>240</td>
<td>237</td>
</tr>
<tr>
<td><strong>Numerical ability</strong></td>
<td>-0.165*</td>
<td>-0.103</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>242</td>
<td>238</td>
</tr>
<tr>
<td><strong>Changed map view</strong></td>
<td>-0.207*</td>
<td>-0.250**</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>192</td>
<td>191</td>
</tr>
<tr>
<td><strong>Changed map year</strong></td>
<td>-0.320**</td>
<td>-0.232**</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>192</td>
<td>191</td>
</tr>
<tr>
<td><strong>Changed SLR slider amount</strong></td>
<td>-0.177</td>
<td>-0.191*</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>192</td>
<td>191</td>
</tr>
<tr>
<td><strong>Map timer (seconds)</strong></td>
<td>-0.238**</td>
<td>-0.164*</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>250</td>
<td>246</td>
</tr>
</tbody>
</table>

* p<0.1, * p < 0.05, ** p < 0.01 (Bonferroni corrected)
4.6 Discussion

These results show limited support for my hypotheses. Contrary to my expectations, respondents did not show evidence of motivated reasoning based on their Six Americas group in their selection of sea level rise amounts or estimates of flood depth or probability. In line with Kunda (1990), these map tasks may have been too detailed and specific to activate motivated reasoning, and may instead have led respondents to focus on answering as accurately as possible. Kahan (2014) supports this view, finding that when members of the U.S. public consider what climate scientists know about climate change – rather than their own beliefs about the issue – their assessments of climate change risk are no longer motivated by political party affiliation. Given the authority often conferred on maps (Harley 1989), many respondents may have interpreted the map as an authoritative scientific statement about how much sea level rise will occur and the depth and probability of associated flooding. Their answers to the map reading questions may therefore reflect their best assessment of the evidence from this authoritative source rather than their personal opinions about climate change.

Consistent with my expectation that self- and place-protective motivated reasoning would affect map tasks through spatial optimism bias, nearby (Sarasota) respondents had lower estimates of sea level rise flood depth than did distant (Penn State) respondents. Once Bonferroni adjusted, these differences were generally marginally significant (0.1>p>0.05). However, I did not find evidence for a distance-based difference on other map tasks. This suggests that motivated reasoning based on audience distance may be more likely to occur for map reading tasks than for selection tasks (such as the use of the slider to select a sea level rise amount), although notably no evidence for motivated
reasoning was observed for the flood probability map reading task. Moreover, because nearby respondents’ estimates of flood depth were not only lower but also more accurate, they may have been motivated not by a desire to downplay flood impacts, but by a desire to understand them correctly. This is consistent with Kahan et al. (2013), who suggest that messages about local climate impacts can motivate respondents to better understand the science so they are more prepared to protect local lives and property.

I also observed the expected correlations between respondents’ accuracy and their subjective numeracy, map reading ability and enjoyment, number of interactions with task-relevant components of the map interface, and total amount of time spent on the map page. Errors in depth and probability estimates were consistently lower with greater numeracy, map ability/comfort, and duration and count of map interactions. These results suggest that if respondents can be motivated to use sea level rise maps more extensively, they may improve their understanding of the local impacts of sea level rise flooding.

4.7 Conclusions and limitations

This study has important implications for the use of sea level rise maps in climate change communication. Respondents’ generally high accuracy on map reading tasks suggests that audiences may find sea level rise maps fairly easy to understand. Moreover, at least for these simple map tasks, motivated reasoning based on prior beliefs about climate change may not be an issue. In line with the suggestions of Kahan et al. (2013), these findings demonstrate that interactive sea level rise maps not only may effectively communicate what scientists think about the local impacts of sea level rise, but also may
avoid (or at least mute) the activation of identity-protective motivated reasoning that is often found in responses to climate change messages.

Future research should address several limitations of this study. My results showed that respondents' selection of sea level rise amounts and the accuracy of their flood estimates differed significantly with their assigned map location. Future research should explore whether such differences are due to variation in the size or shape of the assigned location or in the type of assigned place (e.g., park, roadway, or commercial center); results could inform decisions about what types of places to highlight on sea level rise maps. As discussed above, additional studies could evaluate whether the effects of distance on map reading that were observed here are due primarily to spatial optimism bias and associated motivated reasoning, or to a tendency of those closer to the sea level rise hazard to be more careful in their sea level rise estimates. Studies should also explore whether these results hold for audiences other than my student sample. Finally, additional research is also needed to determine if other, higher-level map tasks – such as decision making, analysis, and interpretation (Clarke 2003) – are as immune to the effects of motivated reasoning as the map reading tasks explored in this study. The next chapter in this dissertation explores whether one such higher-level task – the evaluation of local sea level rise risk after exploring a sea level rise map – is affected by spatial optimism bias or other motivated reasoning.
Chapter V

SEEING SEA LEVEL RISE MAPS AND FEELING AT RISK:
EFFECTS OF MESSAGE DETAIL, AUDIENCE DISTANCE, AND
CLIMATE CHANGE BELIEFS ON RISK PERCEPTIONS

5.1 Introduction

To reduce the psychological distance of climate change and improve public engagement with the issue, many authors have suggested framing it in terms of impacts that are local to the intended audience (e.g., Spence et al. 2012, Moser 2010, Swim et al. 2009, Lorenzoni et al. 2007, Leiserowitz 2007, Nicholson-Cole 2005, Rayner and Malone 1997). Psychological distancing – the tendency to focus on risks to future generations and distant communities while downplaying risks to nearby and familiar people and places – has long been recognized as one of the principal obstacles to climate change engagement (Pidgeon and Fischhoff 2011, Moser 2010, Nisbet 2009, Ockwell et al. 2009, Lorenzoni et al. 2007, Leiserowitz 2005, and Slocum 2004). While surveys of U.S. (Leiserowitz 2005) and UK (Lorenzoni et al. 2007) residents suggest that such distancing of climate change impacts is a significant barrier to climate change engagement in these countries, the evidence for the effectiveness of local framings in reducing this distancing is more mixed. Some research has found that local climate change messages are associated with increased engagement and concern (Scannell and Gifford 2013, Sheppard et al. 2011, O’Neill and Hulme 2009, Retchless 2014a), but at least one other study has found that messages about climate change impacts that are local to an audience may not be as concerning to them as messages
about impacts on distant places (Spence and Pidgeon 2010). These conflicting results may be due in part to differences in the concreteness and detail of their depictions of local climate change, which have also been shown to affect engagement (Nicholson-Cole 2005, O’Neill and Nicholson-Cole 2009, Shaw et al. 2009). However, research has yet to systematically explore this possibility.

To address these conflicting results, this study considers how audience distance may interact with the concreteness of a depiction of local climate change to affect risk perceptions. Because local sea level rise impacts may be a particularly effective way to engage audiences with climate change (Monmonier 2008, Kahan et al. 2013), I use them here to depict local impacts. In an earlier portion of this study (see Chapter 3), I found that risk perceptions were lower for sea level rise impacts in a specific place than for sea level rise in general, particularly for study participants living nearby that place. However, these earlier results were based on a simple prompt asking participants to evaluate sea level rise risk in this specific place, and did not provide the sort of concrete and detailed information about local impacts that is often included in depictions from journalism (see evidence for journalistic practice and imagery from Boykoff and Boykoff 2007 and Nicholson-Cole 2005) and scientific outreach (e.g., O’Neill and Hulme 2009, Sheppard et al. 2011, Scannell and Gifford 2013). Accordingly, this portion of the study uses an interactive sea level rise map (introduced in Chapter 4) to explore how adding a detailed depiction of sea level rise in a specific place may affect perceptions of local-sea-level-rise risk. To address limitations of earlier studies, this study also considers how the effect of exposure to this more detailed depiction of local sea level rise varies across audiences, including those nearby and far
away from the chosen local-sea-level-rise location (Sarasota, Florida), as well as those with
different views about climate change.

The next section briefly reviews the literature on the distancing of climate change,
including its causes, implications for engagement, and the effectiveness of local framings
and detailed depictions in mitigating it. After reviewing the limitations of existing research
– including its failure to disentangle message detail (concrete or abstract) and audience
distance (near or far) – I introduce research questions and hypotheses. A methods section
then describes survey design and implementation, with a focus on how the sea level rise
map was designed to test the effects of message detail on survey respondents’ risk
perceptions. Finally, sections for results, discussion, and conclusions report and evaluate
the effects of message detail on risk perceptions for different audiences.

5.2 Literature review

5.2.1 Distancing of climate change: causes and consequences

Evidence from several studies suggests that distant climate change impacts are seen
as more severe than local impacts due to spatial optimism bias: in the environmental
context, this is the tendency, grounded in positive feelings for one’s self and community, to
view proximal environmental conditions more favorably than distal conditions (Schultz et
al. 2014, Gifford 2011, Gifford et al. 2009, Uzzell 2002). This bias has been observed nearly
universally: not only in wealthier countries – where residents may accurately believe that
climate impacts where they live are likely to be less severe than in countries with lower
adaptive capacity – but also in developing countries which are potentially quite vulnerable
to climate change and other environmental hazards (Spence et al. 2012, Schultz et al. 2014).
As shown in both Hatfield and Job (2001) and an earlier portion of this study, this bias is most evident for environmental hazards that are both nearby and specific (i.e., sea level rise in a specific, nearby place as compared to sea level rise in general).

While there is not yet a definitive explanation for spatial optimism bias, leading accounts have suggested that motivated reasoning may play a role. Schultz et al. (2014) found that people who were happier or from smaller communities also tended to exhibit more spatial optimism, suggesting that the motivation to maintain a positive outlook for one's self and one's community may contribute to this bias. In further support of this motivated reasoning account, both Schultz et al. (2014) and results from an earlier portion of this study suggest that higher levels of engagement and concern for environmental hazards may be associated with greater spatial optimism, perhaps because greater overall concern brings greater need for self- and place-protective reasoning. To complement this motivated reasoning account, other authors (Uzzell 2000, Gifford et al. 2009) have pointed to the possible role of media messages: to the extent that climate change is presented as temporally distant, complex, and uncertain in scientific literature and especially popular media (Uzzell 2000), it may be more difficult to relate to one's daily life, and therefore more psychologically distant (Pidgeon and Fischhoff 2011, Scannell and Gifford 2013). These possible reasons for spatial optimism bias are discussed in more depth in Chapter 3.

To explain why climate change impacts, once distanced, are often found less engaging, researchers (e.g., Swim et al. 2009, Spence et al. 2012, Scannell and Gifford 2013) have drawn on both discounting and construal level theories. Based on theories of economic discounting, rational actors are expected to assign less value to possible future benefits than to certain present-day costs; thus, to the extent that climate impacts are
expected to be most costly in the distant future, such actors can be expected to be less immediately concerned about them and to invest fewer resources in addressing them (Swim et al. 2009). Judgmental discounting suggests that similar undervaluation of environmental risks can occur when spatial optimism bias lead individuals to view local environmental conditions more favorably than conditions in distant places (Swim et al. 2009, Gifford et al. 2009, Gifford 2011). Construal level theory complements this account, holding that threats that are experienced as more distant (in time, space, social connection, or uncertainty) tend to also be construed more abstractly; abstract construals of distant threats such as climate change may be less easily applied in specific and local situations, where a more concrete construal may be required to motivate action and engagement (Liberman et al. 2007, Spence et al. 2012). This is consistent with what Hatfield and Job (2001) call the “environmental paradox”: psychological distance may reduce engagement by focusing concern on environmental problems so large and distant that audiences see little connection between the problems and their daily lives, and therefore feel powerless to address them (Uzzell 2000, Hatfield and Job 2001, O’Neill and Nicholson-Cole 2009, Spence and Pidgeon 2010).

5.2.2 Distancing of climate change: cures?

To reduce distancing and overcome these related threats to engagement, authors have thus suggested emphasizing climate change impacts that are not only local, but also tangible and personally meaningful (e.g., Spence et al. 2012, Moser 2010, Swim et al. 2009, O’Neill and Nicholson-Cole 2009, Lorenzoni et al. 2007, Leiserowitz 2007, Nicholson-Cole 2005, Rayner and Malone 1997). A few authors have tested the effectiveness of local
framings to reduce psychological distance and increase engagement with climate impacts. In a series of studies (Sheppard 2005, Shaw et al. 2009, and Sheppard et al. 2011), Stephen Sheppard and colleagues developed 3-D landscape visualizations of local climate change impacts and adaptation scenarios for waterfront, urban, and hillside communities in British Columbia, Canada; based on preliminary results from “Visioning workshops” with local residents, they suggest that such visualizations can change attitudes and increase engagement, including by significantly increasing concern about local impacts (Sheppard et al. 2011). Similarly, in a focus group study assessing the potential for climate change “icons” (maps and pictures) to engage audiences, O’Neill and Hulme (2009) found that UK-based participants were most drawn to icons that were local and relatable (such as sea level rise flooding in London and the Norfolk Broads), and least drawn to “expert” icons which they found overly remote, impersonal, or technical (such as the thermohaline circulation and the West Antarctic Ice sheet). In a mail survey of residents from three areas in British Columbia, Scannell and Gifford (2013) also found support for the power of local images. Compared to a control that saw no climate impact message, respondents to their study who saw one of several informational “posters” depicting local climate impacts had significantly higher climate change engagement (including measures of interest, concern, and willingness to act); in contrast, differences between respondents who saw global posters and the control group were not significant. Taken together, these results support the hypothesis that local framings of climate change can increase climate change engagement.

However, not all research has supported such claims for the power of local framings. The results of a survey of undergraduate students in Cardiff, UK, suggest that spatial optimism bias may in some cases frustrate efforts to use local framings to engage audiences.
(Spence and Pidgeon 2010). The researchers found that, compared to respondents who were shown climate impacts (principally sea level rise and other flooding) using the spatially distant frame of Rome and Europe, respondents who were shown the same climate impacts using the local frame of Cardiff and the UK expected the impacts of climate change to be less severe. Based on these results, they conclude that communicators who are interested in increasing concern about climate change should highlight its distant impacts. Scannell and Gifford (2013) suggest that the difference between their findings and those of Spence and Pidgeon (2010) could be due to differences in the saliency or certainty of the impacts of their local messages (with more salient or certain impacts generating more concern), although they also stress the need for additional research.

In support of this explanation for these conflicting results, several studies have suggested that to most effectively foster climate change engagement, communications should be not only local, but also concrete, realistic, and relatable. In their work on landscape visualization as a means of communicating climate change impacts in British Columbia, Shaw et al. (2009) contend that their visualizations were effective not only because they were local, but also because they showed tangible impacts on landscapes that were familiar and important parts of the everyday lives of workshop participants. Based on semi-structured interviews about how people visualize climate change and their personal involvement with the issue, Nicholson-Cole (2005) likewise suggests that in addition to being local, engaging climate change communications should include realistic and relatable detail; results from focus groups in O’Neill and Nicholson-Cole (2009) similarly show the highest levels of engagement with images that connect to the details of everyday life. While these studies suggest that concrete and relatable detail may make local climate change
messages more engaging, they have generally been qualitative and observational, and have not disentangled the effect of distance from that of concreteness in climate change messages.

5.2.3 Other limitations of existing research

In existing studies that have compared the effects of local and distant climate-impact stimuli on engagement (Spence and Pidgeon 2010, Scannel and Gifford 2013), participants in a single location have been shown either a local or distant stimulus. While the authors of these studies have attempted to develop stimuli that are the same in all respects except their distance from participants, the locations chosen for distant stimuli in such designs may carry associations that could affect engagement. For example, in Spence and Pidgeon (2010), participants’ assessments of the severity of climate impacts in Rome may have been affected by their prior knowledge and feelings about that location (perhaps related to its central role in the history of western civilization and its continued importance as a modern-day European capital), which may not have been comparable to their knowledge and feelings about Cardiff. One way to address this would be to evaluate the effects of climate-impact stimuli for a single location on engagement for two groups of participants, some from nearby the chosen location, and others far from it. As discussed below, this is the approach I adopt.

In addition to considering the effects of audience distance, it may be important to consider how other audience characteristics affect engagement. Spence and Pidgeon (2010) identify audience effects as an important area for future research, noting that different people will likely respond differently to the same climate-impact stimulus. For
example, they suggest that the Global Warming’s Six Americas framework (Maibach et al. 2009) – an audience segmentation analysis of a representative sample of U.S. residents – could be used to compare the effect of local climate-impact stimuli on engagement for audiences with different pre-existing beliefs about climate change. Because differences among the Six Americas are based in large part in differences in political identity and worldview (Bliuc et al. 2015) that have been associated with motivated reasoning in the interpretation of climate change information (Hart and Nisbet 2011), members of more opinionated Six Americas groups – such as the Alarmed and the Dismissive – might be expected to interpret the climate-impact stimulus in line with their pre-existing beliefs. However, Kahan et al. (2013) argue that a depiction of climate change that shows specific and tangible impacts on daily life may be able to overcome political identities and associated motivated reasoning; this may be particularly true for those in the Cautious or Doubtful groups who are motivated by political commitments, but do not hold to their beliefs about climate change as dogmatically as the Dismissive group.

5.3 Research questions and hypotheses

To begin to disentangle the effects of audience distance and message detail on audience engagement with climate change messages, this study explores how the risk perceptions of students at two distances from a local climate change hazard – sea level rise – vary with the level of message detail (Table 5.1). Because risk perceptions are often grounded in intuition and emotion as well as analysis (Loewenstein et al. 2001, Slovic et al. 2004), I use risk perceptions here as a proxy for respondents’ affective as well as cognitive engagement. Following Lorenzoni et al. (2007, 446), I define engagement as “a personal
state of connection with the issue of climate change,” including cognitive, affective, and behavioral aspects. Thus, while risk perceptions do not speak to behavioral engagement, they may provide insight into the cognitive and affective components.

Table 5.1: Study design (respondent distance crossed with message detail)

<table>
<thead>
<tr>
<th>Respondent distance</th>
<th>Message detail</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concrete</td>
</tr>
<tr>
<td>Near</td>
<td>Near &amp; Concrete</td>
</tr>
<tr>
<td>Distant</td>
<td>Distant &amp; Concrete</td>
</tr>
</tbody>
</table>

To better understand the combined effects of detail and distance on risk perceptions, I explore three research questions:

- How does varying the level of detail with which a specific, local climate change hazard is depicted affect risk perceptions?
- How does this effect on risk perceptions vary with distance and Six Americas group?
- Is this effect on risk perceptions associated with more extensive or intensive interaction with the detailed hazard depiction?

To evaluate hypotheses for these questions, I use a survey of college and university students from both nearby and far away from a local climate change hazard: sea level rise in Sarasota, Florida. To consider the effect of message detail, the survey measures risk perceptions for this hazard both before and after exposure to a detailed depiction of the hazard: an interactive map of local sea level rise. A brief discussion of the research design and hypotheses for each research question follows.
How does varying the level of detail affect risk perceptions? I evaluate the effect of the level of message detail using a repeated measure of risk perceptions for sea level rise in Sarasota over the next century, administered before and after survey respondents use an interactive map showing Sarasota-area sea level rise impacts. To provide points of reference for any change in risk perceptions observed from pre- to post-map, I also measure respondents’ risk perceptions for other, less specific, risk frames – climate change in general and sea level rise in general – before administering the repeated measure of Sarasota-area sea level rise risk. Results for these less specific risk frames are discussed in more depth in Chapter 3.

In line with previous research suggesting that tangible and relatable climate impact imagery may be more engaging, I expect that exposure to the more concrete and detailed depiction of local sea level rise will increase risk perceptions. Consistent with construal level theory, when a concrete and detailed depiction of local sea level rise impacts is provided, it may be easier to connect one’s risk beliefs for sea level rise in general with a highly-specific frame such as sea level rise in Sarasota. Thus, I also expect that, when comparing results from before and after map interaction, participants’ sea level rise risk perceptions for the specific Sarasota-frame will become more similar to their risk perceptions for sea level rise in general.

How does this effect vary with distance and Six Americas group? To evaluate the effect of distance from the local climate-impact stimulus (sea level rise), students were recruited from two locations: colleges and universities in the Sarasota, Florida metro-area (nearby hazard) and the University Park campus of The Pennsylvania State University (far away from hazard). As discussed in Chapter 3, participants used a single-question
instrument to self-identify as a member of one of the Six Americas groups: Alarmed, Concerned, Cautious, Doubtful, Dismissive, or Disengaged.

Although I predict that exposure to the sea level rise map will increase risk perceptions for students from both distances, consistent with spatial optimism bias, I expect this increase to be larger for distant (Penn State) students than for nearby (Sarasota) students. I also expect that risk perceptions for the Alarmed and Concerned will generally be higher than those for other Six Americas groups, both pre- and post- map. However, in line with Schultz et al. (2014) and results from an earlier portion of this study, I expect members of more concerned Six Americas groups will also be more likely to show optimism bias by evaluating Sarasota-area sea level rise as less risky than sea level rise in general. As discussed in Chapter 3, to the extent that their greater concern about sea level rise in general creates a stronger motivation to find reasons why local sea level rise will not be as bad as sea level rise elsewhere, such bias may be more evident among Alarmed and Concerned respondents. Consistent with Kahan et al. (2013), I expect exposure to the sea level rise map to create the largest increase in concern among Cautious and Doubtful respondents. For the Disengaged, I expect that their low level of interest in climate change and its impacts will be associated with little change in risk perceptions from pre- to post-map.

Is this effect associated with more interaction with the detailed hazard depiction? To evaluate the extent to which map use (rather than simple exposure) may contribute to any observed difference between pre- and post- map risk perception, respondents’ map interactions – including pans, zooms, and clicks – were recorded. Because risk perceptions may also vary with the intensity of map use, respondents were
also asked to explore the sea level rise map to identify types places that, according to the map, would be exposed to sea level rise flooding by the end of the century. Respondents who identified more such places were considered to have engaged more intensively in using the map to evaluate sea level rise risk.

In line with research linking more detailed and concrete climate change imagery with higher engagement, I expect that respondents who explore the map more will be exposed to more detail about Sarasota-area sea level rise, and will therefore have higher post-map risk perceptions. For the intensity of map interaction, I expect that respondents who identify more types of exposed places will also have higher post-map risk perceptions. This is consistent with previous studies, which have shown that when more images of flooding or other risks are called to mind, affect and availability heuristics combine to increase risk perceptions (Keller et al. 2006, Slovic et al. 2004). Thus, I expect respondents who use the map to identify more concrete examples of exposure to sea level rise to also perceive higher overall risk for Sarasota-area sea level rise.

5.4 Methods

To test these research questions, the survey was structured to evaluate risk perceptions both before and after interacting with the sea level rise map, and implemented using participants from nearby and far away from the sea level rise hazard. The next sections describe this survey structure and implementation in more detail.
5.4.1 Survey structure

The survey contained 53-55 questions and took approximately a half hour to complete. Respondents began by choosing a Six Americas group that best fit their beliefs and feelings about climate change (Swim in preparation). They then answered questions about their risk perceptions for climate change, sea level rise, and sea level rise in Sarasota adapted from Kahan et al. (2013). Respondents first indicated their risk beliefs for climate change and sea level rise in general, as shown in Box 5.1.

Box 5.1: General climate change and sea level rise risk questions

How much risk do you believe that each of the following hazards poses to human health, safety, or prosperity? Answer on a scale from 0 (no risk) to 10 (extreme risk).

- Climate change
- Sea level rise

Next, all respondents were shown a brief textual description of the location of Sarasota and its exposure to sea level rise: “This survey focuses on the effects of sea level rise flooding on the Sarasota metro area. Located on the coast of southwest Florida, the Sarasota metro area (including the cities of Bradenton, Sarasota, Venice, and Northport and surrounding suburbs) is home to over 700,000 people.” After respondents indicated their familiarity with the Sarasota area, they were then asked to draw on this knowledge when assessing sea level rise risk for Sarasota (Box 5.2).

Box 5.2: Sarasota sea level rise risk question

Please use any knowledge you may have about the Sarasota area to answer the following question. How much risk do you believe that sea level rise poses to human health, safety, or prosperity in the Sarasota metro area during this century? Answer on a scale from 0 (no risk) to 10 (extreme risk).
A short video tutorial then introduced respondents to the interactive map for sea level rise in Sarasota. After watching the video, respondents were asked to explore the sea level rise map and use it to identify which of eight types of places they expected to “experience sea level rise flooding by 2100.” To answer, they checked boxes for one or more of the following: homes or other places of residence, schools, workplaces, roadways or other transportation infrastructure, recreational areas, natural areas, cultural spaces, and other critical infrastructure (hospitals, fire or police stations, utility network).

A second map page then showed respondents a pop-up window highlighting sea level rise in one of four randomly assigned Sarasota-area locations: Dolphin Fountain in Island Park, N. Tamiami Trail just north of its intersection with John Ringling Causeway, St. Armand’s Circle, and Siesta Beach. Each window contained an interactive Google street view to give respondents an on-the-ground perspective, as well as a short paragraph describing the importance of the place to Sarasota and its residents. These places were chosen because they are well known to local residents and are likely to experience significant sea level rise flooding over the next century. Multiple places were used instead of a single place to ensure that any effects on risk perception observed post-map were due to map exposure and interaction in general, rather than the particular type of place highlighted in the popup. Figure 5.1 shows a screen shot of this popup and the associated interactive map for the St. Armand’s Circle location.
As discussed in more detail in Chapter 4, respondents were asked to use this map to estimate average flood depth and flood probability for the assigned location for both 2050 and 2100, and then to evaluate the importance of protecting the location from sea level rise. On a third map page, respondents dropped a pin on the map to select the location in the Sarasota metro area where they expected sea level rise to be most disruptive, and then repeated the tasks of estimating flood depth and probability and evaluating the importance of sea level rise protection, this time using their chosen location. Interactions with these maps (including pans, zooms, and clicks on interface elements and informational links) were recorded using Google analytics for later analysis.
After interacting with the map, respondents were asked to repeat the risk perception question about Sarasota-area sea level rise, as shown in Box 5.3. A final survey section asked respondents several questions about their sea level rise knowledge, comfort with math and maps, world views, demographics, and flood experience.

**Box 5.3: Post-map Sarasota sea level rise risk question**

Please consider your experience interacting with the maps on previous pages when answering the following question. How much risk do you believe that sea level rise poses to human health, safety, or prosperity in the Sarasota metro area during this century?

Answer on a scale from 0 (no risk) to 10 (extreme risk).

**5.4.2 Survey implementation**

To enable comparison of responses on their physical proximity to the sea level rise hazard, the survey was offered to undergraduate students from both The Pennsylvania State University and three colleges and universities in Sarasota, Florida: New College of Florida, State College of Florida, and University of South Florida Sarasota-Manatee.

Sarasota was chosen in part because, as a city on Florida’s gulf coast, it is exposed to sea level rise and related coastal hazards, such as hurricane storm surge (Frazier et al. 2010). Sarasota is also home to several colleges and universities from which I could recruit students to compare with the Penn State sample. Students from earth and environmental science courses were offered extra credit equivalent to 1% of their course grade for participating; the survey was also made available without credit to all students at New College of Florida, a small honors college where formal grades are not offered and many students are environmentally active. The survey was administered from late spring to early fall of 2014, and remained open for approximately two weeks for students in each course or institution.
5.4.3 General sample characteristics

Respondents submitted 571 responses, of which 298 were considered valid and used for analysis. Responses were eliminated because they were entirely blank (241 responses) or were one of multiple responses from the same respondent (32 responses). For multiple responses, the most complete response was generally used, except where this response came after an earlier response in which the respondent had already been exposed to the sea level rise map. In this case, to ensure that the comparison of risk perceptions from pre- to post-map was valid, only the response in which the respondent first saw the sea level rise map was used. Of valid responses, 157 were from Penn State students and 141 were from Sarasota-area students (49 from New College, 9 from State College of Florida, and 83 from USF Sarasota-Manatee). More students identified as female (131), than as male (115) or other (2); however, 50 students (16.8%) did not indicate their gender, either because they skipped the question (2) or because they did not complete the last part of the survey (48).

Sarasota students were more likely (23.4% versus 8.9%) than Penn State students to drop out before completing the survey. Much of this difference may be explained by the higher drop out rate for New College students than for students from other Sarasota schools (46.9% versus 10.9%), likely due to the lack of a formal extra credit incentive for New College students. For all students, dropout was most likely to occur either on the map tutorial page (7.7%) or while using the map (7.4%); only two respondents (0.7%) dropped out later in the survey. Because respondents identified a Six Americas group and answered risk perception questions on the first page of the survey, answers to these questions can be
used to explore whether students who dropped out of the survey differed from those who completed it. Compared to completers, dropouts were more likely to be in the Alarmed group (48.9% versus 30.7%) and more likely to select a risk category above seven (the median value for all respondents) for climate change (61.7% versus 42.3%). These differences may be due in part to the high level of concern among New College students; when these students are removed from the analysis, the percentage of dropouts who identified as Alarmed falls to 29.2%, in line with the percentage for respondents who completed the survey. However, after removing New College students the percentage of dropouts who selected a climate change risk category above 7 is still 58.3%. This suggests that, even after accounting for the higher dropout rate among New College students, students who perceived more climate change risk were also more likely to drop out.

Compared to Penn State respondents, Sarasota respondents were more likely to identify as female (50.4% versus 38.2%) and were also more age-diverse: while most (69.8%) respondents from both locations indicated that they were 18-24 years old, 89.8% of Penn State respondents fell into this age group, compared to 47.5% of Sarasota respondents (27.6% of Sarasota students indicated they were 25-54 years old, while 24.1% did not respond to the question). Comparing Six Americas groups by location, Sarasota respondents were more likely to be Alarmed, while Penn State respondents were more likely to be Cautious or Disengaged (Figure 5.2).

Students’ Six Americas groups suggest that they were generally more concerned about climate change than were respondents from a nationally representative survey of U.S. residents conducted in October 2014 (Roser-Renouf et al. 2014). Compared to this national sample, student respondents were more likely to be Alarmed about climate change, and
less likely to be Doubtful; no student respondents identified as Dismissive (Figure 5.2). Dismissive respondents may be missing from the sample in part because younger individuals tend to show greater environmental concern (see review from Fransson and Garling 1999); students who were Dismissive may also have been less interested in participating in the survey, or may not have enrolled in the earth and environmental science courses from which I recruited. Because few respondents identified as Doubtful, they are grouped with the Cautious for analysis; combining these groups is also theoretically justified, since they are similarly uncertain about both whether climate change is happening and the urgency with which we should respond to it.

![Figure 5.2: Percentage of survey respondents in each Six Americas segment, compared to representative U.S. sample from October, 2014 (Roser-Renouf et al. 2014)](image-url)
Although the distribution of respondents across Six Americas groups in my sample was not representative of that for the U.S., the characteristics of respondents that I observed within each segment were consistent with those that have been observed for national samples. Specifically, survey response patterns were consistent with national findings that the Alarmed are more likely to be women (Maibach et al. 2009, Roser-Renouf et al. 2014) and to hold stronger egalitarian values (Maibach et al. 2009) than other segments, while less concerned segments are more likely to hold individualistic values (Maibach et al. 2009). These results are discussed in more detail in Chapter 3.

5.5 Results

To evaluate the effects of level of detail and audience distance, I compare risk perceptions for Sarasota-area sea level rise measured both before and after exposure to the sea level rise map, for students both nearby and far away from Sarasota and across Six Americas groups. Risk perceptions for climate change and sea level rise in general (measured earlier in the survey and discussed in more detail in Chapter 3) are included in the analysis as points of reference for the repeated measure of Sarasota sea level rise risk. I begin by introducing a paired comparison modeling approach, which I use to show which assessment items (climate change, sea level rise, pre-map sea level rise in Sarasota, or post-map sea level rise in Sarasota) are perceived to be riskier than others. Using these paired comparison models along with raw risk scores, I evaluate how the perceived riskiness of Sarasota sea level rise changes from before to after map exposure, and consider how this change may vary with student distance, Six Americas group, and map interaction.
5.5.1 A paired comparison approach to relative riskiness

Because I am interested in the relative riskiness that respondents assign to risk perception items (e.g., is Sarasota sea level rise perceived as riskier before or after interacting with the map?), I use a paired comparison preference model to develop overall rankings for their riskiness. For each respondent, answers for each of the four risk assessment items are transformed into a set of all six possible paired comparisons (1:2, 1:3, 2:3, 1:4, 2:4, and 3:4), which are then assigned values based on whether the risk score for first item in the comparison is greater than, less than, or equal to that for the second. The R package prefmod (Hatzinger and Dittrich 2012) is then used to analyze this paired comparison data with a modified Bradley-Terry approach (Bradley and Terry 1952). Employing a Poisson log-linear model, prefmod uses these paired comparisons to estimate parameters ($\lambda$) indicating each item’s riskiness relative to the reference item; in this study, I use pre-map Sarasota sea level rise risk as the reference.

As discussed in Dittrich et al. (2007), this paired comparison approach is well suited to ordinal, Likert scale data like that gathered on this study’s 11-point risk perception scale, as it does not assume that the distance between response categories is the same for all respondents, or that responses are normally distributed. Moreover, prefmod extends the traditional Bradley-Terry model to account for ties and dependencies between paired comparisons with a shared item by adding nuisance parameters to the model. It also accommodates subject covariates, permitting consideration of how relative riskiness differs both with respondents’ distance from the Sarasota area and their Six Americas group. Hypotheses about the effect of adding parameters to the model can be tested by comparing deviance differences between models, which have a chi-square distribution.
with degrees of freedom equal to the difference in the number of parameters (Dittrich et al. 2007). For example, for the risk perception data from this study, model fit was significantly improved by including parameters for both ties (deviance change of 93.196 on 1 degrees of freedom, p<0.001) and dependencies (deviance change of 107.137 on 12 degrees of freedom, p<0.001).

The prefmod package also accommodates missing responses so long as they are missing at random (MAR), i.e., depend only on the values of other observed responses (Dittrich et al. 2012). Rubin (1976) contrasts this with missing completely at random, where missingness does not depend on other responses (observed or unobserved), and missing not at random, where missingness may depend on both observed responses and the response that would have been observed if it were not missing (e.g., where the respondent knows which answer she would choose but refuses to indicate her choice, perhaps out of embarrassment). As described in Dittrich et al. (2012), missing due to dropout is most consistent with MAR. Of 57 total missing responses for risk perceptions questions in this survey (5 for general sea level rise risk and 52 for Sarasota sea level rise risk, post-map), only 10 were missing due to skipping rather than dropout. Moreover, as discussed earlier, dropouts were associated with higher previously observed risk perceptions for climate change, which is also consistent with MAR. Missing responses are therefore assumed to be MAR, allowing for the use of nearly all observed risk perceptions in the model, including those of respondents who later dropped out of the survey. However, because prefmod does not accommodate missing subject covariates, risk perceptions for three respondents who did not choose a Six Americas group are omitted from the model.
In addition to respondents’ distance and Six Americas group, several other subject covariates were considered for inclusion in the model as control variables. For example, I considered including female gender because it has been associated with more concern about the environment (Davidson and Fredudenburg 1996) and more worry about climate change (Maibach et al. 2009). I also considered flood experience, which has been associated with increased risk perceptions for flooding (Keller et al. 2006, Kellens et al. 2012). However, no variables related to these factors showed evidence of improving model fit. A variable for female gender came closest to improving model fit, with deviance change of 5.118 on 3 degrees of freedom (p=0.163). Variables for recent flood experience and flood damage did not significantly improve the model, with deviance changes of 0.806 (p=0.848) and 0.085 (p=0.994) respectively on 3 degrees of freedom. I also found that respondents’ randomly assigned map location did not improve the fit of the model (deviance change of 3.860 on 9 degrees of freedom, p=0.920). In addition to not improving model fit, all of these variables except for map location also contained several missing values; adding them to the model therefore would have required list-wise deletion of risk perception values for many respondents. These possible control variables were therefore excluded from the model.

5.5.2 Effect of exposure to sea level rise map on risk perceptions

After exposure to the sea level rise map, risk perceptions for Sarasota-area sea level rise were generally higher than before, in line with or slightly above risk perceptions for climate change and sea level rise in general (Figure 5.3). Preference model results (Table 5.2, Figure 5.4) confirm this. The model parameters (λ) in Table 5.2 show the strength and significance of the tendency to find survey items more or less risky than the reference item
of pre-map Sarasota sea level rise. The p-value for each $\lambda$ is Bonferroni corrected to account with the number of comparisons (3) with the reference item for each group of respondents. The post-map item for Sarasota sea level rise was rated as significantly riskier than the pre-map item ($p<0.001$). The odds of finding item A riskier than item N are found by:

$$\exp(2(\lambda_A - \lambda_N))$$

Using this formula, post-map Sarasota sea level rise has approximately 1.42 times the odds of being rated as riskier than pre-map Sarasota sea level rise.

Figure 5.3: Students’ risk perceptions across climate change stimuli, with percentages below (tan), equal to (gray), and above (green) overall median (7).
### Table 5.2: Parameter ($\lambda$) estimates for item-only model

<table>
<thead>
<tr>
<th>Climate Change</th>
<th>Sea level rise (SLR)</th>
<th>Before map Sarasota SLR†</th>
<th>After map Sarasota SLR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.16278***</td>
<td>0.11204*</td>
<td>0.17684***</td>
</tr>
</tbody>
</table>

* *p<0.05, **p<0.01, ***p<0.001
† reference category

### Figure 5.4: Worth estimates showing relative perceived risk for C (climate change), S (sea level rise), B (before-map Sarasota sea level rise), and A (after-map Sarasota sea level rise) items

The figure shows the worth estimates for different risk items, with C representing climate change, S representing sea level rise, B representing before-map Sarasota sea level rise, and A representing after-map Sarasota sea level rise.
A plot of model worth parameters (Figure 5.4) shows the probability that a given item was rated as riskier than the others. Worth parameters (\(\pi\)) are calculated from item parameters (\(\lambda\)) using the following formula:

\[
\pi_j = \exp(2\lambda_j) / \sum_j \exp(2\lambda_j), \; j = 1, 2, \ldots, J
\]  

As in traditional Bradley-Terry models, these worth parameters indicate the probability of “preferring” a given item to the others (i.e., the probability of rating it as riskier). Accordingly, the worth parameters sum to one; if all items in a four-item model were equally preferred (found equally risky), then each would have a worth parameter of 0.25. The plot of model worth shows that, after map exposure, Sarasota sea level rise is considered the riskiest item, with worth values similar to those for the item for climate change in general, and several percentage points above those for sea level rise in general.

### 5.5.3 Effect of distance on change in risk perceptions

Risk perceptions for students from both distances increased from before to after map exposure. Although Penn State students increased their risk perceptions more than Sarasota students from pre to post map, Sarasota students’ risk perceptions remained higher than those of Penn State students overall, consistent with their higher risk scores on previous survey items (Figure 5.5). Adding student location to the item-only preference model significantly improved model fit (deviance change of 10.634 on 3 degrees of freedom, \(p=0.014\)). Model results (Table 5.3, Figure 5.6) confirmed that students from both locations perceived Sarasota–area sea level rise as riskier after the map compared to before the map; however, once Bonferroni adjusted, this difference was only significant for Penn State Students (\(p=0.126\) on odds of 1.25 for Sarasota students; \(p<0.001\) on odds of 1.56 for Penn State).
State students). Post-map risk was the highest ranked item among Penn State respondents, but ranked only third highest among Sarasota respondents (Figure 5.6); the model indicated that Penn State students were about 1.24 times more likely than Sarasota students to find the post-map item riskier than the pre-map item. However, this difference was not significant (p=0.145).

Figure 5.5: Students’ risk perceptions across climate change stimuli by distance, with percentages below (tan), equal to (gray), and above (green) overall median (7)
Table 5.3: Parameter (λ) estimates for risk perception items by distance

<table>
<thead>
<tr>
<th>Distance</th>
<th>Climate change</th>
<th>Sea level rise (SLR)</th>
<th>Before map Sarasota SLR †</th>
<th>After map Sarasota SLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near</td>
<td>0.19799**</td>
<td>0.17372**</td>
<td>NA</td>
<td>0.11303</td>
</tr>
<tr>
<td>Far</td>
<td>0.13442*</td>
<td>0.05543</td>
<td>NA</td>
<td>0.22248***</td>
</tr>
</tbody>
</table>

* p<0.05, **p<0.01, ***p<0.001
† reference category

Figure 5.6: Worth estimates showing relative perceived risk for C (climate change), S (sea level rise), B (before-map Sarasota sea level rise), and A (after-map Sarasota sea level rise) items by distance
5.5.4 Effect of Six Americas group on post-map risk perceptions

Post map, risk perceptions were higher for all Six Americas groups; increases in risk perceptions from pre to post were highest among the Concerned and Cautious/Doubtful (Figure 5.7). Adding Six Americas groups to the item-only preference model significantly improved model fit (deviance change of 25.801 on 9 degrees of freedom, p=0.002). Model results (Table 5.4, Figure 5.8) confirmed that Sarasota sea level rise was perceived as significantly riskier after exposure to the map for members of the Concerned (p<0.001 on odds of 1.77) and Cautious/Doubtful (p=0.0045 on odds of 1.58) groups, but not for the Alarmed (p=1 on odds of 1.07) or Disengaged (p=1 on odds of 1.09). Notably, unlike the other groups, which considered post-map Sarasota sea level rise to be the riskiest item, the Alarmed group perceived climate change in general as posing the greatest risk (Figure 5.8). Model analysis also showed that, compared to the Alarmed, students in the Concerned and Cautious/Doubtful groups were significantly more likely to find the post-map item riskier than the pre-map item (for Concerned, p=0.008 on odds of 1.65; for Cautious/Doubtful, p=0.050 on odds of 1.47). For the disengaged, no significant differences were observed among preferences for risk items (Table 5.4).

5.5.5 Combined effect of distance and Six Americas segment on post-map risk perceptions

Because both distance and Six Americas group membership improved the fit of the item-only model, they were considered for inclusion together in the same preference model. The combined main effects model for distance and Six Americas group was a significantly
Figure 5.7: Students’ risk perceptions across climate change stimuli by Six Americas group, with percentages below (tan), equal to (gray), and above (green) overall median (7)
Table 5.4: Parameter (λ) estimates for risk perception items by Six Americas group

<table>
<thead>
<tr>
<th>Six Americas</th>
<th>Climate change</th>
<th>Sea level rise (SLR)</th>
<th>Before map Sarasota SLR †</th>
<th>After map Sarasota SLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarmed</td>
<td>0.28958***</td>
<td>0.11207</td>
<td>NA</td>
<td>0.03500</td>
</tr>
<tr>
<td>Concerned</td>
<td>0.18985*</td>
<td>0.16005</td>
<td>NA</td>
<td>0.28610***</td>
</tr>
<tr>
<td>Cautious/Doubtful</td>
<td>0.02360</td>
<td>0.10143</td>
<td>NA</td>
<td>0.22769**</td>
</tr>
<tr>
<td>Disengaged</td>
<td>-0.04540</td>
<td>-0.08555</td>
<td>NA</td>
<td>0.04414</td>
</tr>
</tbody>
</table>

* p<0.05, **p<0.01, ***p<0.001
† reference category

Figure 5.8: Worth estimates showing relative perceived risk for C (climate change), S (sea level rise), B (before-map Sarasota sea level rise), and A (after-map Sarasota sea level rise) items by Six Americas group
better fit than the distance model alone (deviance change of 21.410 on 9 degrees of freedom, p=0.011), but did not significantly improve upon the fit of the Six Americas-only model (deviance change of 6.242 on 3 degrees of freedom, p=0.100). This suggests that Six Americas group membership accounts for some of the previously observed relationship between preference for risk perception items and distance. An additional test found that including the interaction between distance and Six Americas group did not improve fit over the main effects model (deviance change of 6.794 on 9 degrees of freedom, p=0.659).

Results for the combined main effects of distance and Six Americas group are consistent with those observed previously for their separate effects (Figure 5.9), both in this chapter and in Chapter 3. Regardless of distance, Alarmed respondents perceived climate change in general as being much riskier than the other items. Post-map risk perceptions for Alarmed Sarasota respondents were nearly identical to their risk perceptions pre-map; post-map risk perceptions for Alarmed Penn State students were somewhat higher, but not significantly so (p=0.327 on odds of 1.31). Concerned and Cautious/Doubtful respondents from both locations rated Sarasota sea level rise as much riskier after map exposure; for Sarasota respondents, this post map item was seen as similarly risky to sea level rise in general, while for Penn State respondents it was evaluated as being much riskier than overall sea level rise. Disengaged respondents showed comparably little variation in risk perceptions across items, although those from Penn State found post-map Sarasota-area sea level rise most risky and sea level rise in general least risky.
Figure 5.9: Worth estimates showing relative perceived risk for C (climate change), S (sea level rise), B (before-map Sarasota sea level rise), and A (after-map Sarasota sea level rise) items, by combined effects of Distance and Six Americas group (no interaction term)
5.5.6 Effect of map interaction on post-map risk perceptions

Including the number of map interactions performed by respondents did not improve model fit, either when entered as the only covariate to the risk items (deviance change of 0.826 on 3 degrees of freedom, $p=0.8431378$) or when entered along with the main effects for distance and Six Americas group (deviance change of 1.1733 on 3 degrees of freedom, $p=0.759$). Fit also did not improve with inclusion of respondent accuracy on flood depth (deviance change of 0.5912 on 3 degrees of freedom, $p=0.898$) or probability (deviance change of 2.271 on 3 degrees of freedom, $p=0.5181$) estimation tasks. However, adding my measure of the intensity of map interaction – the number of Sarasota-area place types identified in a map search task as exposed to sea level rise – improved fit both when entered on its own (deviance change of 8.2885 on 3 degrees of freedom, $p=0.040$) and along with distance and Six Americas group (deviance change of 12.897 on 3 degrees of freedom, $p=0.005$). Figure 5.10 shows the relationship between the number of places identified and the relative riskiness perceived for survey items. Respondents who perceived sea level rise as riskier relative to climate change before using the map tended to identify more place types; moreover, after using the map, those who identified more place types also tended to find Sarasota sea level rise riskier than other items.

5.6 Discussion

Results from the raw risk scores and preference models generally confirmed my hypotheses. Consistent with the hypothesis that a more detailed depiction of climate change impacts would increase risk perceptions, I found that – compared to risk
Figure 5.10: Worth estimates showing relative perceived risk for C (climate change), S (sea level rise), B (before-map Sarasota sea level rise), and A (after-map Sarasota sea level rise) items, by number of place types respondents identified as being affected by sea level rise on the Sarasota map.
perceptions in a pre-map measure where respondents had seen only a two-sentence description of the Sarasota area – risk perceptions for Sarasota-area sea level rise were higher after exposure to a detailed map of sea level rise flooding. This effect was observed across most combinations of respondent distance and Six Americas groups (Alarmed or Disengaged Sarasota students were the exception). Consistent with the second hypothesis, this effect also tended to raise risk perceptions for Sarasota sea level rise to a similar or higher level than perceived risk for sea level rise in general.

However, the effect of exposure to the sea level rise map was larger for some respondents than others. In line with another of my hypotheses and consistent with spatial optimism bias, distant (Penn State) respondents tended to rate post-map Sarasota sea level rise as the riskiest item, while nearby (Sarasota) respondents tended to rate it as somewhat less risky than either climate change or sea level rise in general. For Six Americas groups, my expectation that exposure to the sea level rise map would raise risk perceptions most effectively for the Cautious and Doubtful while activating optimism bias among the more concerned was partially supported. Map exposure was associated with significant increases in the Concerned as well as the Cautious/Doubtful, while the Alarmed did not significantly increase their risk perceptions. While the failure of the Alarmed to increase their risk perceptions may be due to optimism bias, it does not appear to be associated with spatial optimism, since Alarmed students from neither distance showed significantly increased risk perceptions post-map. Also consistent with my hypotheses, Disengaged respondents showed little change in risk perceptions across items.

Finally, results did not support my hypothesis that more map interaction would be associated with higher post-map risk. Neither the number of respondents' map interactions
nor their accuracy on flood depth and probability estimation tasks was associated with a significant difference in the relative riskiness assigned to the items. However, consistent with my expectations for the effects of more intensive map interaction, respondents who identified more types of affected places during a map exploration task did tend to rate the post-map item as riskier than the others. Thus, the effect of the map on risk perception appears to be driven more by general impressions of how the flooding shown on the map may affect the Sarasota-area community rather than by the extent of map exploration or the accuracy of map reading. These results suggest that even limited interaction with such sea level rise maps may be sufficient to increase risk perceptions, particularly if this exposure raises awareness of impacts on specific places that are important to the local community. Additional research is needed to determine if changes in risk perception are associated with differences in the types of affected places respondents’ identify or with specific types or patterns of map interaction.

Thus, concrete and detailed depictions of climate change hazards (like the sea level rise map used in this study) may be effective in raising risk perceptions for many audiences, both nearby and far away from the hazard. However, consistent with Spence and Pidgeon (2010), my results suggest that any increase in risk perceptions will likely be larger for audiences far from the chosen location than for those nearby. While my depiction of Sarasota-area sea level rise may not have been detailed or precise enough to be fully credible with Sarasota-area respondents, it is also possible that even the most concrete or accurate depiction would not have completely reshaped Sarasota respondents’ existing understanding of their sea level rise risk – particularly since optimism bias and motivated reasoning may lead persons close to a hazard to selectively adopt and integrate new
information about their risk (Grothmann and Patt 2005, Schultz et al. 2014). For distant audiences who know little about the chosen location (such as the Penn State students in this study), local risk perceptions may be more similar to a blank slate, ready to accept details about the hazard’s local impacts – particularly when those details are distant and not personally threatening.

Importantly, the results also suggest that, regardless of distance, concrete and detailed depictions of climate change hazards can be quite effective in increasing risk perceptions for those who are Concerned, Cautious, or Doubtful. Consistent with Kahan et al. (2013), this suggests that detailed depictions of tangible climate change impacts (such as sea level rise) in specific places may be able to reach audiences such as the Cautious or Doubtful who are otherwise uncertain about both whether climate change is happening and the appropriate urgency of mitigation and adaptation responses. This result is also in line with Bruin et al. (2014), who found that flood risk information could be a particularly effective means of reaching audiences that are otherwise skeptical about climate change. Despite this promise for reaching the Cautious or Doubtful, my results also show that concrete and detailed messages may not be an effective way to reach the Alarmed. The reasons for this are unclear: does greater concern about climate change among the Alarmed contribute to a stronger need for place-serving bias at the level of their community (or even country), or are the Alarmed simply more aware than other Six Americas groups of the significant impacts and vulnerabilities that exist elsewhere? Additional research is needed to explore these questions.
5.7 Limitations and conclusions

Other limitations point towards additional ways in which contributions of this study could be refined. Future research should explore how additional individual differences (such as age and gender) may affect interpretation of climate change messages. Moreover, while the consistency of my results with existing studies and theory suggests that they may apply beyond my student sample, additional research should confirm this assumption. Research could also consider how effects on risk perceptions vary with different types of concrete and detailed climate impact stimuli (including videos and other imagery as well as maps) and finer variation in level of detail (rather than the two levels used here). Additionally, while this study suggested that more intensive map interaction might contribute to the observed increase in risk perceptions, studies should confirm this idea by comparing risk perceptions for interactive and non-interactive maps. Finally, to consider engagement more fully, work should extend this research beyond risk perceptions to behavioral intentions.

Despite these limitations, this work carries important lessons for climate change communicators. Consistent with existing research, detailed depictions of tangible climate change impacts may increase risk perceptions for most audiences. While these increases may be largest for distant audiences, consistent with the environmental paradox, smaller increases for audiences nearby the hazard may have a greater impact, as the proximity of the hazard may make it easier for these respondents to translate their increased risk perceptions into action. And, as discussed above, concrete depictions may be particularly effective in raising risk perceptions among audiences that are otherwise doubtful about climate change. However, as my finding that such depictions were not effective among the
Alarmed suggests, communicators should not always assume that local or detailed
depictions of climate change are always best, but should instead carefully consider their
audience and goals before constructing their message.
Chapter VI

GENERAL CONCLUSIONS

6.1 Introduction

This dissertation explored how individual differences – including differences in proximity to the sea level rise hazard and beliefs about climate change – affect risk perceptions and understanding for maps and other messages about local sea level rise. In addition to informing efforts to communicate sea level rise risk, the results of this dissertation also address broader questions about how spatial optimism bias and motivated reasoning may affect communication of local climate change impacts in general. In this chapter, I summarize the main findings from the preceding chapters, review the broader lessons they may hold for climate change communication, and discuss their limitations and implications for future research.

6.2 Summary of main findings

Below, I summarize the main findings from Chapters 2-5 of this dissertation.

• Chapter 2: Based on a review of the literature on sea level rise mapping and the role of individual differences in the interpretation of uncertain information on hazard maps, I found that individuals' interpretation of sea level rise maps may vary with their map reading expertise, beliefs about climate change, and proximity to the sea level rise hazard. I also found support for including information about sea level rise uncertainty on such maps, including through
interactive elements in the map interface and through the use of visual variables on the map itself.

- **Chapter 3:** Based on a survey of individuals from nearby and far away from the sea level rise hazard (both in general and in the specific context of Sarasota, Florida), I found that sea level rise risk perceptions were higher for individuals who were closer to the hazard or were more concerned about climate change. Risk perceptions were also higher for sea level rise in general than for sea level rise in the particular context of Sarasota. Non-parametric analysis showed that nearby respondents were more likely than distant respondents to decrease their risk perceptions when moving from the general sea level rise context to the specific sea level rise context; however, a mixed ANOVA suggested that this result was likely due in large part to the confounding effect of differences in climate change beliefs (as measured via Six Americas group) with distance. These results support my hypothesis that message specificity may contribute to spatial optimism bias when comparing local and global risk perceptions for sea level rise and other climate hazards. However, they also suggest that – contrary to the spatial optimism bias literature – audience distance may not significantly contribute to this bias when controlling for prior climate change beliefs.

- **Chapter 4:** Additional results from the same survey showed that most respondents were able to use an interactive map of sea level rise to estimate flood depth and probability for an assigned location in the Sarasota area with reasonable accuracy. Accuracy tended to improve if respondents had higher subjective map ability, performed more task-related map interactions, or spent
more time using the map. When asked to evaluate sea level rise flooding in both 2050 and 2100, most respondents selected the suggested sea level rise amounts of 1 and 3 feet, respectively. Respondents nearby Sarasota had slightly lower flood depth estimates than distant respondents, suggesting that spatial optimism bias could also affect estimates of flood depth. Contrary to my expectations, respondents did not show evidence of motivated reasoning based on the Six Americas groups – neither in their selections of sea level rise amounts nor in their estimates of flood depth or probability.

• **Chapter 5:** The survey was also used to evaluate how exposure to the interactive map affected risk perceptions for sea level rise in the mapped area of Sarasota, Florida. Exposure to the sea level rise map generally raised risk perceptions above pre-map levels. In most cases, these post-map risk perceptions for Sarasota sea level rise were also similar to or higher than risk perceptions for sea level rise in general. Consistent with spatial optimism, distant respondents were more likely than nearby respondents to increase their risk perceptions from pre to post map. The effect of map exposure on risk perceptions varied with respondents’ Six Americas group: Concerned and Cautious/Doubtful respondents were particularly likely to show increases in risk perceptions from pre to post map, while increases for Alarmed and Disengaged respondents were small and not significant. Higher post-map risk perceptions were also associated with the identification of more vulnerable places during a map exploration task, but not with higher map interaction counts.
6.3 Lessons for communicating sea level rise and climate change

These results suggest that interactive maps of sea level rise flooding may be a good choice for communicating this hazard to audiences that are otherwise cautious or doubtful about climate change. While these groups remained less concerned about Sarasota sea level rise than the Alarmed or Concerned, their risk perceptions rose significantly after interacting with the map, to levels that were equal to or above their concern about sea level rise in general and much above their overall concern about climate change. Moreover, for the audience and map tasks in this study, these groups’ more doubtful climate change beliefs did not appear to result in motivated reasoning when selecting a sea level rise amount or performing map reading tasks. In line with Kahan et al. (2013) and Bruin et al. (2014), such flood maps therefore do appear to be a promising means of raising awareness and concern about local climate change impacts among the Cautious and Doubtful.

Before disseminating messages about local climate change impacts, climate change communicators should also carefully consider possible interactions between the specificity and detail of these messages and the distance of audiences from these impacts. Based on the results of this study, low-detail messages about climatic impacts in specific places – such as passing mentions of sea level rise in a particular place – appear unlikely to engage audiences’ concern, regardless of their distance. For nearby audiences, such messages may encourage spatial optimism. For distant audiences, if the place is not well known (as was the case in this study), audience members may lack sufficient information about the place to form an opinion about its exposure to climate hazards. More detailed messages about local climate impacts – such as the interactive sea level rise map used in this study – appear to hold potential for reducing spatial optimism in nearby audiences. Such messages may
also be particularly effective in increasing risk perceptions for distant audiences who previously knew little about climate impacts in the featured place. However, the more modest increases for nearby respondents may be of greater interest to climate change communicators, since these respondents may be better positioned to act on their increased concern.

6.4 Limitations and future research

Future research should address several of this study's limitations. Additional studies could explore whether my results for map reading tasks and risk perceptions hold for non-student samples and for maps of different places and climate hazards. Because my findings for risk perceptions were generally consistent with the literature, I expect they will likely hold for Alarmed, Concerned, Disengaged, and Cautious/Doubtful respondents from other samples, but this assumption should be tested. Moreover, it would be useful to repeat this study with a sample containing Dismissive respondents; compared to the Cautious/Doubtful, I expect that such respondents would be more likely to exhibit motivated reasoning on the map reading task, and less likely to increase their risk perceptions after map exposure. Research should also explore how altering the presentation of uncertainty on sea level rise maps affects responses – both to the map reading and risk perception items considered in this dissertation, and to more complex decision making tasks.

In addition to addressing these limitations, my future research could explore results from questions that were included in the survey but are not discussed in this dissertation (i.e., questions marked “NA” in Tables 1.2-1.4). In particular, I would like to consider: which
types of places respondents identified as most likely to be severely disrupted by Sarasota sea level rise; the flood depths and probabilities that they estimated for these places; and the importance that they assigned to protecting them (survey part two, Table 1.3). Consideration of these results could help explain why the accuracy of flood depth and probability estimates was found to vary with assigned map location in Chapter 4 of this dissertation. I would also like to further explore the Google Analytics data I gathered on map interactions (including pans, zooms, interactions with the slider tool for selecting sea level rise amounts, and clicks on informational links). This research could build on existing discussions of how interactive elements can be used to communicate uncertainty – both in general (Roth 2012 and 2013) and on sea level rise maps (Kostelnick et al. 2013 and Chapter 2 of this dissertation). Such research could also compare map interactions across Six Americas groups. Finally, I could also explore possible relationships between the results reported in this dissertation and respondents’ emotions while interacting with the map (survey part two, Table 1.3) as well as their knowledge about sea level rise (survey part three, Table 1.4).

6.5 Recapitulation

By continuing to explore these questions, I hope to build on the results presented here. Interactive sea level rise maps appear to be easily understood, and may help audiences that are doubtful about climate change recognize a risk to coastal communities that they would otherwise ignore or discount. These maps may also address spatial optimism by bringing nearby audiences’ risk perceptions for local sea level rise back into line with their level of concern about sea level rise in general. These results confirm
interactive sea level rise maps’ communication potential. Future research should explore their effectiveness for other populations, locations, and climate hazards.
References


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Appendix

COMPLETE SURVEY
INFORMED CONSENT FORM FOR SOCIAL SCIENCE RESEARCH
The Pennsylvania State University

Title of Project: Your Views on Sea Level Rise in Sarasota Bay

Principal Investigator:
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Advisor:
Dr. Brent Yarnal
Penn State Department of Geography
302 Walker Building
University Park, PA 16802
814-863-4894, albar@essc.psu.edu

Purpose of Study: This survey has been designed to help researchers learn how different audiences interpret and respond to maps of sea level rise. It is hoped that this research will help improve the communication of information about this hazard.

Procedures to Be Followed: You will be asked to answer up to 55 multiple choice questions on a survey, including several questions about an interactive map of sea level rise in the Sarasota metro area. You will also have an opportunity to submit anonymous feedback.

Duration: It should take less than 30 minutes to complete this survey.

Statement of Confidentiality: Your participation in this research is confidential. While every effort will be made to ensure that the technology used protects your confidentiality, no guarantees can be made regarding the interception of data sent via the Internet by any third parties. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

Right to Ask Questions: Please contact David Retchless at 814-865-3434 or dpr173@psu.edu with questions or concerns about this study.

Extra Credit for Participation: Your instructor will offer extra credit equivalent to 1% of your final grade for completing this survey. NOTE: TO RECEIVE THIS EXTRA CREDIT, YOU MUST ENTER YOUR NAME IN THE BLANK BELOW THIS CONSENT FORM SO THAT WE HAVE A RECORD OF YOUR PARTICIPATION.

If you do not wish to participate in the survey but would still like an equivalent amount of extra credit (1%) you may complete a 30 minute, 1-page written assignment on sea level rise. To learn more about this alternative assignment, please click here.

Voluntary Participation: Your decision to be in this research is voluntary. You do not have to answer any questions you do not want to answer. You can stop at any time without any penalty. To stop, close the browser window for this survey.

You must be 18 years of age or older to take part in this research study.

Completion and return of the survey implies that you have read the information in this form and consent to take part in the research. Please print this form to keep for your records.

CONSENT: By entering your name below, you indicate that you are at least 18 years old, have read the above information, and agree to participate in this survey.

Please enter your name correctly. The name that you enter will be used to assign extra credit for participation in this survey.

Your Name (first and last):
Beliefs and Feelings about Environmental Hazards

Please answer the following questions about sea level rise and related hazards.

Which of the following best describes your beliefs and feelings about climate change?

- **Alarmed**: "I am very concerned about climate change and think the government and individuals need to act now."
- **Concerned**: "I am concerned and think we need to take action but we have time to decide what the appropriate responses should be."
- **Cautious**: "I suspect that climate change is happening but I am not certain. We have time to make careful decisions about when and whether to respond."
- **Disengaged**: "I have not really thought much about it."
- **Doubtful**: "I suspect that climate change is NOT happening but I am not certain. I am concerned more about overreacting to climate change."
- **Dismissive**: "I do not believe climate change is occurring and certainly do not think humans have caused it. So, I'm not motivated to take or support action to address it."

How much risk do you believe that each of the following hazards poses to human health, safety, or prosperity? Answer on a scale from 0 ("no risk") to 10 ("extreme risk").

<table>
<thead>
<tr>
<th></th>
<th>No risk</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>0</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>0</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

This survey focuses on the effects of sea level rise flooding on the Sarasota metro area. Located on the coast of southwest Florida, the Sarasota metro area (including the cities of Bradenton, Sarasota, Venice, and Northport and surrounding suburbs) is home to over 700,000 people.

How familiar are you with the Sarasota, Florida metro area?

- Totally unfamiliar, have never heard of Sarasota before now
- Have heard of Sarasota, but have never looked for it on a map
- Have looked at maps of Sarasota once or twice
- Have looked at maps of Sarasota more than once or twice but have never visited there
- Have actually visited Sarasota once
- Have visited Sarasota more than once
- Have lived in Sarasota before or have second/family home there
- Currently live in Sarasota or surrounding metro area

Please use any knowledge you may have about the Sarasota area to answer the following question.

How much risk do you believe that sea level rise poses to human health, safety, or prosperity in the Sarasota metro area during this century? Answer on a scale from 0 ("no risk") to 10 ("extreme risk").

<table>
<thead>
<tr>
<th></th>
<th>No risk</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level rise in the Sarasota metro area</td>
<td>0</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>
Video Tutorial for Sea Level Rise Map
This video tutorial provides an introduction to the interactive map that you will use to explore Sarasota-area sea level rise.

The next several screens will ask you to use an interactive map to explore the effects of sea level rise flooding in the Sarasota metro area.

To learn how to use this map, please watch the below video tutorial.
Map Tutorial: Step-by-Step Instructions

This tutorial provides an introduction to the interactive map that you will use to explore Sarasota-area sea level rise.

The interactive sea level rise map will load in the frame below.

Step-by-step instructions describing how to use this map will automatically appear in a popup window when the map loads. Review the instructions carefully, then click the 'x' button on the instructions window (or anywhere else on the map) to close it.

After reading the instructions, please take a few minutes to explore the map. Begin by setting the slider to '0 ft' to see where the present-day shoreline is at high tide. Then use the year selector (for 2050 or 2100), slider (for 0-7 ft sea level rise), and flood depth and probability views to explore how sea level rise will move this shoreline inland over the course of this century.

After you are done exploring, please answer the question below the map.

INSTRUCTIONS

Follow these steps to show the flooding that 0-7 feet (ft) of sea level rise may cause in the Sarasota metro area. The red numbers show which part of the interface to use to perform each step.

Click or tap on a step for expanded instructions.

- **Step 1**: Select a year
- **Step 2**: Select a sea level rise amount
- **Step 3**: Select a view
- **Step 4**: Set the transparency

To see these instructions again, click the "?" icon in the lower right-hand corner of the "Sea Level Rise" window.

Which of the following types of places in the Sarasota area do you expect to experience sea level rise flooding by 2100?

Base your answer on your exploration of the map and any knowledge you may have of the Sarasota area.

Check any that apply:

- Homes or other places of residence
- Schools
- Workplaces
- Roadways or other transportation infrastructure
- Recreational areas
- Natural areas
- Cultural spaces
- Other critical infrastructure (hospitals, fire or police stations, utility network)
Sea Level Rise at the Dolphin Fountain

Please take a moment to read the information in the pop-up window about the Dolphin Fountain. Then use the map to answer the questions beneath it about sea level rise at this location.

The Dolphin Fountain at Bayfront Park is one of the best-known public art installations in Sarasota and a symbol of the city. In addition to public art, Bayfront Park (also known as Island Park) includes amenities such as a restaurant, fishing, playgrounds, and green space. Its location along the waterfront between downtown Sarasota and Sarasota Bay provides those living, working, or visiting downtown with easy access to bay-front recreation.

For the Dolphin Fountain (location indicated by the white outline), what is the average depth of sea level rise flooding within the outlined area most likely to be by...

- 2050
- 2100

<table>
<thead>
<tr>
<th>Depth of Sea Level Rise (ft)</th>
<th>No Flooding</th>
<th>0-1 ft</th>
<th>1-2 ft</th>
<th>2-3 ft</th>
<th>3-4 ft</th>
<th>4-5 ft</th>
<th>5-6 ft</th>
<th>6-7 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

For the Dolphin Fountain (location indicated by the white outline), what is the average probability of sea level rise flooding within the outlined area most likely to be by...

- 2050
- 2100

<table>
<thead>
<tr>
<th>Depth of Sea Level Rise (ft)</th>
<th>Very Low (≤5% chance)</th>
<th>Low (5-20% chance)</th>
<th>Moderate (20-50% chance)</th>
<th>High (50-60% chance)</th>
<th>Very High (&gt;60% chance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In your opinion, how important is it to protect the Dolphin Fountain from sea level rise?

- **Very important**: This place is clearly threatened by sea level rise this century and is essential to the city.
- **Somewhat important**: This place will probably be threatened by sea level rise this century, but only minor steps should be taken to protect it.
- **Not very important**: This place may be threatened by sea level rise this century, but it is not worth protecting.
- **Not at all important**: This place is unlikely to be threatened by sea level rise this century.

If you need to view the instructions again while using the map, click the [] button in lower-right corner of the "Sea Level Rise: Sarasota Bay" window. You can also find more information about sea level rise by clicking on the "Learn More" tab at the left edge of the map.
Sea Level Rise at St. Armand’s Circle

Please take a moment to read the information in the pop-up window about St. Armand’s Circle. Then use the map to answer the questions beneath it about sea level rise at this location.

**Sea Level Rise: Sarasota Bay**

Drag slider to select a sea level rise amount

(height of water above present-day high tide):

- Possible by 2100

By 2100, 0 to 6 feet of sea level rise is possible. 1.5 to 3.5 feet is likely.

**St. Armand’s Circle**

Home to more than 130 upscale shops and restaurants, St. Armand’s Circle is both a major tourist attraction and a popular destination for locals. The circle is located on historic St. Armand’s Key, one of several barrier islands to the west of downtown Sarasota. The key was first developed as a commercial district by circus magnate John Ringling, and is connected to the mainland by the Ringling Causeway. Today, the circle’s shopping, dining, and historic gardens are a major draw for tourists, who contribute over a billion dollars annually to the Sarasota area’s economy. To protect this economic and cultural resource from flooding, pumps have been installed to remove water from the circle during storms and unusually high tides.

If you need to view the instructions again while using the map, click the (?) button in lower right corner of the "Sea Level Rise: Sarasota Bay" window. You can also find more information about sea level rise by clicking on the "Learn More" tab at the left edge of the map.

**For St. Armand’s Circle (location indicated by the white outline), what is the average depth of sea level rise flooding within the outlined area most likely to be by...**

<table>
<thead>
<tr>
<th>Depth of Rise (ft)</th>
<th>0-1 ft</th>
<th>1-2 ft</th>
<th>2-3 ft</th>
<th>3-4 ft</th>
<th>4-5 ft</th>
<th>5-6 ft</th>
<th>6-7 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**For St. Armand’s Circle (location indicated by the white outline), what is the average probability of sea level rise flooding within the outlined area most likely to be by...**

- **Very Low** (5-20% chance)
- **Low** (20-50% chance)
- **Moderate** (50-80% chance)
- **High** (80-100% chance)
- **Very High** (100% chance)

<table>
<thead>
<tr>
<th>Probability Level</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (5-20%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low (20-50%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moderate (50-80%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High (80-100%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Very High (100%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**In your opinion, how important is it to protect St. Armand’s Circle from sea level rise?**

- **Very important**: This place is clearly threatened by sea level rise this century and is essential to the city.
- **Somewhat important**: This place will probably be threatened by sea level rise this century, but only minor steps should be taken to protect it.
- **Not very important**: This place may be threatened by sea level rise this century, but it is not worth protecting.
- **Not at all important**: This place is unlikely to be threatened by sea level rise this century.
Sea Level Rise at Siesta Beach

Please take a moment to read the information in the pop-up window about Siesta Beach. Then use the map to answer the questions beneath it about sea level rise at this location.

Siesta Beach is a popular fun in the sun spot for locals and visitors alike. It is perhaps best known for its famous "powdered sugar" sand. Unlike the coral sand found on most beaches, the very fine, bright white sand on Siesta Beach is made of quartz which is so reflective that it remains cool underfoot even on the hottest days. Complemented with its picturesque location on Kiawah Island (a barrier island to the west of Sarasota), this sand has earned Siesta Beach many awards, including Dr. Beach's Best Beach in America in 2011. The beach's shallow waters and year-round (regardless of the weather) make it a particularly popular destination for families with young children.

For Siesta Beach (location indicated by the white outline), what is the average depth of sea level rise flooding within the outlined area most likely to be by...

<table>
<thead>
<tr>
<th>Year</th>
<th>0.1 ft</th>
<th>1.2 ft</th>
<th>2.3 ft</th>
<th>3.4 ft</th>
<th>4.5 ft</th>
<th>5.6 ft</th>
<th>6.7 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For Siesta Beach (location indicated by the white outline), what is the average probability of sea level rise flooding within the outlined area most likely to be by...

<table>
<thead>
<tr>
<th>Year</th>
<th>Very Low (≤5% chance)</th>
<th>Low (5-25% chance)</th>
<th>Moderate (25-50% chance)</th>
<th>High (50-80% chance)</th>
<th>Very High (&gt;80% chance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In your opinion, how important is it to protect Siesta Beach from sea level rise?

- **Very important**: This place is clearly threatened by sea level rise this century and is essential to the city.
- **Somewhat important**: This place will probably be threatened by sea level rise this century, but only minor steps should be taken to protect it.
- **Not very important**: This place may be threatened by sea level rise this century, but it is not worth protecting.
- **Not at all important**: This place is unlikely to be threatened by sea level rise this century.
Sea Level Rise at Tamiami Trail

Please take a moment to read the information in the pop-up window about Tamiami Trail. Then use the map to answer the questions beneath it about sea level rise at this location.

Sea Level Rise: Sarasota Bay

Drag slider to select a sea level rise amount (height of water above present day high tide):

Possible by 2100

By 2100:
- 0 to 0.5 feet of sea level rise is possible
- 0.5 to 3 feet is likely
- 3+ feet is very likely

Tamiami Trail

Carrying an average of 35,000 cars a day, the section of Tamiami Trail immediately to the north of downtown Sarasota is one of the busiest roads in the Sarasota metro area. This major north-south artery connects downtown Sarasota with the International Airport, several colleges, and cultural venues such as the Van Wezel Performing Arts Hall. Tamiami Trail also provides access to the Ringling Causeway, which serves as the main connection between downtown Sarasota and the barrier islands to the west.

For this section of Tamiami Trail (location indicated by the white outline), what is the average depth of sea level rise flooding within the outlined area most likely to be by...

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>0</th>
<th>1-2</th>
<th>2-3</th>
<th>3-4</th>
<th>4-5</th>
<th>5-6</th>
<th>6-7+</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For this section of Tamiami Trail (location indicated by the white outline), what is the average probability of sea level rise flooding within the outlined area most likely to be by...

<table>
<thead>
<tr>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (5-20% chance)</td>
</tr>
<tr>
<td>Low (20-50% chance)</td>
</tr>
<tr>
<td>Moderate (50-80% chance)</td>
</tr>
<tr>
<td>High (80-100% chance)</td>
</tr>
<tr>
<td>Very High (100% chance)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>...2050</td>
</tr>
<tr>
<td>...2100</td>
</tr>
</tbody>
</table>

In your opinion, how important is it to protect this section of Tamiami Trail from sea level rise?

- **Very Important**: This place is clearly threatened by sea level rise this century and is essential to the city.
- **Somewhat Important**: This place will probably be threatened by sea level rise this century, but only minor steps should be taken to protect it.
- **Not Very Important**: This place may be threatened by sea level rise this century, but it is not worth protecting.
- **Not at all Important**: This place is unlikely to be threatened by sea level rise this century.
Imagine that the amount of sea level rise YOU expect to occur by 2100 happened tomorrow. Using the map below, identify the place on the map where you think that this amount of sea level rise would have most disruptive impact on the daily routine of Sarasota area residents.

Once you have identified this place, mark its location by placing it between the crosshairs at the center of the map and clicking the “Choose Location” button.

While looking for your most disruptive place, remember that you can use the pan and zoom tools in the upper-right-hand corner of the map to see new areas.

If you need to view the instructions again while using the map, click the ? button in lower-right corner of the “Sea Level Rise: Sarasota Bay” window. You can also find more information about sea level rise by clicking on the “Learn More” tab at left edge of the map.

Which of the following best describes the place you marked on the map?

- Home or other place of residence
- School
- Workplace
- Roadway or other transportation network
- Recreational area
- Natural area
- Cultural space
- Critical infrastructure (hospital, fire or police station, utility network)
- Other

For your chosen location (indicated by the red placemark), what is the most likely depth of sea level rise flooding by...

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>0.1</th>
<th>1.2</th>
<th>2.3</th>
<th>3.4</th>
<th>4.5</th>
<th>5.6</th>
<th>6.7</th>
<th>No flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For your chosen location (indicated by the red placemark), what is the probability of sea level rise flooding by...

<table>
<thead>
<tr>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (5-10% chance)</td>
</tr>
<tr>
<td>Low (5-20% chance)</td>
</tr>
<tr>
<td>Moderate (20-50% chance)</td>
</tr>
<tr>
<td>High (50-90% chance)</td>
</tr>
<tr>
<td>Very High (90-100% chance)</td>
</tr>
</tbody>
</table>

In your opinion, how important is it to protect your chosen location from sea level rise?

- Very important: This place is clearly threatened by sea level rise this century and is essential to the city.
- Somewhat important: This place will probably be threatened by sea level rise this century, but only minor steps should be taken to protect it.
- Not very important: This place may be threatened by sea level rise this century, but it is not worth protecting.
- Not at all important: This place is unlikely to be threatened by sea level rise this century.
Beliefs and Feelings about Sea Level Rise in Sarasota

Now that you have used the map to explore how sea level rise will affect several places in the Sarasota metro area, please answer the following questions.

Please consider your experience interacting with the maps on previous pages when answering the following question.

How much risk do you believe that sea level rise poses to human health, safety, or prosperity in the Sarasota metro area during this century? Answer on a scale from 0 ("no risk") to 10 ("extreme risk").

<table>
<thead>
<tr>
<th>No risk</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Extreme risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level rise in the Sarasota metro area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Which one of the emotions in the diagram below best describes how you felt while interacting with the sea level rise maps?

Choose an emotion, then click on a circle in the "spoke" adjacent to this emotion to rate how intensely you felt it. Larger circles indicate more intense emotion; smaller circles indicate less intense emotion.

If you did not feel any emotion at all, please click the upper half-circle in the center of the wheel (labeled "None"). If you experienced an emotion that is very different from any of the emotions in the wheel, please click the lower half-circle (labeled "Other").

The above instrument, called an Emotion Wheel, is used to measure as precisely as possible the type and intensity of the emotion you experienced while interacting with the sea level rise maps in this survey. Note that the words provided often represent a large "emotion family" and may thus refer to a whole range of similar emotions. Thus, the Anger family also covers emotions such as rage, irritation, annoyance, indignation, fury, frustration, or being upset or mad; the Fear family includes anxiety, worry, apprehensiveness, fright, or panic. Some of the words, such as love, hate, or guilt, can be used to refer to long-term affective states, but in this case checking those labels means that you have had a salient temporary feeling that belongs to the families of Love, Hate, or Guilt. Different intensities often correspond to different members of an emotion family. Thus, irritation can be considered a less intense emotion belonging to the Anger family and anxiety a less intense emotion belonging to the Fear family.
Knowledge about Changing Sea Levels
To the best of your ability, please answer the following questions about the causes, history, and future of sea level change.

**Sea level has remained fairly constant throughout Earth's history.**
- True
- False
- Don't know

**Melting sea ice has the potential to raise sea level by several feet.**
- True
- False
- Don't know

**Other than melting glaciers and ice sheets, which of these factors has made the largest contribution to the rise in global sea level over the past 100 years?**
- Warming of ocean surface waters
- Melting sea ice
- Increased groundwater extraction
- Don't know

**During the last ice age, about 10,000 years ago, when ice sheets were at their maximum extent, sea level was:**
- About 400 feet lower than at present
- About 400 feet higher than at present
- About the same level as today
- Don't know

**Over the next century, sea levels in most parts of Florida are expected to rise:**
- Much less than the global average
- About the same as the global average
- Much more than the global average
- Don't know
Map and Math Skills
Please answer the following questions about your comfort and proficiency with maps and math.

**How comfortable and competent do you feel in general when using maps?**

- Very uncomfortable - I feel very unskilled
- Slightly uncomfortable - I’m willing to try
- I can handle map tasks - I’m neutral about how I feel about them
- Fairly comfortable - I can use maps reasonably well
- Very comfortable - I’m great at map tasks

**How much do you enjoy using or looking at maps?**

- I hate using maps, avoid them as much as possible.
- I dislike using or looking at maps, although I’ll use them when I have to.
- I neither like nor dislike maps, they’re a fact of life.
- I somewhat enjoy looking at maps, although I don’t do it too much simply for recreation.
- I really enjoy maps for their own sake, I could spend significant amounts of time just looking at an atlas or geography book just for the fun of it.

For each of the following questions, please check the box that best reflects how good you are at doing the following things:

<table>
<thead>
<tr>
<th></th>
<th>Not at all good</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Extremely good</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>How good are you at working with fractions?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>How good are you at working with percentages?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>How good are you at calculating a 15% tip?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>How good are you at figuring out how much a shirt will cost if it is 25% off?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
### Your Worldview

Please answer the following questions about your general outlook on life in our society.

**People in our society often disagree about how far to let individuals go in making decisions for themselves. How strongly do you agree or disagree with each of these statements?**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Moderately disagree</th>
<th>Slightly disagree</th>
<th>Slightly agree</th>
<th>Moderately agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>It’s not the government’s business to try to protect people from themselves.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Government should put limits on the choices individuals can make so they don’t get in the way of what’s good for society.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>The government should do more to advance society’s goals, even if that means limiting the freedom and choices of individuals.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Sometimes government needs to make laws that keep people from hurting themselves.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>The government interferes far too much in our everyday lives.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>The government should stop telling people how to live their lives.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**People in our society often disagree about issues of equality and discrimination. How strongly do you agree or disagree with each of these statements?**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Moderately disagree</th>
<th>Slightly disagree</th>
<th>Slightly agree</th>
<th>Moderately agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrimination against minorities is still a very serious problem in our society.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Our society would be better off if the distribution of wealth was more equal.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>We need to dramatically reduce inequalities between the rich and the poor, whites and people of color, and men and women.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Society as a whole has become too soft and feminine.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>We have gone too far in pushing equal rights in this country.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>It seems like blacks, women, homosexuals and other groups don’t want equal rights; they want special rights just for them.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
More about You

Please answer a few additional questions about you, your residence, and your experience with flooding.

Which of the following best describes your living situation?
- Homeowner
- Renter
- Living with parent or guardian
- Living in a dorm or other college housing
- Other

How far is each of the following places from the ocean? Answer using your best estimate.

<table>
<thead>
<tr>
<th></th>
<th>Less than a quarter mile</th>
<th>Less than half mile</th>
<th>Less than a mile</th>
<th>Less than five miles</th>
<th>Less than ten miles</th>
<th>Ten miles or greater</th>
<th>Not applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Your parent(s) or guardian(s) home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Your workplace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Your school</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

? If your parents or guardians live in different places, answer based on the parent or guardian who lives closest to the ocean.

Have you personally experienced flooding in your local area recently or not?
- Yes
- No
- Don't know

Has flooding ever damaged property belonging to you or your family?
- Yes
- No
- Don't know

What is your gender?
- Male
- Female
- Other

How old are you?
- under 18
- 18-24
- 25-34
- 35-54
- 55+

What is the highest level of education you have completed?
- 12th grade or less
- Graduated high school or equivalent
- Some college, no degree
- Associate degree
- Bachelor's degree
- Post-graduate degree

How did you learn about this survey?
- From my college or university instructor
- From friends or family
- From a website or other online source
Thank you! Press submit to complete your survey.

Thank you for taking this survey. Your responses will be used to help us understand how different audiences respond to maps of sea level rise. If you would like to spend more time exploring the sea level rise map used in this survey, a copy is available at http://sir-viewer.s3-website-us-east-1.amazonaws.com/. You are welcome to share this link with others.

If you would like to learn how well you scored on the test of sea level knowledge contained in this survey, you may want to try NASA's Sea Level Quiz. Many of this survey's questions about sea level knowledge were taken from this Quiz.

Please remember to press submit to complete your survey.

If you have any questions about this survey, or would like to request a copy of the results, please email David Retchless at dpr173@psu.edu. You may also use the form below to submit anonymous comments.
Vita

David Retchless

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EDUCATION

PhD, Geography. The Pennsylvania State University, August 2015
  • Dissertation: Understanding Local Sea Level Rise Risk Perceptions and The Power of Maps to Change Them: The Effects of Distance, Detail, and Doubt

MSc, Geography. The Pennsylvania State University, August 2011
  • Thesis: Public Perceptions of Spatial Analogs for Climate Change: A Survey of Centre Region, Pennsylvania Residents (Brent Yarnal, advisor)

BA, Program of Liberal Studies, University of Notre Dame, May 2004

PEER-REVIEWED PUBLICATIONS