THE CARTOGRAPHY OF CLIMATE CHANGE IN
UNITED STATES MEDIA

A Dissertation in
Geography
by
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Abstract

Climate change is a multidimensional, complex, spatially uneven, and changing problem which has significant impacts to the environment and society. Maps are a particularly powerful means by which to communicate these impacts, and the media and government outreach programs are often tasked with communicating to audiences to bridge the gap and translate between science and the public through maps. However, it is unclear how government and the media attract readers, reduce complexity, and make the issue of climate change tangible and less abstract for map readers. This research explored the decisions expert mapmakers made to connect with scientists and translate knowledge related to climate change to audiences through maps. Using interviews with expert mapmakers at major media organizations and government agencies, this research illustrated how design decisions were made to create climate change maps, and what aspects of these map designs made them vivid for audiences by bringing the topic of climate change to life. Finally, using content analysis this dissertation research identified the types of climate change maps that employed vivid designs that may connect best with audiences to be persuasive and understandable. Results from this dissertation research identified that mapmakers first decided on a story they wanted to tell through generating ideas with colleagues and then used “the story” as a decision-making structure which determined how they communicated with scientists to get data and distill science into meaningful information in a map design. Vivid climate change maps were those which employed visual salience, visible change, color use which aligned with cultural and emotional connotations, cartographic best practices, and novel designs. These vivid maps were often designed by elite media organizations who balanced cartographic best practices with new and novel designs to tell in-depth stories to readers. This dissertation research illustrated how cartographers can serve as translators to improve the connections between science and the people for whom science asks its questions.
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Chapter 1

Introduction

1.1 Introduction

Climate change is a multidimensional, complex, spatially uneven, and changing problem which has significant impacts on the environment and society (IPCC 2014). Because climate change is difficult to see on a human perceptual scale, it is challenging to see the impacts of human actions of the past and thus for humans to make behavioral changes towards mitigation and adaptation in the future. In addition, climate change has become increasingly politically contentious. Climate researchers along with other scientists face the challenge of making their science relatable, tangible, and understandable for a broad audience. The media and government outreach programs have been tasked with communicating to wide audiences to bridge the gap and translate between science and the public (Boykoff and Boykoff 2007, Moser and Dilling 2011, Hannigan 2014). As such, these communication groups must balance the complexity of the science with accurate and understandable communication.

Maps are used across media, science, and government in an effort to communicate, attract readers, reduce complexity, and make the issue of climate change tangible and less abstract for their readers. Maps are a useful and powerful means to convey the causes, impacts, mitigation, and adaptation strategies that illustrate the geographic disparities inherent in a changing climate. These maps of climate change allow mapmakers to illustrate the connections between humans and the ever-changing environment, and their availability on the web allows for these maps to be disseminated widely. Maps have already been shown to be effective in communicating climate change (Retchless 2015). Additionally, within the cartographic research community, calls have been made for cartographers to focus on maps that are relevant to the environment and society (ICA 2016, Robinson et al. 2017). Much of the research on climate change mapping has focused on specific types of maps (Retchless 2014), geovisualization tools for specific map readers (Retchless 2015), the cartographic failures (McKendry and Machlis 2009), or the display of uncertainty (Kaye et al. 2012, Retchless and Brewer 2016, Johannsen et al. 2018). However, little research has explored how expert mapmakers created maps which resonate with audiences or classified the elements necessary to create these types of maps that tell stories and are vivid to their audiences. In this way, this research expanded on previous research to explore how and what decisions expert mapmakers made to connect with and translate to broad audiences through maps.
1.2 Intellectual contributions and dissertation goals

This dissertation investigated the design processes and design aspects of climate change maps in the media. The goal of this dissertation was to establish a new direction for cartography as a translational discipline: a discipline focused on creating tangible products that directly address societal challenges. Climate change, in turn, served as an excellent case study by which to explore these decisions and designs.

This research advanced understanding within cartography and climate change communication by improving our knowledge of how to design maps of climate change for the public. Climate change presents challenges to cartographic communication because it is multi-scale, multivariate, dynamic, complex, and uncertain, and because there has been increasing political contention related to the topic. Because of this contention, cartography and climate change communication research needed to explore ways to convey this complex phenomenon and identify how these maps could be persuasive toward future actions related to sharing information for mitigation and adaptation. Many professional cartographers have been employed as visual and data journalists across media organizations and government agencies. These individuals have explored ways in which to create visual spatial representations of climate change which connect with their wide audiences. Specifically, this dissertation investigated how these climate change mapmakers in United States media and government agencies balanced complexity and communication to translate this information to the public in meaningful ways.

1.3 Structure of dissertation

The structure of the dissertation is as follows. The introductory chapter of this dissertation sets out the objectives, goals, research questions, intellectual contributions, and a general literature review for the dissertation. The empirical chapters which follow (Chapter 2, 3, and 4) were prepared as single-author manuscripts to be submitted individually for publication as peer-reviewed articles. Because these papers were prepared as distinct manuscripts, each includes its own introduction, literature review, methods, results, and conclusions. Chapter 2 will be submitted to The International Journal of Geo-Information for a special issue on storytelling with maps. Chapter 3 will be submitted to The Cartographic Journal. Chapter 4 will be submitted to the Cartography and Geographic Information Science journal. Chapter 5 serves as both the conclusion and a working draft of a future research agenda related to how cartography might reimagine itself as a translational discipline which focuses on bridging the gap between science and the public.
1.4 Research objectives and questions

There were three primary objectives of this dissertation addressed in the chapters which follow. The objective of Chapter 2 was to understand how climate change mapmakers make decisions and design maps of climate change. The objective for Chapter 3 was to illustrate the ways in which the concept of “vividness,” a term from the communication domain, can be extended to the cartographic domain for improving communication of complex spatial topics which have broad impacts on society. Vividness is a term used in the communication domain to describe information “likely to attract and hold our attention and to excite the imagination to the extent that it is (a) emotionally interesting, (b) concrete and image provoking, and (c) proximate in a sensory, temporal, or spatial way” (Nisbett and Ross 1980, 45). It has been theorized to be persuasive (Taylor and Thompson 1982). The objective of Chapter 4 was to empirically evaluate how the aspects of vividness in maps, established in Chapter 3, were employed in climate change maps. Table 1.1 presents the objectives and research questions for each of the following empirical chapters.

1.5 Literature review

This dissertation draws on and makes contributions to literature in cartography, specifically cartographic communication and dynamic mapping, as well as climate change communication, by evaluating the impact of cartographic design on communication through maps. Since literature on these topics informs the whole dissertation, I review this background context in this section. Included in each of the empirical chapters is a shorter and more specific literature review related to each manuscript.

1.5.1 Academic cartography

In the United States, Arthur Robinson’s dissertation and later publication as The Look of Maps (1952) initiated empirical research on cartographic design for communication. His research and other subsequent research focused on the use of cognitive theories and methods for understanding maps and mapping and had roots in psychology and information processing theory (MacEachren 1995, Montello 2002). The mid-20th Century also saw French cartographer Jacques Bertin (1967|83) establish the visual variables as the building blocks of cartographic design of static maps through his study of semiotics. These variables describe the different graphic elements cartographers have in their toolbox to create the design of a map. The original set by Bertin has since been modified and extended (e.g., MacEachren 1995) and the common set of variables now includes: size, shape, hue, saturation, lightness, spacing, perspective height, and arrangement (Slocum et al. 2009). Later work made theoretical connections between the cognitive and semiotic approaches
(MacEachren 1995), and research across both domains established which data types should be appropriately represented by each visual variable (Brewer 1994, Garlandini and Fabrikant 2009). The late 1980s also saw the establishment and growth of critical cartography beginning with J.B. Harley’s (1989) “Deconstructing the Map” which drew on critical theory, specifically Foucault, and called for the evaluation of representations of power within maps. What followed was a new stem of cartography which focused on cartographers critically evaluating who produces map content and pushed the field to evaluate the potential for and enable a democratization of mapping.

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<td>changes related to creating these maps</td>
<td>complex climate data understandable to wide audiences?</td>
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<td>2) How were design decisions made to create these maps of climate change?</td>
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<td>3) To what extent did the best practices of the practicing mapmakers follow the</td>
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<td>Illustrated ways in which the concept of vividness could be extended to the</td>
<td>guidelines from academic research?</td>
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<td>cartographic domain</td>
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<td>Evaluated how the aspects of vividness were and were not employed across</td>
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<td>climate change maps</td>
<td>readers?</td>
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<td>2) What aspects of climate change did these maps portray and what aspects of</td>
</tr>
<tr>
<td></td>
<td>cartographic design did these maps employ?</td>
</tr>
<tr>
<td></td>
<td>3) Did these maps convey climate change vividly and which organizations produced</td>
</tr>
<tr>
<td></td>
<td>vivid maps?</td>
</tr>
</tbody>
</table>

**Table 1.1.** Outline of empirical chapters (Chapters 2-4), objectives, and research questions.

Maps can now be dynamic, possible through the addition of animation and interactivity, and the data used to create these maps now comes from a more diverse set of producers. Interactive maps allow map readers, often referred to as map users in the interactive domain, to explore geographic data using a variety of *interaction operators* including pan, zoom, and
mouse clicks on the map to retrieve information within the map interface (Roth 2013). Similar to the visual variables, these interaction operators are the tools available to the cartographer when making a map interactive. Animated maps are maps that often illustrate change through movement (Thrower 1959, Cybulski 2016). Within the animated domain, cartographers have a set of dynamic variables at their disposal which include: duration, rate of change, and order (DiBiase et al. 1992). Finally, data to create these maps in both the static and dynamic domains not only comes from government agencies and private entities, but now can be user-generated through a combination of volunteered geographic information (VGI) and other (non-volunteered) user content as devices, such as smartphones, increasingly serve as sensors to generate geographic data (Elwood et al. 2012).

Research in the dynamic domain, which includes both interaction and animation has focused on geovisualization, a means for experts to explore unknowns (MacEachren 1995), and more recently on geovisual analytics as a means for supporting analytical reasoning and informed decision making (Andrienko et al. 2007, Keim et al. 2008, Roth et al. 2017). Much of this research on dynamic maps has focused on maps for experts. However, dynamic maps are no longer limited only to expert map users, but are available for communication and exploration of geographic information by a general audience (e.g., Bhowmick et al. 2008, Vincent et al. 2018). Additionally, with the move to the dynamic domain, methods have expanded beyond cognitive experiments with quantitative analyses, to include qualitative and mixed method approaches (Suchan and Brewer 2000). The influx of these new mapping tools and techniques which are primarily web-based make the development of these dynamic maps easier; however, static maps are still widely available.

Recent research agenda articles in academic cartography pushed the discipline beyond its well-established past. A special issue on Envisioning the Future of Cartographic Research identified key themes and future research questions of importance to the cartographic research community given that maps and cartography are more 1) dynamic, 2) insightful, 3) responsive, and 4) diverse than ever before (Griffin et al. 2017). There are many calls in these agenda articles. Specifically related to this dissertation research are calls to move beyond experimental methods and for cartographers to address challenges related to designing maps and using geographic data which is meaningful to society (Robinson et al. 2017). These “maps that matter” are those which illustrate problems which are important to humankind and sustainability. They are maps which are designed to pique interest, are tacitly understandable, and “generate insights from complex, large, unstructured, varied data on problems that have broad impacts to society and our environment” (Robinson et al. 2017, 34). This dissertation research specifically investigated how practicing cartographers have created maps that matter for their broad audiences by focusing on the specific case of climate...
change which draws from research in science communication and specifically climate change communication.

1.5.2 Climate change communication

Climate change communication draws from health, risk, and science communication theory (Nerlich et al. 2010). It also presents its own challenges to communication, related to the invisible causes, distant impacts, delayed or absent gratification for action, complexity and uncertainty of the science, and our own self-interests toward the status quo (Moser 2010, Nerlich et al. 2010). Climate change communication, while a nascent field, is large and spans the domains of psychology, history of science, media studies, communication sciences, and geography.

Despite opposition from some climate change communication researchers, many researchers still rely on the knowledge-deficit theory for justification for providing more and more information to the public on climate change. This theory posits a progression from information, to awareness, to concern, and finally to a response or action. Many scientists latch on to this theory to describe the failure of communication as that of lack of education (Cagle and Tillery 2015). Some research found that more knowledge actually led to less action towards mitigation or adaptation to climate change (e.g., Kellstedt et al. 2008), while other studies (e.g., Nolan 2010) found a correlation between knowledge and planned behavioral change. In addition, calls within the climate change communication research community have focused on avoiding viewing “the public” with one broad stroke. Instead, researchers have advocated for providing different information to individuals based on other factors including, a person’s emotions (Joffe 2008, Otieno et al. 2014) and connection to the environment (Schultz 2002), as well as their stage of behavior change (unawareness, awareness, concern, and response) (Chess and Johnson 2007, Nerlich et al. 2010).

Research in visual communication revealed that graphics and pictures are integral to climate change communication (van der Linden et al. 2014, Harold et al. 2016). These visuals are used to raise awareness by reducing the complexity of the science for a public audience (Weingart et al. 2000, Boykoff and Boykoff 2007, Smith and Joffe 2009, DiFrancesco and Young 2010, Manzo 2012). Recent research established guidelines on effective visual communication of climate change (Harold et al. 2016). These guidelines focused on four key aspects: 1) directing visual attention, 2) reducing complexity, 3) supporting inference making, and 4) integrating text and graphics. These guidelines are applicable to maps of climate change; however, the study by Harold and others did not specifically address maps which have their own set of challenges to create effective communication. Instead, a few cartographic scholars have studied the connection between cartography and climate change communication which is described in the next section.
1.5.3 Cartographic climate change communication

Research in both cartography and climate change communication inform climate change mapping. Research specifically connecting climate change and cartographic design has been limited to a few studies. Past research in this domain primarily focused on cartographic design of climate change maps by critiquing the design of maps in the IPCC reports (McKendry and Machlis 2009), creating new point symbols for climate change impacts (Stoimenova 2011), and by establishing guidelines for illustrating uncertainty (Kaye et al. 2012, Retchless and Brewer 2016, Johannsen et al. 2018). Recent research connected aspects of mapping with established issues related to climate change noted in psychology research, including: motivated reasoning, spatial optimism bias, and individual differences in how map readers reacted and changed their views of climate change using interactive maps of sea level rise (Retchless 2015, Retchless 2017). Results from Retchless’ research, in particular, indicated that maps were effective tools for communicating climate change and provided a starting point for more cartographic research in climate change communication. Combinations of interactivity, animation, and static mapping provide cartographers with an extensive toolset to communicate climate change and is a domain ripe for continued empirical research.

1.6 Summary of empirical chapters

The three empirical chapters of this dissertation illustrate how maps of climate change were designed by expert mapmakers in United States media and government agency outreach programs (Chapter 2), how these mapmakers created emotional interest and vividness in their map designs (Chapter 3), and the extent to which different media organizations and government entities created vivid climate change map designs which were meaningful to audiences (Chapter 4). This final section of Chapter 1 provides a brief summary of the three empirical chapters, which are also summarized in the conclusion in Chapter 5.

1.6.1 Chapter 2: Expert climate change mapmaking in the United States

In the first study, Chapter 2, I evaluated the design processes and decisions related to how maps of climate change were made to communicate to large audiences. Previous research saw a disconnect between communication science and practicing communicators. Calls were made to understand the choices of communication practitioners to better connect science with practice (Kahan 2013). In this paper, I evaluated the current practices and design decisions which were made by mapmakers at The New York Times, National Geographic, NASA, and NOAA through a series of interviews. I compared these best practices to those called for in the academic literature to evaluate the differences (e.g., Harold et al. 2016). The results of this research illustrated that audience, purpose, and the development of the “story”
told through the map provided a decision-making structure by which the mapmaker chose how to make the mapped data accessible for readers. In addition, it was clear from the interviews that many of these mapmakers were aware of academic research related to cartographic design and climate change communication and had attempted to incorporate some of the lessons from that research into their designs.

1.6.2 Chapter 3: Elements of vivid cartography

In Chapter 3, I presented the concept of vividness from the advertising and psychology literature. Vivid content has been defined as content which is “likely to attract and hold our attention and to excite the imagination to the extent that it is (a) emotionally interesting, (b) concrete and image provoking, and (c) proximate in a sensory, temporal, or spatial way” (Nisbett and Ross 1980, 45). Vivid content is theorized to be persuasive to audiences (Taylor and Thompson 1982). I reviewed how vividness has been defined in other domains, and how it might be connected to literature in cartography. I proposed an extension of the definition to the cartographic domain based on a series of interviews I conducted with expert mapmakers at government agencies and media organizations, where I asked about the creation of maps that matter, in other words, vivid maps, for their audiences. The results of Chapter 3 were a set of aspects of a vivid map which were supported in the cartographic and data visualization literature.

1.6.3 Chapter 4: Cartographic analysis of compelling climate change communication

In the final empirical chapter, I used content analysis to evaluate a set of 242 maps of climate change from the United States media for the use of vividness aspects from Chapter 3. This research drew on previous research related to the potential for vividness to be persuasive. Using content analysis and non-metric multidimensional scaling, this research revealed that only a few maps employed and balanced the vividness attributes. In general, most of the maps followed cartographic best practices, yet fewer of the maps illustrated topics which were relevant to society, or employed novel designs; key aspects of a vivid map. Those that did employ all of the aspects of vividness were often designed by elite media organizations such as The New York Times and National Geographic who employ large numbers of cartographers and graphics editors. These organizations can be more aware of their audience, and had more time, money, and other resources to tell compelling stories to audiences.
Chapter 1 References


Chapter 2
Expert Climate Change Mapmaking for Communication

2.1 Introduction

Maps are a powerful way to communicate climate change because they can illustrate the spatial disparities inherent in a changing climate. Indeed, maps are often used by the media and other communication practitioners to translate academic knowledge into meaningful information for broad audiences. Ultimately the goals of graphics and maps of climate change designed for the public are to support inference and decision making. Indeed, there are a number of advantages for supporting these tasks as well as some challenges to cartographically representing climate change. Some of the advantages of representing climate change cartographically include the ability of maps to: 1) represent space and time in a single graphic, 2) illustrate the spatial disparities inherent in climate change, and 3) represent both the human and physical changes related to climate change in a single representation.

Mapmakers must also grapple with several challenges to making these maps. First, these maps must balance between accurate representation of the science of climate change while reducing complexity for public audiences. In this way, these maps must illustrate climate change without being so simplistic that these representations fail to represent the science. Second, maps in the media must be noticeable enough to draw attention and keep attention.

One does not have to look far to see that despite an increase in the amount of information about climate change, this is also paralleled by disinformation campaigns and generally a failure for humans to act towards mitigation. Kahan (2013) argued that one reason for this action failure was a disconnect between science communicators (practitioners) and communication scientists. Kahan called for both the research and practice of communication to be “evidence-based” at all levels by transitioning from laboratory experiments to field-based methods. Because lab experiments are narrower in their ecological validity, Kahan argued that communication scientists could only make simplistic suggestions for communication practitioners, yet no research had been done to evaluate how communication practitioners are already communicating. In addition, communication science failed to incorporate lessons learned by these practitioners. The research presented in this paper evaluated the ways in which practicing cartographic communicators have created maps and the extent to which these practitioners follow guidelines derived from communication science. Kahan called for communication scientists to work alongside practitioners. He noted that practitioners were already communicating—perhaps effectively—to wide audiences on the topic of climate change, but their “informed conjecture” or “plausible surmises,” of what worked and what did not work has not been
tested, or, for that matter, even explored much in the science communication literature. This research evaluates this “informed conjecture” as a first step to understanding how communications practitioners may already be effectively connecting with their audiences. According to Kahan (2013), practitioners should make themselves aware of the science of climate change communication, while also working with empirical researchers to “observe and measure” (14) the strategies they have used in their communications.

In practice, communication practitioners are a diverse group and include the media, government agencies, communications staff at universities, etc. It seems to be a stretch to ask these individuals to conduct research with communication scientists in addition to their current workloads, but if climate change communication is to be evidence-based, it makes sense for communication science to understand what practices are being used by these individuals with the goal of later testing the effectiveness of these decisions. Indeed, little research in science communication has systematically evaluated how communication practitioners are communicating.

Motivated by Kahan’s (2013) call for integration of the science and practice of climate change communication, I conducted a series of semi-structured single and group interviews with mapmakers at major media organizations and government agencies to first understand what best practices were employed to balance the challenges of climate change mapping with the advantages of mapping this type of information, and second compare how these best practices compared to guidelines in the academic research. The goal of this research was to identify how expert mapmakers were designing maps and to understand whether these practitioners were following guidelines and best practices for creating what Harold et al. (2016) called “accessible” climate graphics, graphics that can be easily understood and interpreted by the general public.

This research was thus guided by the following research questions:

1. What were the best practices of practicing climate change mapmakers in making complex climate data understandable to wide audiences?

2. How were design decisions made to create these maps of climate change?

3. To what extent did the best practices of the practicing mapmakers follow the guidelines from academic research?

The rest of this paper is organized into five sections. I begin with reviewing the relevant background literature related to creating accessible graphics and maps which reduce complexity in climate change to make it understandable. The methods section describes the semi-structured interviews and analysis methods. The results and discussion section follows
and frames the results within the context of the research questions and relevant literature. Finally, the paper concludes by summarizing how this study answered the research questions.

2.2 Background

2.2.1 The media and stories about climate change

The media is one of the primary means by which the public interacts with information about climate change (Boykoff 2008, Smith and Joffe 2009, Schmidt 2013). While the connections between science, the public, and policy are often viewed as a complex “inter-tangled” web (Smith 2005), the media does serve to translate scientific knowledge into information useable by the public (Boykoff 2008). The media, in turn, uses visuals, including maps, extensively to reduce complexity, add emotional interest, and create compelling multimedia stories about climate change. Certain media organizations have seen the advantages of graphics in telling news stories. Indeed, the growing field of data journalism and visual journalism means major news sources are hiring data visualization experts and cartographers to create compelling visualizations.

Stories have long been used by journalists to draw readers in and keep their attention. The term data journalism describes the use of data and visualizations to tell these stories in the media (Cairo 2012). Storytelling in maps is a newer term to the domain of cartography. Notably, Esri’s Story Maps (Esri Inc.) now allow expert and novice mapmakers to create their own narratives with their own geographic data. The Esri Story Map concept was developed by Allen Carroll, the former art director and chief cartographer at National Geographic. Increasingly, research in cartography related to storytelling has focused on the use of narrative in the map (Caquard 2013, Song 2018), and on the potential to illustrate emotion in maps through visualizing experiences through space and time (Caquard and Cartwright 2014). As these two fields, journalism and cartography, become increasingly intertwined, it is important to understand how stories are created and designed through the medium of the map.

2.2.2 Visually communicating climate change

While there exists a large body of empirical knowledge on effectively communicating climate change, less research has focused on the design of visuals to communicate climate change. While general best practices in graphic and map design can inform climate change communication, these practices are not linked specifically to the complexity of communicating climate change. Harold et al. (2016) recently, however, compiled a review of insights from psychological research because they believed that graphics used to communicate climate change were difficult to decipher. Their review of psychological
insights derived from empirical research provided an easy-to-use guide for how to create accessible graphics based on a large body of empirical research (Table 2.1). Their guidelines focused on: 1) avoiding intuitive judgements, 2) directing visual attention, 3) supporting inference making, and 4) integrating text and graphics. They argued that “creating graphics of climate change data that overcome comprehension difficulties and avoid misconceptions ha[ve] the potential to enhance climate change communications” (Harold et al. 2016, 1080). While their guidelines did not specifically mention maps, their insights can be extended to the cartographic domain and provide a useful way in which to evaluate maps differently than simply evaluating the use of cartographic best practices. It remains to be seen the extent to which expert mapmakers follow these guidelines, an important first step in evaluating the effectiveness of current designs and practices for maps which are disseminated to wide audiences. In this research, I compared the use of these guidelines with the best practices of the cartographers I interviewed.

<table>
<thead>
<tr>
<th>Psychological Insights</th>
<th>Guidelines to Improve Accessibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid intuitive judgements</td>
<td>Use empirically derived principles to inform design. Test graphics to determine viewers’ comprehension</td>
</tr>
<tr>
<td>Direct visual attention</td>
<td>Present only the visual information necessary towards the communication goal</td>
</tr>
<tr>
<td></td>
<td>Direct viewers’ attention towards the pertinent information toward that goal</td>
</tr>
<tr>
<td></td>
<td>Make important visual features of the graphic perceptually salient to capture attention</td>
</tr>
<tr>
<td></td>
<td>Chose designs that are familiar to viewers and connect with their prior knowledge</td>
</tr>
<tr>
<td>Support inference making</td>
<td>Remove or reduce the need for spatial reasoning skills by illustrating inferences directly in the graphic</td>
</tr>
<tr>
<td></td>
<td>Direct viewers toward the most important relationships in the data</td>
</tr>
<tr>
<td></td>
<td>Decisions to create animated graphics should be informed by cognitive principles. Consider providing user controls.</td>
</tr>
<tr>
<td></td>
<td>Match visual representation to metaphors that aid conceptual thinking</td>
</tr>
<tr>
<td>Integrate text with graphics</td>
<td>Keep the graphic and text close together by using text within a graphic when necessary</td>
</tr>
<tr>
<td></td>
<td>Use text to help the viewer comprehend the graphic.</td>
</tr>
</tbody>
</table>

Table 2.1. Insights and guidelines for creating accessible climate graphics (From Harold et al. 2016).
2.3 Methods

2.3.1 Semi-structured interviews

To answer the first three research questions posed above, this study used semi-structured interviews with expert cartographers and science writers at the primary organizations in the United States who produce climate change maps. Semi-structured interviews are interviews where a set of questions is established and pre-determined for an interview, but the format also allows the researcher to have flexibility to ask follow-up questions and other questions depending on the flow of each discussion (Dunn 2010). Unlike structured interviews which require the researcher to ask the same questions of all participants in the same way, or unstructured interviews which only focus on broad topics, semi-structured interviews allow for each interview to follow a similar pattern but also allow the interviewer to explore tangential topics if they arise in the conversation. This type of interview was necessary to answer these research questions given the wide variety of design strategies and processes used by the cartographers across different workplaces. Semi-structured interviews have been used extensively in geography, particularly by human geographers, and in the past 20 years they have gained popularity in GIScience for exploring processes of use or development of maps and map elements (e.g., Monmonier and Gluck 1994, Suchan and Brewer 2000, Robinson et al. 2011).

2.3.2 Research participants

Between 2015 and 2017, with the assistance of four undergraduate students, I collected 242 maps of climate change in the United States print and digital media (see Chapter 4). Of the maps in the set, the majority of the maps were produced by NASA, NOAA, The New York Times, National Geographic, and the US Global Change Research Program (USGCRP) which produces the National Climate Assessment (NCA). The New York Times and National Geographic produce their own graphics in-house which are published in their own media. Government sponsored graphics are republished across a wide range of media including the prestige media like The Washington Post or in new digital media, such as Vice, Vox, Mashable, and Buzzfeed. Due to the large number of maps produced by NASA, NOAA, The New York Times, and National Geographic, I conducted a set of 16 interviews with experts at these organizations (Table 2.2). I did not conduct interviews with the USGCRP because this is an ephemeral group of individuals who serve the USGCRP during the production of the NCA every few years, but are primarily researchers housed at universities and national laboratories.
Table 2.2. List of interview participants, affiliations, type of interview, and job titles.

The experts I interviewed go by many job titles across these four organizations which are listed in Table 2.2. Despite these differences in title, they all either represented climate data, managed employees who represent the data, or wrote about science and collaborated with mapmakers.

At government agencies there are many groups who make maps. I only spoke to individuals in the Earth Observatory group at NASA and the Climate.gov group at NOAA. In the rest of this document, I often refer to “NASA” and “NOAA” without explicitly naming the groups within these agencies, however, the results presented in this dissertation are only derived from the individuals in those particular groups.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Name</th>
<th>Job Title</th>
<th>Interview Type</th>
<th>Interview Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA Earth Observatory</td>
<td>Josh Stevens</td>
<td>Senior Data Visualizer</td>
<td>Individual</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Pola Lern</td>
<td>Former Science Writer</td>
<td>Individual</td>
<td>Common Area</td>
</tr>
<tr>
<td>National Geographic</td>
<td>Damien Saunder</td>
<td>Former Director of Cartography</td>
<td>Individual</td>
<td>Conference Room</td>
</tr>
<tr>
<td></td>
<td>Lauren Tierney</td>
<td>Former Graphics Editor</td>
<td>Individual</td>
<td>Conference Room</td>
</tr>
<tr>
<td></td>
<td>Lauren James, Ryan Williams</td>
<td>Senior Graphics Editor (James), Maps and Graphics Research Editor (Williams)</td>
<td>Group</td>
<td>Conference Room</td>
</tr>
<tr>
<td></td>
<td>Ryan Morris</td>
<td>Senior Graphic Editor</td>
<td>Individual</td>
<td>Conference Room</td>
</tr>
<tr>
<td>The New York Times</td>
<td>Jeremy White, Tim Wallace, Larry Buchanan, Amanda Cox</td>
<td>All Graphics Editors except Cox who is Editor of The Upshot</td>
<td>Group</td>
<td>Conference Room</td>
</tr>
<tr>
<td></td>
<td>Derek Watkins</td>
<td>Graphics Editor</td>
<td>Individual</td>
<td>Phone</td>
</tr>
<tr>
<td></td>
<td>Nadja Popovich</td>
<td>Graphics Editor</td>
<td>Individual</td>
<td>Phone</td>
</tr>
<tr>
<td></td>
<td>Tim Wallace-follow up</td>
<td>Graphics Editor</td>
<td>Individual</td>
<td>Phone</td>
</tr>
<tr>
<td>NOAA Climate.gov</td>
<td>LuAnn Dahlman</td>
<td>NOAA Affiliate- Project Lead for Maps and Data Section</td>
<td>Individual</td>
<td>Video Conference</td>
</tr>
<tr>
<td></td>
<td>Mary Lindsey</td>
<td>NOAA Affiliate- Data Visualization Coordinator</td>
<td>Individual</td>
<td>Video Conference</td>
</tr>
<tr>
<td></td>
<td>Rebecca Lindsey</td>
<td>NOAA Affiliate- Editor of for News and Features Section</td>
<td>Individual</td>
<td>Video Conference</td>
</tr>
</tbody>
</table>
I identified participants through my personal contacts with mapmakers at The New York Times, NASA, and National Geographic. Participants at NOAA responded to a general call via email to Climate.gov. From the initial set of interview participants, I used snowball sampling to identify other participants. The initial contacts introduced me to other potential interviewees at their organizations who had worked on climate change mapping or writing.

The research participants came from a wide variety of backgrounds, including: science, journalism, and cartography. Many of these media organizations and government agencies have, in recent years, employed cartographers educated at universities with top cartography production labs, including the University of Wisconsin-Madison Cartography Lab and the University of Oregon Infographics Lab. These mapmakers were trained in cartographic design principles and best practices established through academic cartographic research (e.g., Slocum et al., 2009), and gained experience in production design while in school. However, nine of my participants had other educational backgrounds which were not necessarily focused on cartographic design. These individuals ranged from science experts who became communicators, or journalists who learned about cartographic design and climate science through their jobs. Some of the participants were a combination of both with one degree in communication or journalism and a second degree in science.

2.3.3 Developing the interview questions

The goal of the semi-structured interviews was to answer the research questions posed in the introduction to this chapter including, understanding best practices used by climate change mapmakers, how and why design decisions were made by these experts, and what aspects of academic best practices were used in design decisions. Through asking questions related to design decisions, it was also necessary to understand the processes at these different organizations for creating graphics, e.g., how they collaborated with others or received feedback from map readers. To achieve these goals, a set of interview questions was developed with input from two other cartographic researchers to foster conversation and discussion around these topics. I conducted test interviews with one cartographic researcher to hone the questions. The interview questions broadly focused on the workflow for creating maps of climate change. Subsets of questions focused on audience and purpose, data manipulation, designs decisions, science representation, integration with written stories, and dissemination. The final set of questions related to how these cartographers dealt with the increasing contentiousness of climate change politically. This paper elaborates on the results of the interviews related to all but the last set of questions. The full set of interview questions (excluding follow-up questions) are listed in Appendix A.
2.3.4 Interview Procedure

To conduct the semi-structured interviews, I traveled to The New York Times in midtown Manhattan, National Geographic in downtown Washington, DC, and NASA’s Goddard Space Center in Greenbelt, MD between December 2016 and March 2017. Travel to these workplaces provided work environment context as well as a means by which both I and the interview participants could view maps at the same time during the interviews. Interviews with individuals at NOAA’s Climate.gov were conducted between September and June of 2018 with GoToMeeting video conferencing software which allows users to share screens. Employees who worked on mapping at NOAA’s Climate.gov were decentralized and primarily telework. This form of interviewing worked well for understanding how these individuals worked together as a team in this workplace context. In addition, I conducted three interviews with graphics editors at The New York Times via phone in December 2017 since I had already visited the headquarters in New York, and additionally, some of these individuals were not co-located at the central headquarters. Conducting these interviews via video conferencing and phone allowed me to 1) interview more participants who were unavailable during in-person meetings, 2) be less obtrusive in workplaces, and 3) to save time, money, and other resources needed for travel. Prior to conducting each interview, I tried to collect as many maps as possible authored by my interview participants to have an idea of what projects they would be able to speak to during the interviews.

My first interview with four graphics editors at The New York Times was conducted as a group interview due to time constraints of the participants. Instead of asking specific questions from the list of interview questions (Appendix A), I posed general themes to the participants based on the question list. During this interview, it became clear that visual stimuli were needed to help foster discussion. This interview was conducted in a conference room with a large wall-mounted monitor. One participant searched for and interacted with maps while other participants explained design decisions. This method of coincidently viewing maps was reproduced in the subsequent interviews at other organizations. I would either provide printed graphics for the participants to view and talk about while answering questions (e.g., I brought a binder full of maps designed by each interview participant at National Geographic), or the participants would search for their own graphics to share with me (e.g., participants at NOAA’s Climate.gov shared their screen with me and talked about the maps on their website). The maps provided opportunities for mapmakers to point out examples of particular cartographic techniques and talk through specific design decisions.

In most cases, the interviews were conducted in conference rooms at the various workplaces or sometimes in the interviewee’s office. Besides the initial group interview at The New York Times, only one other interview, at National Geographic, was conducted as a group
interview due to the time constraints of the interviewees. In these group interview cases, the interviewees often had worked together on mapping climate change, and thus group interviewing provided a glimpse into how these professionals worked together on projects. The rest of the interviews were conducted individually.

The interviews lasted between 25 and 65 minutes depending on the time availability of the interviewee, the conference room, and the number of interviews already conducted at the organization. Follow-up questions were sent to participants via email for written responses when clarification was necessary.

Upon beginning the interview, I gave participants the informed consent document to explain the project which included my contact information (see Appendix B). I also orally explained the project. Based on the Institutional Review Board (IRB) protocol established, the interviewees were told their names would be used in the research unless they indicated otherwise. Because the interviewees were in some ways speaking both for themselves and their organizations, all of the quotes used in this dissertation were double-checked with the interviewees who asked to be consulted before their inclusion. In some cases, where I was unable to double-check quotes, I removed identifying information. I also informed the participants the interviews would be recorded. Upon oral agreement, I started the recording.

I began each interview by asking the participants to “walk me through the general workflow” they used to design a map. Once the interviewee(s) answered the first question, I continued on to the next questions. The semi-structured nature of the interview allowed me to skip questions when they were already answered or change the order of the questions, if the flow and content of the conversation made sense for that choice. This method allowed the interview to be more organic than if the questions were always asked in order. Detailed notes were taken throughout the interview by myself or a separate note taker.

2.3.5 Transcription and analysis

The recorded transcripts from these interviews were transcribed by Production Transcription, a transcription service. I verified and edited the transcriptions, as needed, to assure that the transcription was accurate. The result of the transcriptions was over 262 pages of text.

I followed transcription and analysis methods presented by Cope (2010) and used Atlas.TI qualitative data analysis software to analyze the transcribed text. I first coded the transcribed interviews in vivo. To do this, I read through the interview transcriptions and created codes related to my research questions or unexpected themes in the interviews. This initial coding resulted in nearly 140 codes, far too many codes to be useful (Cope 2010). To reduce the
number of codes, I identified codes which were similar or overlapping and combined these quotes into a single code to avoid overlap. At this stage, I also grouped the codes into major themes as they related to the original research questions or new themes identified in the *in vivo* coding. Through this process I determined that some codes were too vague. Quotes initially assigned to these vague codes were assigned to specific codes in the second round of coding, and vague codes were removed. In addition, some codes were removed because they did not answer the research questions posed in this chapter (or in Chapter 3) and thus were unnecessary. The full final list of 82 codes and 17 major themes are included in Appendix C.

Figure 2.1 illustrates the Atlas.TI interface. On the left are the list of codes I created with their corresponding themes. For instance, Affect.memory is the “Affect” theme and the code is “memory”. The center panel is the transcribed text from an interview, and the right panel shows how I coded each block of text into quotes. Two themes emerged that aligned with the research questions posed in this chapter, “complexity” and “workflow.” Together these two themes accounted for 19 codes (Table 2.3) and 302 quotes.

![Atlas.TI Interface Screenshot](image)

**Figure 2.1.** Screenshot of Atlas.TI interface. The left panel shows the themes and codes. The center panel is the transcribed interview text. The right panel shows how each text block was coded into quotes.
<table>
<thead>
<tr>
<th>Theme</th>
<th>Code</th>
<th>Explanation</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity</td>
<td>Abstract/tangible</td>
<td>participant described how they made abstract tangible</td>
<td>25</td>
</tr>
<tr>
<td>Complexity</td>
<td>For a reason</td>
<td>complexity was left in map for a reason</td>
<td>3</td>
</tr>
<tr>
<td>Complexity</td>
<td>Metaphors</td>
<td>map or story used metaphors for communication to reduce complexity</td>
<td>6</td>
</tr>
<tr>
<td>Complexity</td>
<td>Reducing complexity</td>
<td>cartographers reduced complexity through design</td>
<td>43</td>
</tr>
<tr>
<td>Complexity</td>
<td>Complexity</td>
<td>participant described difficult balance between simplicity and complexity</td>
<td>10</td>
</tr>
<tr>
<td>Workflow</td>
<td>Colleague criticism/review</td>
<td>participant described internal review process for maps</td>
<td>22</td>
</tr>
<tr>
<td>Workflow</td>
<td>Pitching stories</td>
<td>participant described how stories are pitched</td>
<td>14</td>
</tr>
<tr>
<td>Workflow</td>
<td>Planning graphic</td>
<td>participant described planning out graphic</td>
<td>8</td>
</tr>
<tr>
<td>Workflow</td>
<td>Researching for story</td>
<td>participant described researching for story and graphic</td>
<td>11</td>
</tr>
<tr>
<td>Workflow</td>
<td>Timing</td>
<td>participant described timing or time allocated for a story</td>
<td>27</td>
</tr>
<tr>
<td>Workflow</td>
<td>Workflow for story</td>
<td>general workflow of a story</td>
<td>19</td>
</tr>
<tr>
<td>Workflow</td>
<td>Collaboration</td>
<td>participants described collaborating with coworkers</td>
<td>6</td>
</tr>
<tr>
<td>Workflow</td>
<td>Deciding on graphics</td>
<td>participants described deciding on what graphics to include in a story</td>
<td>5</td>
</tr>
<tr>
<td>Workflow</td>
<td>Design decisions</td>
<td>participants described making decisions about design</td>
<td>27</td>
</tr>
<tr>
<td>Workflow</td>
<td>Personal evaluation</td>
<td>participant described their own personal evaluation of graphic</td>
<td>2</td>
</tr>
<tr>
<td>Workflow</td>
<td>Pulled in for graphics</td>
<td>participant described being pulled in to work on graphics for a story that was already developed/developing</td>
<td>4</td>
</tr>
<tr>
<td>Workflow</td>
<td>Connections with scientists</td>
<td>participant described connections and conversations between scientists and journalists</td>
<td>54</td>
</tr>
<tr>
<td>Workflow</td>
<td>Map reader feedback</td>
<td>participant described getting feedback from map readers</td>
<td>12</td>
</tr>
<tr>
<td>Workflow</td>
<td>Redesign for next graphic</td>
<td>participant described changing designs over time, retrospective analysis</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2.3. Codes, explanations, and quote counts for “Complexity” and “Workflow” themes.
2.4 Results: The “story” as a decision-making structure

This research illustrated that across all four sources, storytelling was the guiding goal for writers, cartographers, and others at these organizations. Participants noted that “the story” allowed the graphics and maps to be incorporated with the text. It is through these components that the reader was taken on a journey. In this way, the map, through its design and layout, guided the reader through a narrative. My participants described using the story to allow for the content to be more memorable and stick with the reader.

For example, in The Melting of Antarctica map (Figure 2.2), the cartographer took readers on a journey to understand how the continent of Antarctica is changing over time. Through the integration of the title, text, locator map, and other graphics this map illustrates the dynamics of a changing climate. The title and subtitle text set up the story to give context to how the current situation is different than before. Areas of the map are made more salient through the use of the visual variables and map tips which guide the reader to the important key aspects of the story. In this map, it is clear that there is a big change happening in this place, even in a static map, readers can see that there are dynamic processes at work.

![Image](image_url)

**Figure 2.2.** The Melting of Antarctica map exemplifies an intricate and detailed map design by National Geographic. This design, though static, allows map readers to get both a general sense of the topic and dig down to get more detailed information (Tierney et al. 2017).

It is through the story that cartographers and writers all had a common and easy decision-making structure to follow. Everything from audience, purpose, map design, writing, and other graphics all needed to align with the story. In this way, my participants described their decision making to revolve around one question, “does this align with the story I am trying to tell?” The goal was to avoid overwhelming audiences by sticking with one through-line by which the reader could follow the story from the text through the graphics. A selection of
quotes representing this decision-making structure across all four organizations is presented in Table 2.4.

While audience and purpose differed across organizations (Section 2.4.1), through the development and execution of a story, there was a common workflow across all of the organizations related to the purpose the story serves (Figure 2.3). This also was not exclusive to climate graphics, but could be applied to any number of different topics. This workflow began with pitching the story and initially investigating current research (Section 2.4.2), connecting with and communicating with scientists and gathering data (Section 2.4.3), making design decisions related to reducing complexity (Section 2.4.4), and then getting feedback to readjust for future graphics through reviewing with colleagues, publishing, promoting, and getting outside comments and criticism (2.4.5). I present the results related to the audience, purpose, and workflow for the story in the following sections.

![Figure 2.3. The process for creating climate change graphics.](image)
<table>
<thead>
<tr>
<th>Organization</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA Earth Observatory</td>
<td>If there’s a scientific term that I use I won’t shy away from using it, but I will try and make sure that I’m consistent in defining terms if I do use them, and sometimes I’ll have to ask myself “Does this add to the story, or does this make it unnecessarily complicated?”</td>
</tr>
<tr>
<td>The New York Times</td>
<td>I guess the primary goals are storytelling goals. How can we make this sink in for a reader, how can we communicate this to a reader better or easily, is there a better way to kind of show this type of thing so that it sticks with the reader more? We have a whole department devoted to just figuring out what we should tell visually, what visual stories, what visual shots we should take. We settled onto this approach where we break [the story] into three chapters, and each chapter is a bit of a somewhat standalone story, but they also flow together and build off one another. Doing it that way enabled us to use visuals as the introduction for each of the stories. We’re testing out some cool technology because … as people in the graphics department here, part of our job is to try to transport our readers visually to a place rather than having them imagine it. We try to give them a strong visual that will transport them into the story, and if there’s some high-resolution drone camera that we can use to show floodwaters, that’s far better than some European space agency radar data… Our task with that was, to some extent, helping figure out how the photos and writing could flow together along with any graphics that we might have the opportunity to do.</td>
</tr>
<tr>
<td>National Geographic</td>
<td>I think just early on, figuring out what story you’re trying to tell or what one or two aspects of climate change, for example, you’re trying to tell, and just really focus in on those and getting accurate representation, accurate symbolization. So then it’s not as overwhelming. The story is the main driver that on each piece you’re already looking through that lens, and you have to pick pieces that fit with a story or a narrative that you can tell that’s related to whatever topic is being written about. In putting together a climate change map for general audiences, [we] focus in on one aspect of the story and talk about related items, but you don’t necessarily need to dump all of those items on a map. It’s about focusing on the narrative of the source, because the source will tell you. It’s their drama, it’s their daily life.</td>
</tr>
<tr>
<td>NOAA Climate.gov</td>
<td>Another strategy that we use is we try to use stories. There’s a whole body of research, communication research, on the unique and powerful triggers that are associated with a story, the story form or that sort of narrative of a character struggling against obstacles, motivated by some desire for something. How they overcome those obstacles, that sort of thing.</td>
</tr>
</tbody>
</table>

Table 2.4. Selection of quotes from participants across the four organizations to illustrate the reoccurring theme of “the story.”
2.4.1 Audience and purpose: Government entity maps vs. mass media

Climate change maps are of interest to a wide range of individuals. Across the four organizations, however, there were differences in audience and purposes of the map designs. At NASA, NOAA, The New York Times, and National Geographic, many of the participants would not describe their readers as a singular homogenous “public.” Participants in this study generally described their audiences as the science-interested public, and further explained that their readers were often educators, sometimes policymakers, or simply individuals who were interested in the types of science studies these organizations featured. Across the organizations, there were similarities and differences in their audiences and purposes which are described below.

At NASA and NOAA, employees and contractors described their audiences and purposes similarly across both agencies. Maps created by these government entities were more widely distributed than the maps from National Geographic and The New York Times. This is primarily because these agencies are taxpayer funded to conduct “open science” which has a goal of making scientific research accessible to the public. Some readers specifically sought out government-based climate information through 1) subscribing to RSS feeds, 2) directly checking government outreach websites, or 3) explicitly viewing the agencies’ social media feeds. However, the overarching goal was for these maps to be picked up and republished by the mass media. One NOAA affiliate said, “We want them to be reused. We want the media to pick them up and say, ‘Ooh, that’s a good-looking image. We want to use that in our story’” (e.g., Figure 2.4). At NASA, one visualizer described the need to create images that could be reused across many different types of media. In particular, he noted that NASA’s Earth Observatory team provided both an annotated image and an image without labels so other sources, like TV production companies, could add their own text at an appropriate size for their audience and purpose.

Government agency outreach groups often write stories to accompany their maps and include links to the original scientific study. Even though their maps are designed to be republished elsewhere, this allows media companies who do not have science experts on staff to directly use the content from these scientific-focused government agencies.

In comparison to government agency maps, maps produced by The New York Times and National Geographic are designed for publication in their own outlets, and are not designed to be republished across the media. Within both of these organizations, their maps are usually copyrighted and not republished in other locations. These maps are shared across their own websites and social media accounts with the hope that they may be reshared more widely on the web. A graphics editor at The Times described an instance when maps about climate change “broke through” and were widely shared, “One way we can tell that people
took to it was that it wasn’t just straight traffic from The Times but a lot of traffic from social and emailing. That’s usually a sign that we broke through, through organic sharing, not just from our own promotion.” Indeed, all of these organizations have seen changes to their audiences and purposes of their maps as a result of the sharing and retweeting that happens because of social media. Because of the limits of copyright, media organizations have a clearer idea of their audiences. In comparison, government agencies have very little control over where their maps are disseminated and how they are used by organizations which republish them. However, across all of the organizations, my participants were generally unable to describe what exactly caused their maps to “break through” or go viral.

Figure 2.4. NOAA map of 2016 global temperatures compared to average (NOAA’s National Centers for Environmental Information 2017). This map was republished across many different sources at the beginning of 2017 to illustrate that 2016 had been the hottest year on record. Some of the places it was republished include, The Washington Post, Climate Central, and The Guardian.

2.4.2 Pitching a story and doing initial research

Scientific publishing in major journals is important for promotions and the tenure process at universities, and for establishing oneself as a leading scientist. Publishing in high impact
journals like *PNAS*, *Science*, and *Nature* also has compounding impacts on the greater dissemination of scientific research. Journalists use these major journals as fodder for scientific stories. Those I interviewed at NASA, NOAA, The New York Times, and National Geographic all noted that interesting findings in major journals served as one of their primary sources of information for writing a story.

Across these organizations, often participants described pitch meetings where employees identified interesting stories and decided as a group how the story might be told. Usually these pitch meetings involved bringing in people from across the organization to take part in idea development. For instance, at NASA, pitch meetings happened every week via a conference call with NASA employees at Goddard Space Flight Center (Maryland), Johnson Space Center (Texas), and the Jet Propulsion Lab (California) to identify as many story ideas as possible. From that initial set, stories which the mapmakers felt would be interesting and might have data available for mapping were flagged, and datasets were identified to be used to tell the stories. At The New York Times, for instance, the graphics department, responsible for the creation and design of the maps in their paper, sometimes pitched their own ideas for stories, or sometimes were pulled into a story later in the process when it was determined that a map would add to the writing or other graphics. At National Geographic, one cartographer identified that often photography drove the story ideas, and writing and graphics followed, in many, but not all, cases.

Once the story was decided, the participants described doing initial research. Lauren Tierney, former cartographer at National Geographic described looking up all available information related to a particular story. “Depending on the topic, I’ll do a Google search, check recent news articles for that topic… also, [I’ll] go through Google Scholar and [read] recent journal articles.” She further explained that this process allowed her to assure the data was available for the story. Participants at other organizations also described this aspect of the process. In addition, many of the participants noted that this period of initial research was their chance to understand as much as they could about the topic for themselves. Pola Lem, a science writer on the Earth Observatory team at NASA, described her initial research:

One of the first questions I ask [myself] is ‘How is this different from previous research? What does this show that we didn’t already know in this large body of work in this discipline?’ From a reporting perspective [the goal is] to understand the difference between a study that’s just come out and all these other things in the body of research before it.

Sometimes research for the story was conducted entirely by the graphics staff and writers, in other cases, there were research editors or freelancers who assisted. Together these individuals collaborated to research, write, gather data, and create a compelling story as a team.
2.4.3 Connections and conversations with scientists: Attention to being factual about science

In this sub-section, I relay how my participants described their connections and conversations with scientists, and how they made sure to get the facts straight directly from the source. In every interview, my participants described the open dialog with scientists and their willingness to help my participants understand the topics they were mapping. They provided assistance by advising and describing the complexity of climate change while maintaining accuracy. In addition, many scientists shared data to visually tell the story. In addition, my participants noted that all quotes and statements were checked, and often double-checked, with scientists to assure accuracy.

Each person brought their own expertise to the team, including the cartographer, photographer, writer, researcher, and the scientist. In many cases, the scientists were almost viewed as part of the team. One cartographer said that decisions were never made in isolation,

[We go] back and forth with the expert [to say], ‘We took your words [and] shifted to this, which is still accurate, but it’s a little bit more general-audience friendly. What do you think?’ And most of the time they [say], ‘Oh, yeah, that’s great.’… And sometimes, you send [the graphic] to the scientist or expert, and they say, ‘No, no, no. We have to put in uncertainty or we’re not sure about this. Can we just gray this area out?’ Sometimes, it’s a real challenge and sometimes we have to work a little bit harder and come up with language that’s appropriate that both the scientist is happy with and will be general-audience friendly.

In other organizations, participants described these compromises. At government agencies, contractors described the conversations as being focused on trying to balance the readers’ needs with the scientists’ needs. In those cases, there was a focus on the need to compromise to maintain relationships with the scientists who either worked in the same agency or might prove to be reliable sources in other stories. In the recounting of these compromises, my participants explained that everyone came to the project with an idea of what was best. At times the communication experts felt it was worth taking a stand instead of compromising when they felt they had a better idea of cartographic design or communication. Scientists often wanted to assure accuracy, and other times my participants described the scientist’s emotional attachment to the design of their map as they had produced it. This emotional attachment to design often came up in relationship to conversations about the rainbow color scheme which was critiqued by many participants since it is so commonly used in climate and weather graphics despite calls in climate science to end its use because it has been shown to lead to incorrect interpretation of data (e.g., Light and Bartlein 2004).
Often journalists collected more information than they might need for a story, but did so to assure that they were maintaining accuracy. Larry Buchanan at The New York Times said, “For every one or two experts quoted, you might call five or six.” Other participants described asking the scientists to reiterate a point multiple times and in multiple ways or to explain a topic as if they were explaining to a child. For example, they might ask the scientist how would they break down complexity to make a concept understandable to an elementary school student. One participant noted that the more she worked on climate science communication, the less adept she was at pressing scientists to break down complex topics since she had developed more knowledge about climate dynamics over time, noting an advantage novice communicators have over more established experts in the communication field.

In some cases, scientists pointed out the most salient aspect of the story to the communicator. It was this process that my participants described as allowing them to hone their story. One National Geographic employee described,

> When you actually look at the data set… you’re not going to see [the] pattern in that data, and [the scientists] know you’re not going to see the pattern in that data, but they do say ‘Look at this specific data set where you can see the trend.’ It’s about focusing on the narrative of the source, because the source will tell you. They’re going to know where you’re going to see this.

Finally, because all of the organizations I interviewed are considered credible, and because many of these participants were geographers, cartographers, or have other science backgrounds, their credibility was useful in their conversations with scientists. One graphics editor at The New York Times described the credibility the graphics staff had with scientists because they were geographers and thus could understand the science and human-environment interactions. This allowed them to easily pick up the phone and converse with the scientists in a way that might not be possible without the authority and credibility that comes with working at one of these elite organizations or having the relevant background knowledge.

### 2.4.4 Reducing complexity, creating metaphors and emotion, and making key data salient

My participants reduced complexity and added emotional interest in their design by creating metaphors and making key data salient. At National Geographic, while many of the maps are static they are also quite intricate and detailed which allows readers to get a general sense of a topic but also dig down for more detailed content (e.g. Figure 2.2). Cartographers used simple legends and “map notes” to visually guide the reader through the graphic (Figure
Map notes, in particular, allowed the cartographer to tell a story through a static map, and reduced the complexity in the graphic by guiding a reader and preventing them from getting lost in the map design.

Figure 2.5. Section of the Melting of Antarctica map. Map notes, like the one here called “Already doomed,” help guide map readers through a story told with an intricate map (Tierney et al. 2017).

Metaphors serve as effective ways in which to tell stories (Harold et al. 2016), and they can be used in graphics as well as text. In the interviews, participants noted using reference points to things people know and have seen to explain more complex topics. For example, the graphics staff at The New York Times talked about trying to provide comparisons. In some cases, they noted that they did this through size comparisons (e.g., Figure 2.6). In other cases, they described trying to find more whimsical comparisons that readers could connect with. For example, Tim Wallace said of providing metaphorical context to the reader for the maps in Figure 2.7,

I talked to several scientists to try to figure out what a zeta joule was…, and the comparison that I came up with for the amount of energy that’s been gained in the oceans between these years was [equal to] 140 billion hair dryers running over the same number of years

Sometimes this was through incorporating text with the graphic, and in other cases it was through illustration. One interesting graphic in National Geographic about the “Melting of
Antarctica” used the Statue of Liberty to illustrate how much water levels would rise given the melting of different parts of Antarctica (Figure 2.8). This provided an easy visual which was incorporated into the map design.

![Graphic of the extent of major wildfires in 2017 compared to the size of Washington, DC. (Tierney 2018). While this graphic is in the Washington Post, it is a good example of using the comparison to a local geography for understanding the extent of distant events.](image)

**Figure 2.6.** Graphic of the extent of major wildfires in 2017 compared to the size of Washington, DC. (Tierney 2018). While this graphic is in the Washington Post, it is a good example of using the comparison to a local geography for understanding the extent of distant events.
**Figure 2.7.** Set of small multiple maps representing the heating of the oceans over the past century (Wallace 2016).

**Figure 2.8.** Section of The Melting of Antarctica map showing the use of metaphor to illustrate potential sea level rise if parts of Antarctica were to melt (Tierney et al. 2017).

It is through these metaphors that communicators brought the concept of climate change to life. They reduced the abstractness of the mapped concept to connect to readers’ lived
experiences. As Ryan Morris at National Geographic said about a 2.5D map of rising sea levels in New York City (Figure 2.9), emotion was created through the water flooding the land and buildings, “when you are looking at little buildings [they] are going to be inundated with water. This is something people understand and they’ve seen before and experienced before, so it feels a little bit more real.”

At government agencies, on the other hand, my participants described using familiar designs instead to connect with their prior knowledge and understanding of maps. Sometimes this was in the form of using a template, as is common at NOAA, or simply following a style guide which clearly set out guidelines for design and appeared to be common at both agencies. In particular, Josh Stevens noted, “we try to use known conventions and best practices rather than trying to introduce something totally new and novel, which might push the cartographic bounds but not necessarily be something the public grasps. So, we try to be really familiar in our approach.” At the government agencies, maps were limited to having a particular look and feel and often used template designs, which were decidedly non-emotive. One contractor even said “We’re a government site after all. There’s no emotion here.”

Figure 2.9. Map of sea level rise in New York City during a potential future superstorm in 2100 (Morris et al. 2013). The graphics editor who worked on this map noted the emotion he tried to impart in the map by illustrating New York City with such detail.

Another way to direct attention and reduce complexity was to pull out all but the most salient aspect of the data by giving the reader a quick visual impression. For instance, if the most important point of a map was to illustrate an increase, my participants would describe taking out everything from the map that did not help the reader come to that conclusion. At
NOAA, they followed Tufte’s (1983) *data-ink ratio* rule to reduce complexity in the designs. They noted that when they put minimalism at the forefront of their design decisions they were able to create easy to understand graphics which focused on the most important data to tell the story. In other cases, participants described using animation to illustrate that something changed and to give a visual impression through movement.

My participants also described breaking down data into smaller chunks. Many participants described this as allowing a reader to create meaning out of small bits of information and to understand a concept instead of being overwhelmed by a large amount of data in one graphic. The New York Times has recently created maps which used *scrolly-telling* to reduce complexity in their designs. Scrolly-telling allows a reader to scroll down a page in which the act of scrolling initiates an interaction and the reader can see the map or graphic change. This type of technique allowed graphics editors to give the reader just enough information in a single display, until the reader scrolled down further to get more information.

### 2.4.5 Getting feedback

Harold et al. (2016) stressed the importance of “test[ing] graphics during their development to understand viewers’ comprehension of them” (1085) as a guideline for creating accessible climate graphics. However, as Tim Wallace at The New York Times noted, “We’re not able to do the kind of user studies that an academic does.” Despite not being able to run user studies, my participants described many ways in which they got feedback on their designs.

Several participants noted that their first step in assessing the design of a graphic was to step-back from their own graphic as they worked to assess whether they themselves could understand it. In some cases, participants noted that they would go through iterations of their design even before anyone laid eyes on it.

In many of the interviews, participants explained that they never worked in isolation, there were always eyes on the static or interactive graphic in the form of coworker feedback and critique before the graphic was published. At National Geographic, in particular, there was a very clear, systematic, and extensive process for soliciting and receiving feedback on maps which included meetings, as well as the process depicted in Figure 2.10, where everyone at the organization was encouraged to provide feedback for everyone else. Damien Saunder, former Director of Cartography at National Geographic explained how the process was viewed by the cartographers,

> Cartographers come in and they want this feedback… and they respect that feedback. Everyone, no matter whether you’re the most elite person that we have here or not, you all have to go through the same process. It’s just expected. It’s not questioned. It’s completely professional. We pick the living
daylights out of this stuff. Sometimes even three-quarters of the way down the schedule path, if we still think [a graphic is] not working, we’ll trash it and try again. It’s a pretty crazy approach and it takes a bit of getting used to. It’s a lot of fun, actually.

Figure 2.10. Two rooms at National Geographic display every page of the two upcoming issues of the magazine. Sticky notes and pens are available on the counters for anyone at the organization to provide feedback by sticking their comments directly on the proof pages. Photo by Carolyn S. Fish.

At NOAA’s Climate.gov, there was an editorial process and hierarchy which allowed several people to see graphics and maps before they were finally published. In NASA’s Earth Observatory team, they shared a Wiki where they posted drafts to be viewed by colleagues. At The New York Times working in close proximity in the newsroom’s open-concept office design allowed graphics editors to easily solicit feedback as they worked on a story.

The New York Times and National Geographic also consistently received awards for their designs which gives an indication of what types of designs were well-received by the broader news graphics community. Even with winning awards, design has changed over time and maps that won awards a few years ago used designs that graphics editors shy away from now because they felt those previous designs were too intricate for audiences. The cartographic and visual journalism communities have also provided feedback on designs at conferences and via Twitter by giving comments or critiquing designs.

While these organizations were constantly measuring user interaction on their own websites, many participants said they really did not have a good idea of when a graphic was successful or not because there were many reasons one story might get more attention than another. Often stories were competing with breaking news which might significantly reduce the number of people who click on a webpage. It was unclear how much information my
participants got about how widely a graphic was shared. My participants also may have felt uncomfortable with sharing this information with me.

Some participants also described feedback that came through less technical means. One graphics editor relayed running into a neighbor who gave unsolicited feedback, and a few participants noted being sent letters usually thanking them for making a particular graphic.

Participants also described getting feedback from specific user groups. In some cases, some participants described receiving emails from scientists, meteorologists, or professors who had comments and suggestions related to how the science was portrayed in a graphic. In other cases, participants described being contacted by educators, such as K-12 teachers, who asked for the images, often times black-and-white images which could easily be photocopied, to use in their classrooms.

Some of this feedback has led to changes in designs over time. Notably, The New York Times changed some of their designs recently. The Times moved from focusing on complex interactive designs to simple interactions which were initiated by a user simply scrolling down the page (Tse 2016), and in some cases this meant removing interaction all together to create more static graphics to keep things simple for users.

### 2.5 Discussion

It is clear that the design decisions and processes my participants used aligned with the insights presented in research on graphics, and particularly the suggestions from Harold et al.’s (2016) guidelines for creating climate change graphics. Overwhelmingly, my participants followed cartographic conventions to create maps which were understandable (e.g., Brewer 2016, Slocum et al. 2009). They also clearly drew from other data visualization literature (e.g., Tufte 1983).

It was clear that “the story” served as a primary decision-making structure for mapmakers and writers at all four of these organizations. Through asking themselves “does this align with the story I am trying to tell?” my participants easily made decisions about how to reduce complexity in their writing and designs. The story also provided a starting point for the entire team in the process of creating graphics which aligned with the article. The process across the four organizations thus followed a similar flow, which brought together a team of writers, graphics editors, scientists, and other researchers. Throughout the process, each individual continually asked the question of whether adding or reducing content still allowed them to tell a coherent and cohesive story which a reader could follow. The concept of storytelling with maps is a new concept in the cartographic literature, although this research
showed that this connection had clearly already been established in cartographic practice in the media.

Audience and purpose are key aspects of telling stories but are also key aspects of cartographic design. Knowing more about your audience allows communicators to create more compelling content for their readers, and allows mapmakers to create maps which align with their readers’ goals. In this case, it was clear that media organizations had a better idea of their audience than government agencies, which allowed media organizations to create more specific graphics which did not rely on templates. I argue, however, that government agencies who had less control over their maps have had a larger impact because these maps were disseminated far beyond their own websites. This is possible because these maps were not copyright limited like the media organization maps. Finally, even at media organizations, the advent of social media has meant that sometimes maps, graphics, and stories were widely disseminated beyond their subscribers. Media organizations and government agencies, alike, were all less aware of who their audiences might be on social media and what purposes the map might serve to these growing viewers.

Often the media in popular discourse is blamed for failing to “get the facts right,” and in social science literature, the relationship between science and the media has been described as fraught; however, research looking at the interface between the two identified that this contention between science and the media is not always the case (Peters et al. 2008). In support of Peters’ findings, the relationship, as described from the perspective of my participants, was generally positive. It appeared that there was open dialog between scientists and my participants to assure they accurately represented a scientific study. My participants described scientists’ willingness to 1) share data, 2) answer questions, and 3) clarify and restate conclusions. In some cases, my participants described having to compromise to a scientist’s design but in other cases, a few of my participants even commented that scientists later asked to use their graphics in their own academic presentations at conferences.

In their review of the cognitive and psychological insights to improve climate change data visualization, Harold et al. (2016) noted the need to reduce complexity to make climate change graphics accessible (Table 2.1). My participants, knowingly or not, followed nearly every aspect described by Harold et al. (2016). By using the decision-making structure of the story, my participants removed extraneous information from the graphic with the goal of “present[ing] only the visual information that is required for the communication goal” (1085) and directed readers’ attention to the storyline throughout the map, accompanying graphics, and written story. My participants also described making important visual features in the story salient. They did this sometimes through the use of technology like scrolly-telling or by reducing extraneous information by following Tufte’s (1983) data-ink ratio. In addition, through the use of style-guides and sometimes templates my participants also
focused on keeping the design of the map familiar and thus easy to read for audiences. As suggested by Harold et al. (2016) my participants also used metaphors and text on the map in the form of map notes to direct readers' attention and support inference making. They did this through adding text to the map, creating additional illustrations, and simplifying designs over time through feedback from readers, colleagues, and design competitions.

While these mapmakers were unable to test designs on specific users, these individuals got feedback in other ways which were helpful toward designing better graphics for the future. Most importantly, self-reflection and colleague critique was described as invaluable by the participants. This concept of soliciting feedback from experts aligned with other research which showed that novice map users often have incorrect assumptions about what types of map design are most effective, and expert feedback can be more useful (Hegarty et al. 2009). However, as these science communicators focus more on specific topics, such as climate change, it becomes more difficult for them to think critically about what might work or not for a general audience. Collaboration which focuses on creating teams which combine fresh eyes and seasoned experts might be ideal for designing stories which are best for general audiences.

2.6 Conclusions

In this paper, I reported on a study to understand the design decisions made by climate change mapmakers in the media and at government agency outreach programs. Specifically, I asked three questions:

1. What were the best practices of practicing climate change mapmakers in making complex climate data understandable to wide audiences?

Across the different organizations creating maps of climate change there was a common process for creating maps of climate change. This process had several steps (Figure 2.3), starting with 1) pitching ideas and doing initial research, followed by 2) consulting with scientists to get data, 3) reducing complexity through creating metaphors and emotional interest, and by making key data salient, and finally these mapmakers got feedback (albeit in unconventional ways) through 4) reviewing with colleagues, 5) publishing, 6) promoting, and 7) getting outside criticism to 8) readjust for future graphics.

2. How were design decisions made to create these maps of climate change?

The creation of a story provided a decision-making framework to guide mapmakers in their design. The story allowed the mapmaker to decide what to include in a map, identify how it would connect with the text, and how to adjust the design of the visual variables used in the
map to align with the story. This adds to a growing literature on storytelling with maps which was reviewed in Section 2.2.1.

3. To what extent did the best practices of the practicing mapmakers follow the guidelines from academic research?

Climate change mapmakers relied on many best practices. First, they followed cartographic conventions (e.g., Slocum et al. 2009, Brewer 2016) and best practices from data visualization (e.g., Tufte 1983). My participants also described reducing complexity through a variety of different methods including making key data salient, telling a story, and creating metaphors by providing context and comparisons. Based on the cognitive and psychological insights described in Harold et al. (2016) and comparing these to the best practices employed by my participants, it is clear that these mapmakers did generally follow these best practices. Kahan (2013) and Harold et al. (2016) might argue that the type of feedback these mapmakers get from colleagues is insufficient for testing these graphics, but I argue that testing designs on readers was not possible in these environments with the quick-pace necessary for producing these maps. Instead, these mapmakers relied on other means of getting feedback which was used to improve future graphics.

It was also clear that while climate change mapmakers relied, to some extent, on their own conjecture since they were trained in cartographic design and information visualization either formally through their education or informally through their jobs. It may be helpful to use storytelling as a way to guide new cartographers to make decisions. Future cartography courses could center around telling a story which then allows the students to identify their audience and purpose, what data they need, and how it should be displayed.

In some cases, it was also clear that the communication experts I interviewed were aware of the academic literature on the subject of creating effective climate change communication. As called for by Kahan (2013), future research would be well served to use the decisions made by these communicators as fodder for future research. In the case of maps, the designs these mapmakers believed were most effective at communication could serve as future stimuli to test whether these designs are indeed successful. This future work would better connect practitioners and communication scientists and would provide these mapmakers with a clear way in which to know if, when, and how their graphic was successful for audiences.
Chapter 2 References


NOAA’s National Centers for Environmental Information. 2017. “Land and Ocean Temperature Percentiles Jan-Dec 2016.” Annual 2016 Global Temperature and


Chapter 3
Elements of Vivid Cartography

3.1. Introduction

Creating maps which convey the science, impacts, and mitigation strategies related to climate change is of increasing importance. The media and government agencies are attempting to create maps which both convey current research but also reach and influence wide audiences beyond the scientific realm. Through this act, mapmakers are trying to make climate change information clear and persuasive for audiences in the hopes that the public takes action toward mitigation or adaptation efforts. The goal of these cartographers is to make “maps that matter” (Robinson et al. 2017)—maps that illustrate problems which are important to humankind and sustainability. These maps that matter should pique interest, be understandable, and “generate insights from complex, large, unstructured, varied data on problems that have broad impacts to society and our environment” (Robinson et al. 2017, 34).

Vividness, a term not used in the cartographic realm, can be one way of describing these maps that matter. In other communication domains, vividness describes content which is “likely to attract and hold our attention and to excite the imagination to the extent that it is (a) emotionally interesting, (b) concrete and image provoking, and (c) proximate in a sensory, temporal, or spatial way” (Nisbett and Ross 1980, 45). Vividness can add to literature on persuasive map design, and help practicing cartographers potentially make design decisions about how to create persuasive maps on topics which have broad impacts to society and the environment. This paper, informed by empirical research, illustrates the connections between vividness and cartographic research and practice to identify the aspects of a vivid map.

The knowledge-deficit model (for review see: Cagle & Tillery 2015) is often used as justification for simply providing the public with more information about climate change without regards to the quality of the information (O’Neill and Nicholson-Cole 2009), personal views and morals, or connections to the environment and emotions (Joffe 2008, Otieno et al. 2014, Swim and Bloodhart 2015). The model states that the more information provided, the greater the potential behavioral change; however, beyond simply providing accessible information, climate change information must also evoke emotional interest in the topic in order to lead to a behavioral change (Moser 2010). With the increase in the amount of visual information we encounter every day, visuals also must be interesting enough to lead a viewer to remember the information (Borkin et al. 2013, Borkin et al. 2016). Vividness
describes content which does more than simply provide more information to readers; it attracts attention, evokes emotion, and makes distant topics proximate to readers. In this way vividness is doing more than providing information, it is being persuasive to audiences.

The purpose of this study was to create a definition of a vivid map and answered one key research question: How did climate change map makers create maps which connected with their audiences to create emotional interest and make confusing topics tangible to map readers. Through a series of interviews, I derived common themes the participants used to describe creating maps that matter. I then connected those themes to the vividness definition. These interviews were conducted with primary actors in cartographic climate change communication at major media organizations and government agencies. The results of this study present a set of cartographic design aspects which future mapmakers can incorporate and follow to create vivid maps. This paper concludes with a call for these aspects to be tested in future research related to map persuasion.

3.2 Vividness

Vividness is a controversial topic in the social psychology and advertising domains. As defined by Nisbett and Ross (1980) vivid content is “likely to attract and hold our attention and to excite the imagination to the extent that it is (a) emotionally interesting, (b) concrete and image provoking, and (c) proximate in a sensory, temporal, or spatial way” (45). Vividness is often used by advertisers to persuade readers (Eaton 2011), and it has been used to describe content which is oral, written, visual, and multi-media (Taylor and Thompson 1982). The effects of vividness on persuasion, however, are mixed in the research literature. Many studies have illustrated that the effects of vividness are “illusive” and sometimes even completely absent (for review: Taylor and Thompson 1982), while a smaller set of other studies showed that it did have an effect (Reyes et al. 1980, Kisielius and Sternthal 1984, Shedler and Manis 1986, Kelley et al. 1989, Smith and Schaffer 2000, Guadagno et al. 2011).

In their review of the empirical vividness literature which showed the illusiveness of the vividness effect, Taylor and Thompson (1982) also compared studies of salience and vividness. They found salience studies consistently had an effect while vividness studies did not. They identified several reasons for these differences. Vividness studies were primarily concerned with measuring attitudes, while salience studies were focused on measuring perceptions. The Taylor and Thompson review also theorized that the difference in effect might have been related to the types of stimuli and participants used. In salience studies, differential attention was manipulated using within-subject experimental designs. For instance, in studies of salience, participants were often asked whether one aspect of the stimuli attracted attention over another. Vividness studies, on the other hand, used between-
subject designs where differential attention was not manipulated between two stimuli. Taylor and Thompson theorized that this difference might be related to differential attention manipulation, as was done in salience studies. Indeed, Guadagno et al. (2011) recently illustrated that the vividness effect was clear when the key point of an advertisement was made vivid. In their study, they implicitly linked the concept of salience with vividness by illustrating that vividness had an effect when the key aspects of the content were vivid, not the background.

While the definition from Nisbett and Ross (1980) is widely used across all vividness studies, the determinations of what types of content (and thus, stimuli) were deemed vivid or pallid were made with little to no reasoning. Perhaps the illusiveness of vividness may be linked to this inconsistency. For example, in several studies pictures and videos were considered to be vivid stimuli, compared to written information which was deemed as the pallid stimuli (e.g., Nisbett and Borgida 1975, Borgida 1979). But does making information pictorial always mean the information is more vivid? It might be possible that in some cases, written content could be more vivid than pictorial content.

I argue that vivid information is that which brings topics to life and attracts attention by making them emotionally interesting, concrete as opposed to abstract, and proximate to readers by making the topic understandable, less far off, and more connected to audiences’ prior knowledge. In this way, topics can be made more relevant and memorable through how they are described or visually represented, which makes this type of content more likely to influence decisions or attitudes. While much of the vividness research was conducted in the early 1980s, the term vivid is often still used to describe visuals, dreams, and even maps. I argue in this paper, that vividness can and should be extended to maps, and research on the topic should be revived.

Finally, the vividness of geographic information has been shown to lead to greater memorability of the content through its distinctiveness (Tom and Tversky 2012). Similar to salience, this aligned the definition of vividness with that of novelty. Novelty is one way to attract attention, and is delineated from vividness in that it does not in and of itself attract attention in the same way (Stroebe and Fennis 2015). It may be possible, however, that when working in tandem with salience that novelty can make content more emotionally interesting, proximate, and image-provoking.

3.3 The case of maps

Vividness is not a term used in the cartographic literature. However, maps can be emotive, attention grabbing, and persuasive and, in this way, I argue maps with particular aspects can
be vivid. I review these concepts from the cartographic and information graphic literature here.

### 3.3.1 Emotion

Until recently, little research in the cartographic domain grappled with the concept of emotion in maps. While this is still a growing research endeavor, three main aspects to maps and emotion were described and reviewed in Griffin and McQuoid (2012): 1) mapping emotion, 2) using maps to collect information about emotions, and 3) understanding emotional responses to maps. This third aspect is particularly relevant here to describe the connection between emotion and mapping. It describes one way of bridging humanistic geography and cartography domains, and adds to the well-grounded cognitive cartography research which dominated cartography at the end of the 20th and beginning of the 21st century.

Affect and emotion are connected to how humans make sense of the world and it is through this connection that affect and cognition are intertwined. Our emotional responses can dictate how we encode information about our surroundings. Recent research explored emotional responses to color schemes in maps (Fabrikant et al. 2012, Anderson 2018) and there have been calls for more research related to emotion in maps beyond color (e.g., a workshop titled Maps and Emotion at the 2017 International Cartographic Conference was designed to spark research ideas). In addition, including emotion in how we view, understand, and research maps allows for the inclusion aesthetics in mapping (Kent 2005). Indeed, aesthetics and beauty are linked to our emotional responses. It is through their design or lack-of thought towards design that a map may evoke particular responses in its readers. Finally, the prior knowledge and feelings a map reader brings to reading a map also impacts the emotional responses to the design. It is through these connections other scholars have made between maps and emotion that maps can be vivid. They can illustrate emotion and lead to emotional responses.

### 3.3.2 Attention

Drawing in and directing attention is one of the goals of cartographers as they guide a map reader through a map. Lloyd (2005) reviewed how attention research from other domains of information science might be applied in the cartographic domain. Attention in maps is inherently tied to vision and can be directed in two ways: bottom-up and top-down processing (Lloyd 2005). Research on attention in maps draws from Gestalt principles, specifically figure-ground, for describing what aspects appear more salient as the figure versus the ground in map designs (MacEachren 1995). Within cartography, recent research related
to attention has focused on salience, visual contrast, visual hierarchy, and motion which are reviewed here.

Salience, which is a key aspect to direct attention, has largely been tested with psychophysical experimental designs to understand eye fixations and reaction times to cartographic displays using eye-movement analysis (Itti et al. 1998, Itti and Koch 2001). Research in this domain showed that thematic relevance within a map should be congruent to the most perceptually salient aspects of the design (Fabrikant and Goldsberry 2005). For example, the primary theme of the map should align with the aspects which draw the most attention and eye fixations. In part, cartographers create this salience through visual hierarchy and contrast.

Visual contrast, which is sometimes referred to as visual differences (Dent 1972), uses the visual variables (Bertin 1967|1983) to show difference between elements on a map. Cartographers create contrast between the layers of the map using one or more of the visual variables to create an effect of difference. For instance, a cartographer might choose to have text stand out on an image-hybrid basemap where text is overlaid on satellite imagery to give context. To do this, the cartographer might use bright colors, large text, and white haloes to create contrast with the visually intricate basemap. In the thematic map context, the cartographer might want a particular land-use variable to stand out to readers on a land-use/land-cover map. When this particular variable accounts for fewer pixels on the map than other land use variables, the cartographer might use a highly-saturated color (e.g., bright yellow) to highlight those pixels in a sea of primarily green and grey used for the other land-use variables (Brewer 2016). Through the use of color hue and saturation, these smaller pixel groups will now stand out compared to the other variables.

Visual hierarchy, similar to contrast, makes particular aspects of a map design stand out to readers, but also gives hierarchy to the elements, layers, or sub-layers of a map (MacEachren and Mistrick 1992, Dent et al. 2008). For example, in a road network layer, highways might be the most important roads to show, followed by major arterial roads, followed by minor local roads. In this case, the cartographer can create this hierarchy through giving the more important roads prominence using the visual variable of size. In this instance, the cartographer would design the higher speed and more important roads with thicker lines, while dirt roads, less important in the network, would be drawn with thinner line widths.

Research in psychology has shown that motion attracts attention (Franconeri and Simons 2003, Abrams and Christ 2006). In cartography, the research on motion and attention is related to animated maps. Cartographers use moving or flashing symbols to direct attention to areas in an animated map display (e.g., DiBiase et al. 1992). Problems with directing attention to changes was noted by some scholars (e.g. Fish et al. 2011), and other research
identified the problem of split attention in animated map displays because sometimes map readers have many places they need to look on an animated map display (Harrower 2007).

Maps which employ salience, visual hierarchy and contrast, as well as motion have the potential to be vivid maps since these maps attract and direct attention to key data. Maps that fail to employ these aspects may direct attention away from the key message. This research investigates how cartographers attract and direct attention with maps in the modern age.

### 3.3.3 Persuasion in cartography

Only a small subset of cartography research has focused on persuasiveness of map design. This topic has been dominated by the popular book by Mark Monmonier, *How to Lie with Maps* (1996). Monmonier wrote on the persuasiveness of common maps. Some of his examples included development plan maps for persuading local governments, and how impacts of aggregation, classification, and color impact the reading of statistical maps. He described how cartographers add “white lies” to their maps, sometimes unintentionally, and he illustrated the effects of these lies on the persuasiveness of a map to its readers.

Other research in the domain of persuasive cartography has been primarily conducted by two researchers in the cartographic research domain. Judith Tyner’s work in the 1970s and ‘80s was important for illustrating how cartographic content could be persuasive (1974, 1982). Much of her work, and later Muehlenhaus’ work, focused on overt persuasion or propaganda, and both researchers developed a categorization of persuasive maps. Tyner’s work did note that sometimes persuasion occurs through how a map reader interprets the map. She stated that maps have the power to persuade because they are often viewed as objective truths, authentic, and believable, which was later reiterated by MacEachren (1994).

Muehlenhaus, more recently, evaluated rhetorical styles of mapping (2012, 2013, 2014). His analysis resulted in a list of map elements that can be altered to impact the persuasive capabilities of maps. His research argued that there are two types of maps, rhetorical and rational, and implied a continuum between the two (2014). He listed political propaganda maps as the most persuasive maps (rhetorical) and scientific visualizations as being objective (rational) (Muehlenhaus 2014). His continuum implied that there can be a purely objective map, and these objective maps do not persuade and never aim to persuade. Other authors might disagree with this viewpoint of pure objective truth. Indeed, Monmonier stated: “There’s no escape from the cartographic paradox: to present a useful and truthful picture, an accurate map must tell white lies” (Monmonier 1996, 1), implying that even with the goal of telling truth, cartographers must alter the design in some respects to provide the necessary information to the map reader.
The research in this paper extends the term vividness into the cartographic realm by drawing connections between this cartographic literature on emotion, attention, and persuasion with the definition of vividness from Nisbett and Ross (1980). This research drew on a series of semi-structured interviews with expert mapmakers at NASA, NOAA, The New York Times, and National Geographic (detailed in Chapter 2). These interview conversations centered on how to make climate change maps which affect and influence audiences. From these interviews, there were several common themes which connect to how maps can draw attention, create emotional interest, and persuade audiences. I elaborate on the methodology of conducting these interviews and how I connected these topics to the vividness definition in the following section.

3.4 Methods

The goal of this research was to develop a set of aspects of a vivid map because vividness is linked with persuasion and thus these maps may be more persuasive to audiences. Unlike other vividness studies which provided little information on why particular content was vivid, this research identifies the aspects of a vivid map. Future research can assess whether maps which employ these aspects are indeed persuasive.

This research relied on semi-structured interviews with 16 elite cartographers, graphics editors, and occasionally their managers to identify themes related to creating maps of climate change which they felt influenced their audiences. These participants were identified by first collecting a large number of maps of climate change and identifying the most common producers of these maps. I conducted interviews at The New York Times, National Geographic, NASA, and NOAA. I connected with and organized interviews through email, personal connections, and snowball sampling. A detailed description of the participants in the study can be found in Table 2.2.

Semi-structured interviews, unlike other types of interviews (unstructured and structured) allow the researcher to follow an interview question guide, but also to interject to clarify or ask new questions as needed (Dunn 2010). This type of interview was ideal for investigating vividness in maps since this is not a term known to cartographers or graphics editors. I developed a set of interview questions which were designed to answer specific research questions related to how design decisions were made in regards to making maps of climate change which were effective for audiences. The interview questions for this study were developed with input from two other cartographic researchers familiar with the project (see Appendix A). During these interviews, it became clear that topics such as attention, emotion, memory, and persuasion were common themes in their design decisions. I asked follow-up questions in which participants could elaborate on how these major themes were part of their design process. Thus, even while I did not ask specific questions related to vividness in maps,
tangential topics were common in the conversations and follow-up questions helped participants to elaborate on how these were important for their design process.

The interviews were conducted in person, via GoToMeeting, or on the phone, depending on the availability of the participant. All of the interviews were conducted between December 2016 and June 2018 and lasted between 25 and 65 minutes each. In addition, some of the interviews were conducted in a group setting due to availability of the participants. During the first interview, which was conducted as a group interview at The New York Times, one participant searched for example maps, while the others commented about design decisions. This was a useful process and allowed participants to avoid speaking in abstract terms. I repeated this process for the other interviews either by having participants search for their own maps and speak about them or, in the case of National Geographic, I brought a binder of printed maps from the Magazine as visual stimuli for conversation.

At the start of each interview, I gave the participants an overview of the project and the informed consent document which explained the project and provided them with my contact information. Based on my IRB protocol, I was allowed to use my participants’ names (see Appendix B). All of my participants agreed to this, though, some wanted me to double-check their quotes with them before their inclusion in this dissertation. In those cases, I did double-check quotes with those participants or removed identifying information in the text for the quotes I was unable to double-check. I also informed my participants that I would be recording and would later have the recording transcribed. I began recording once I had oral agreement from all participants.

To code the data, I used Atlas.TI, a qualitative data analysis software used to code transcribed text. I followed methods presented by Cope (2010) and coded in vivo first. I then reduced the number of codes by identifying overlapping and unused codes. In this second stage of coding, I identified major themes, or groupings of codes. The final list of codes (n=82) and major themes (n=17) are included in Appendix C. The “design” theme, which contained codes related to vividness, emerged as presenting aspects of a vivid map which then could be tested for their persuasiveness in future studies (Table 3.1).
<table>
<thead>
<tr>
<th>Theme</th>
<th>Code</th>
<th>Explanation</th>
<th>Count</th>
</tr>
</thead>
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<td>Animation</td>
<td>design used animation</td>
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<td>15</td>
</tr>
<tr>
<td>Attention/</td>
<td>design aimed to grab</td>
<td>making important data salient</td>
<td>21</td>
</tr>
<tr>
<td>salience</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>conventions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color Schemes</td>
<td>participant described color</td>
<td>schemes used</td>
<td>39</td>
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<tr>
<td>Constraints</td>
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<td>constraints on design</td>
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<td>described data</td>
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<tr>
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<td>Interactivity</td>
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<tr>
<td>Style guide</td>
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<td>style guide or a consistent style was used at an organization</td>
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<tr>
<td>Visual hierarchy</td>
<td>visual hierarchy was</td>
<td>described</td>
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Table 3.1. Codes, explanations, and quote counts for “Design” theme.

3.5 A vivid climate change map

There were five key themes which emerged from the interviews related to the three key aspects in the vividness definition: 1) emotionally interesting, 2) concrete and image provoking, and 3) proximate in a sensory, temporal, or spatial way. I present results from the
interview study as they related to the five key themes of: 1) visual salience, 2) visible change over time, 3) color use, 4) cartographic best practices, and 5) novel design styles which I determined were the key aspects of a vivid map of climate change.

3.5.1 Visual salience

Across the interviews, my participants consistently commented on the need to make important data salient in their displays to align with the story they were trying to tell through the maps and accompanying text and other graphics. As noted in Chapter 2, it was clear that “the story” allowed mapmakers to easily decide what was important and needed to be featured in the map’s design.

One way my participants directed attention was by making key data salient in the design. It was clear through these interviews that my participants had this in mind as a goal for their graphics. Ryan Morris at National Geographic described this process,

We want to elevate [the point of the map]. We want to make it so that people say, ‘Yeah, I get that. I see what you’re saying.’ It’s not about dumbing it down, it’s just about shining a brighter light on the more engaging aspects and being thoughtful about that articulation, whether it be visual or organizational, to create a thread that people want to keep reading... That’s the mark of success.

To do this, my participants described reducing the complexity in everything except the key data. To do this, basemap designs were simplistic while thematic data stood out to readers and directed their attention to the data and not the background. For example, in Figure 3.1, the cartographer, John Nelson, pushed the basemap information down in the visual hierarchy to elevate the key thematic data to make that data salient to map readers. In addition, this also meant mapmakers had to focus the story on just one aspect, and they avoided having complex story lines which could confuse readers. Typically, this dictated the use of just a few data layers focused on the one point of the map. To create this effect, my participants described using visual hierarchy and contrast, the visual variables, layout design, or generalization to make the key data stand out to readers. In some cases, participants described making an easy-to-understand map key or making sure to avoid words that might not be understood by a general audience.

Participants also described salience as being a thought behind the early stages of designing a map. My participants described conversations mapmakers had with scientists to help identify the key point the scientist might want to make clear through the graphic. One National Geographic employee said, “Sometimes it’s a matter of forcing the hand of the expert and
saying, ‘I can only say one thing about this trend. What is the one thing I can show or the one data set that will capture all of this?’”

**Figure 3.1.** Map of hurricane and tropical storm locations and intensities since 1851 (Nelson 2012). This data and similar design were featured in the July 2013 issue of National Geographic Magazine. This map illustrates how cartographers elevate the thematic data in maps and push the basemap information back in the hierarchy.

### 3.5.2 Visible change over time

Across the interviews, it was clear also that visually representing change over time was a key component to making maps of climate change which were accurate and had an impact on audiences. In one group interview, my participants noted that a map of climate change *must* show change over time. Maps which showed change over time as it relates to climate change illustrated 1) anomalies, or differences from a current or previous averages, 2) different potential outcomes under different mitigation schemes, or 3) potential future scenarios compared to the current situation (e.g., Figure 3.2). Across many of the interviews, participants expressed the advantages and disadvantages of creating different maps that visually illustrated change over time. In this section, I review the types of representations my participants used to visibly illustrate change and attract attention through these designs.
Figure 3.2. Map of a tick establishment probability in the eastern United States for the present and in 2080 (United States Global Change Research Program 2014). This map illustrates one way in which to show change over time by illustrating a potential future scenario compared to the present situation.

3.5.2.1 Change maps

Change maps show the difference between two snapshots in time (Monmonier 1990). To represent time in these maps, the more recent snapshot is subtracted from the older time snapshot. These maps have advantages of illustrating change in one single map without animation which is ideal for some media, especially when simplicity is necessary and display space is limited. These maps were a popular choice for showing anomalies of single climate variables, such as precipitation and temperature (Figure 3.3). My participants did not spend much time describing these map designs, although nearly all of the organizations did make these types of maps. They account for a larger percentage of the maps at government agencies than at media organizations.
3.5.2.2 **Small multiples**

Small multiples, a term popularized by Tufte (1983), are a series of static maps where each map shows a single snapshot (e.g. Figure 3.4). These maps show snapshots of a location with an identical basemap design where the overlaying data illustrates either change over time of one variable or a series of different variables. The map reader can see the differences by visually comparing across maps in the set (e.g., Fabrikant et al. 2008). At The New York Times, participants described small multiples in the context of trying to simplify content for their readers. Tim Wallace, at The Times, described one project where they initially started with an animation and then discussed whether small multiples might work better,

> It almost got to the point where [we asked], “Well do we just want a before and after right next to each other? Because that’s ultimately what people want to see anyway.” … We’re simplifying so much because ultimately if you’re creating a piece of content, if the main goal of that content is simple then you should be able to accomplish it [with a simple map].

**Figure 3.3.** A change map which illustrates difference in average temperature by comparing the November 2016 average with the 1981-2010 average (NOAA Climate.gov 2016).
Figure 3.4. Set of small multiples illustrate the increase in number of days over 100 degrees in the contiguous United States (Wallace and Marsh 2016).
3.5.2.2 Animation and interactive sliders

Animation is another popular way of illustrating change over time. My participants spoke about animation in many of the interviews, and the ways in which they created these moving maps either with or without interactivity. Animation without interactivity was often created through the use of animated GIFs. These designs autoplay in social media feeds and loop continuously. In contrast, maps with interactivity typically afford users a time slider. Users can advance time on the map at their own pace.

National Geographic, unlike the other organizations, primarily relied on change maps and small multiples for illustrating change over time since the Magazine is a print publication. The organization only included animation in their multimedia displays. Damien Saunier at National Geographic described using animation in multimedia displays like Snapchat which encouraged younger audiences to learn from National Geographic in new ways,

We use a lot of animation now because people are just so used to seeing things move, so even if we maybe don’t need to animate it, we might just add a little animation just to catch people’s attention. It feels right in this Snapchatty really fast-paced animating scene. We’re still trying to figure how that pace fits here in a completely different medium and a mindset for the user.

Beyond animation, National Geographic cartographers spoke about the need to include visible change over time in representations, but generally spoke less about the intricacies of creating these representations of change over time than at the other organizations.

Across the rest of the interviews, descriptions of animation dominated conversations when the topic was focused on representing change over time. Participants spoke about how popular these forms of representation are for audiences. NOAA’s Climate.gov team identified that their most popular map was an animation. “We’ve had at least one viral, truly viral hit. It was a visualization that we produced for the ‘Arctic Report Card’ a couple years ago. It was an animation that showed sea ice age” said one NOAA affiliate.

Often participants spoke about the simplicity of having animated GIFs which can be easily shared and thus increased dissemination of mapped information related to climate change. At NASA, Josh Stevens described using this type of animation, “We’ll put out short GIFs, three seconds long, and that actually works well because it shows a dynamic process, and it’s the perfect size for Twitter. We notice those GIFs get shared big-time.”

Across the organizations, mapmakers made decisions about when to use interactivity, simple animations without interactivity, or static small multiple displays. At NOAA, interactivity in
the form of time sliders were used extensively to allow map readers to interact with animations (e.g., Figure 3.5). This was partially because these maps were designed to be picked up by media sources who may take static snapshots of the paused animation. However, at other organizations, there was less focus on adding interactivity to animations. At NASA, Josh Stevens spoke about the need to keep animations short and simple because of time constraints in production and because animated GIFs were easily shared compared to interactives.

Figure 3.5. Map illustrating difference from average precipitation with a time slider at the bottom allowing the user to view change over time (NOAA’s Climate.gov 2018).

Nadja Popovich, graphics editor at The New York Times, described making these decisions between animation, interactivity, and small multiples. She focused on one example, a set of two animated GIFs which illustrated the increase in 95-degree days around the globe. Screenshots of the animations are shown in Figure 3.6.

In this case, I can see an argument for allowing people to stop and explore [with interactivity], but also the story is in the trend [more] than in any of the individual frames. That’s why in this case, I wasn’t really too concerned about creating a button that allowed you to explore the in-between phases. The story I’m trying to tell is it’s getting hotter worldwide... Whereas if the trends I wanted people to see were more local, I think that then you would want people to be able to dig in using interactivity.
Figure 3.6. Screenshots of two animations depicting potential number of 95-degree days across the globe through the end of the century (Plumer and Popovich 2017). The maps on the left illustrate the scenario if no action is taken to curb burning fossil fuels, and the maps on the right illustrate the scenario if countries follow their commitments under the Paris Agreement (right).
This was contrasted with her decision between animation and small multiples. Popovich continued by saying,

> For these 95-degree day maps, the reason to do an animation … is we were trying to show change over time… You could use something like small multiples, but I think at this [global] scale if you have a bunch of … maps then people would have to compare them to each other while keeping the entire [previous map] in mind. Whereas [with animation, you can] just watch it happen and watch that heat spread before your eyes.

In general, my participants saw advantages of animated GIFs and other maps that move for conveying stories about a changing climate which attracted attention across a wide set of platforms from Snapchat to Twitter to a simple webpage.

### 3.5.3 Color use: Congruency and connotation

Across all of the interviews there were consistent comments about the use of color. Common critiques of maps in the interviews related to data classification schemes and even rainbow color schemes. The general consensus was that the use of color in the maps needed to align with the data in the map in two ways, by using colors schemes which aligned with 1) data measurement and structure, and 2) cultural connotations and emotion of the dataset.

Participants often commented about the use of color schemes and sequences which aligned with the underlying data and how it was structured. This aspect of the use of color for statistical data has been tested empirically in cartography (Brewer 1994, Olson and Brewer 1997). My participants often talked about the three types of color schemes established in this literature: sequential, diverging, and qualitative. They illustrated that this categorization was important for providing guidelines for the types of color schemes which are appropriate for different types of data. For example, sequential color schemes made sense to use when the data was ordinal, interval, or ratio, and diverging color schemes were ideal when the data had a structure which diverged or had a meaningful midpoint. This was especially important at the government agencies where consistency was key to their maps.

Many of the participants spoke about diverging color schemes since these were often used for climate data to show increases versus decreases, or to show hot versus cold. LuAnn Dahlman, a NOAA affiliate, illustrated how she made decisions on break points and midpoints for diverging color schemes, “In this particular case [of temperature], …we thought, ‘Gosh, when it’s below 50, yeah, that’s when you put a jacket on. It’s cool. We’ll [set the midpoint] right there.’” Additionally, her colleague Rebecca Lindsey said, “We only use hue shifts and color shifts when they’re meaningful or significant in the data.” She continued to illustrate this point further when she talked about using multiple hues in a linear dataset,
Although that is linearly varying data, we introduced different hues in the palette because there were specific thresholds that were significant to salmon survival. There was a temperature break where above that temperature, salmon would be stressed, and then there was a second temperature threshold above which it was likely fatal to salmon. So, we used multiple hues that shifted at those temperatures but we don’t ever do that for arbitrary reasons.

At media organizations, mapmakers also spoke about classifying data and making color schemes to make maps easy for their readers to understand. Tim Wallace at The Times described the map in Figure 3.7, “We had been publishing this style of climate change map for a few years so all I did was swap in the background image and make sure that the breaks are intuitive.”

At NOAA, in particular, they were tasked with creating maps throughout the year to illustrate NOAA climate data. This meant that my participants had to grapple with creating and using color schemes which worked across all 12 months for a variety of climate variables. LuAnn Dahlman illustrated that this task required looking at the entire range of data to make decisions about colors, “We look at our Julys and we look at our Decembers, and we saw what the full range of data were before we came up with the ramp… One of the biggest issues… is finding color ramps that have as many colors as you need to cover all seasons of the year into the past and the future.”

Besides assuring that colors made sense for the data structure, participants focused on the use of colors based on color connotations. For instance, participants used red to illustrate hot and blue to illustrate cold which align with other conventions in our society. Lauren Tierney described using colors which aligned with these color connotations,

> If you’re trying to get across the point [that] the Arctic is melting drastically, you use purples and blues… for the background because it’s cold, but with the key data, you’d want to use that red, that orange color because that’s a color that you see that and it’s like, ‘oh, that’s heat or it’s not good.’ So definitely going for—I don’t know if dramatic is the right word—but just really using color and design and drive home that key point of this is warming up, this is melting.

Colors have cultural connections as well. At The New York Times, participants mentioned potential problems with their maps outside the United States where colors have different connotations. Specifically, participants wondered how their maps, especially those which used red, might be perceived in China where red has a different connotation than in the United States. Although my participants did not come up with a solution to this potential problem, this conversation illustrated their awareness of cultural colors connotations.
Globally, 2015 was the warmest year in recorded history.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{new_york_times_map}
\caption{New York Times map of global temperatures compared to average (The New York Times 2016). This map was featured above-the-fold to illustrate that 2015 had been the hottest year on record up to that time. This record was broken by the year 2016. Class breaks are every half degree Celsius to be intuitive for map readers.}
\end{figure}

Color connotations also were connected with eliciting an emotional response from readers. Graphics editors at The New York Times spoke of the use of red which led audiences to think of heat. They noted that perhaps a red map was all it took for readers to get worked up
to take action, even if that action involved simply sharing the map with their social media followers. Tim Wallace described the use of color in Figure 3.4,

I did an op-ed map with Bill Marsh, it’s really simple, looking at the days above 100 degrees projected out to 2100 and—I don’t know what they did with this to promote it but it went, at least their desk said that it was semi viral for a couple of days. Sometimes it’s just a red map I think, we’re like, “Oh my gosh, it’s so hot.” You see something like 163 days above 100 degrees in Phoenix per year by 2100 and you might get worked up and tweet it out.

In some cases, participants commented about how red was problematic. Meteorologists have been adding more colors to their maps to convey new extreme heat in some locations, and the media is republishing these maps with titles such as “Arizona so hot weather map almost runs out of colors” (Torresgrossa 2017) or “Australia adds new colour to temperature maps as heat soars” (Carrington 2013). Josh Stevens at NASA commented that there was no need to add more colors to the map, since these temperatures were not the highest temperatures ever recorded. These extreme temperatures are just happening more often.

One thing that I do notice … looking at these temperature maps are sort of the race to red… Anecdotally they tend to be getting more red and more purple for temperatures that wouldn’t have seen those same things 10 years ago. They’re changing the class breaks, but even adding [color] palettes on top of [color] palettes making these maps look really extreme… They make their map look more extreme and it gets picked up [by other media]. Maybe those colors mean something to somebody, but it seems like the number of colors used has grown over time.

At the government agencies, it was clear they had conventions about the use of particular color schemes for different variables. For instance, a drought map might use one color scheme while a temperature map used another scheme. It was through talking about these climate variables that it was clear that these individuals had explored different ways in which to illustrate these variables so they were noticeably different from each other to allow audiences to identify which variable they were viewing (e.g., Figure 3.8). This use of color schemes was usually committed to a style guide that these participants referred to for maintaining consistency across their maps and to create their own conventions through their designs. For instance, Josh Stevens at NASA said,

Whenever we map sea surface temperature anomaly, which is a good way to show El Niño and La Niña, we use a muted red/blue color scheme, and one of the reasons that we do that is we also show sea surface temperatures, [not anomalies], which uses a more pure red and blue color scheme. This way our readers are not confused they’re the same thing.
Figure 3.8. Two maps designed by NASA’s Earth Observatory team showing subsurface soil moisture anomaly and drought intensity (Stevens and Dauphin 2018a, 2018b). These maps illustrate how two similar and related topics were designed with different color schemes so readers can immediately identify that they represent two different variables.
3.5.4 Other cartographic best practices

My participants commented extensively on the use of cartographic best practices. The best practices most common in our conversations were related to projections, symbolization (symbology), legend design, and layout. The use of these best practices allowed map readers to easily understand the map in its familiarity of design, and I argue that these are a vital aspect of vividness. If a vivid map is a map that matters, and a map that matters is one that is tacitly understandable. A vivid map must follow best practices that have been tested and used by cartographers with the goal of making maps easily understandable for audiences. In this section, I briefly review how these conventions came up in conversations with participants, how their uses differed across organizations, and their connection to cartographic communication.

At the government agencies, there was a clear focus on these design aspects which were often part of style guides or templates to create consistent designs across a series of maps. In the case of government agency maps the best practices related to layout, legend design, symbolization, and projections were all important for making maps part of a set and gave credibility to the data and the design which were presented in their style guides. The consistency across the maps in their design made it obvious that the map had authority in its familiarity and similarity to other maps by the same source. One NASA visualizer described their style guide,

> We have a style guide that describes our font, what size to use, colors and things like that, and we adhere to that pretty strictly. It’s got things like typography, we also add a shadow effect, like when they want satellite images that have all kinds of detail in the background. So, we have very specific settings for those. We have a section on establishing a visual hierarchy…

At media organizations, layout, for instance, was less consistent than in government agency maps. Layout of a media map was designed to guide the reader through an intricate story. Instead of having a layout template, each map and story was designed to be distinctive. The layout served as a guide to direct attention through the use of white space to focus the reader on the key data.

Legends, also called map keys, were mentioned as a way to reduce complexity for the reader through using simple language. Participants described legends as one of the ways they reduced complexity in the design. Unlike GIS defaults, cartographers worked with copy editors to identify wording for the legend title and element definitions. In some cases, this meant reducing precision in the data. For instance, they did this by annotating the legend with simple “high vs. low” for easy interpretation, as opposed to having precise numeric data.
At The New York Times, graphics editors spoke about how they wanted their maps to have a subtle design so map readers would not even think about the projection. This was repeated by other participants who described choosing a projection to make the data stand out, but they said they did not necessarily want their readers to notice it. At the government agencies, their style guide dictated what projections worked best for particular scales, and helped to create consistency across map designs. At media organizations, on the other hand, they explored using different projections to highlight data in different ways. Sometimes this meant using oblique views and other transformations of space that draw the readers’ attention and highlighted the data in a particular way.

3.5.5 Novelty

While many of the participants spoke about following cartographic conventions they also elaborated on the use of novel designs and data in their maps. They spoke about the need for their maps to stand out and make an impact on readers. Primarily these novel designs were the focus at National Geographic and The New York Times as opposed to the government agencies. Although it was clear through collecting a large set of climate change maps (reported on in Chapter 4), certain groups within NASA used design novelty. In particular, the NASA Scientific Visualization Studio group used 3D and oblique views along with animation to create compelling videos. Figure 3.9 is a screen capture of one of their most republished animated maps. In contrast, the Earth Observatory group members who I interviewed shied away from these novel designs because they had to produce maps and graphics quickly and want their maps to be easily shared.
Figure 3.9. Screenshot of circulation of carbon dioxide in the atmosphere (Putnam et al. 2014). This is an animated map which shows how, over the course of a year, CO₂ circulates around the globe.

At National Geographic, cartographers spoke about the ability to push bounds in their designs at the Magazine. Working at the Magazine meant there was already an acceptance they knew the cartographic conventions and best practices, and they were given the freedom to break those rules and molds to create something different for each map. This meant that while there was a similar look and feel to the maps in the Magazine, there was also variety in the design and the maps do not all look the same.

At The New York Times, more than any of the other organizations, there was a greater focus on the use of novelty. The constraints of time and resources were often described as the only limiting factors to trying new designs. Ultimately, their goal was to display data in a new striking way in addition to communicating to readers. If communication could be accomplished with a novel design, these new designs were encouraged. My participants at The Times spoke about the use of drones specifically. Drone technology was used to dip below cloud cover to collect data previously unavailable following climate-related disasters, or to create cool cinematic shots by doing dives or quickly zooming out from a location to give greater geographic context of a place. In some cases, these types of technology drove the design of the story because the graphics editors knew they would have access to drone footage. Derek Watkins, a graphics editor at The New York Times described the different types of drone footage they used,
Graphics has been trying to do more drone work in different ways. Because often, if Josh [Haner is the] photographer somewhere shooting some drone video, he’s going to want the very dramatic—narratively dramatic, almost cinematic shots. Whereas, oftentimes, [the graphics department] might lean more towards wanting to get the shot that we know that we can go back and annotate and diagram and go with the graphic because that’s the way that we’re used to thinking.

One particular piece titled “Greenland is Melting Away,” graphics editors used drone footage and *scrolly-telling*, where a reader scrolls down a page to initiate an interaction in a graphic. In this particular map, by scrolling the reader is zoomed closer and closer to areas of melting on the Greenland ice sheet (Figure 3.10) Derek Watkins again explained,

> We pretty quickly settled on the general idea that we ended up publishing …

> We were inspired by the old *Powers of Ten* documentaries, where you start very zoomed out and then zoom in closer and closer, like powers of ten and explain the scale of the universe in that way. We finally made this zoom-in interactive thing that zooms into the island [of Greenland] while you’re scrolling down the page.

The design of the Greenland piece is an archetypical example of the types of novel designs currently being developed at The New York Times. This piece represented a simplification of interactivity melded with cinematic drone footage. The scrolly-telling design fit with the transition at The Times away from highly interactive graphics. The graphics editors spoke about drawing from a conference presentation by Archie Tse (2016) where he called for simplifying interactions for users. There was a period of time, Tse noted, when interactivity was so complex at The Times that users failed to see buttons and thus did not fully explore interactive graphics. Graphics editors at The Times reasoned that readers did not necessarily want to explore these graphics for extended periods of time. In addition, increasingly readers are now reading articles and exploring graphics on smartphones and other touch-screen devices. In these cases, the typical user interaction is scrolling. The scrolly-telling design instead allowed mapmakers to grab attention by adding transitions to their designs without asking their audiences to search for buttons.
Scientists know that the melting of Greenland is accelerating. As the temperature rises, large lakes form on the surface of the ice, which in turn create a network of rivers.

“The rivers melt down faster than the surrounding ice, like a knife through butter,” Dr. Smith said.

The rivers then flow down into giant holes in the ice, called moulins, which drain through tunnels in the ice sheet and out into the ocean.

“The ice sheet is porous, like Swiss cheese,” Dr. Smith said. “We didn’t know that until this year.”

This summer in Greenland, the scientists set up their camp on the ice, where they hoped to capture the first comprehensive measurements of the rate of melting.

Figure 3.10. Screenshots from the Greenland is Melting Away interactive map piece (Buchanan and Watkins 2015). Map readers scroll down the page and are zoomed closer to the ice sheet.
Often the reasoning behind adding these novel designs was to make this information stand out in the constant stream of visual information readers encounter every day. Larry Buchanan, graphics editor at The Times, described this,

[There are] hundreds of stories a day [that] come at you, you have to decide what to click on and what to consume and so if we can make this surprising or more interesting or the form speaks to the content in a specific way, maybe all of those things that we agonize over actually do make a difference to our reader.

In some cases, novelty did not necessarily mean using new technology or data, but simply meant creating a different effect not typically used in map design. Nadja Popovich, at The New York Times, spoke about using simplicity to create something “weirder than people are used to seeing” through simply showing polygons of the glaciers in Glacier National Park in 1966 overlaid by polygons of the glaciers’ extent in 2015 (Figure 3.11). Popovich indicated that this mapping project, while simple, was widely shared by audiences because it was immediately clear to readers what they were looking at, but the data also was shown in a different way then they might normally see.

Figure 3.11. Screenshot of a section of the “Mapping 50 Years of Melting Ice in Glacier National Park” piece (Popovich 2017). The simplified and static design of these maps are novel because this type of map design is not typical.
On the more complex and novel technology side of map making, The New York Times has invested in augmented reality (AR) and virtual reality (VR) through the creation of a team within the Graphics Department that focused on creating specific AR/VR experiences related to news stories. In some cases, the push to do an AR/VR feature drove what data were collected. A companion story was often created for regular web users which was less complex to draw larger audiences than the AR/VR version. Tim Wallace at The New York Times explained while there has been a push to reduce the use of complex interactivity in traditional web stories, this parallels the increase in the use of AR/VR where audiences are perhaps looking for these types of highly interactive and immersive experiences.

Finally, there also comes a point where a design is no longer novel. As cinematic drone footage becomes more common, it may become overused and boring to readers, as did highly interactive web graphics. There is a balance of using novelty to be interesting enough for it to be remembered, while avoiding overdoing it to the point where readers are no longer awed by a new design or technology.

3.6 Discussion: Connecting interview themes with vividness definition

The vividness definition by Nisbett and Ross (1980) describes content which is “likely to attract and hold our attention and to excite the imagination to the extent that it is (a) emotionally interesting, (b) concrete and image provoking, and (c) proximate in a sensory, temporal, or spatial way” (45). This definition is helpful in many ways, but also has limitations in that it does separate what is vivid from the consequences of vividness. In this section, I connect the key themes of the interviews for making maps that matter to themes in the cartographic and data visualization literature and the vividness definition by Nisbett and Ross (1980). The results of this study illustrate what aspects of a map make it vivid, and future research can and should test the consequences of designing maps with these aspects to identify whether these maps do indeed elicit emotional responses, hold attention, and excite the imagination.

I would also argue that vivid maps have always existed, but what makes them vivid changes over time as novel designs, fads, and fashions change within cartography. However, a vivid map has the potential to be persuasive and provides a holistic way in which to evaluate map design to expand beyond traditional cartographic research which focused on psychological studies which were limited in ecological validity.
3.6.1 Visual salience in maps: Connection to vividness definition

Salience, in cartography, is associated with how the visual variables are manipulated to give thematic data visual meaning in cartographic design. In this way, salience has also primarily been associated with contrast and hierarchy to guide the map reader’s eye to particular aspects of the map through their visual search within a display. In the interviews, my participants described using the visual variables to make certain aspects of the map design salient. I argue that salience has already been connected to the concept of vividness through Guadagno et al.’s (2011) study, and since it is already an established term within cartography and is widely used to make maps which resonate with audiences, it makes sense to include salience in the definition of a vivid map.

3.6.2 Visible change over time in maps: Connection to vividness definition

Tufte (1983) described graphics of space and time as a way to make four or five dimensions concrete and understandable to their audiences. In other ways, illustrating space and time in graphics and animations can make the topic proximate in a sensory or temporal way by allowing readers to see the changes over time. In small multiples readers can imagine and make inferences about the changes between snapshots, and in animations readers can see the transitions in the display. By explicitly representing change over time in maps, readers are not forced to try to grasp an abstract concept, instead the change is concretely presented to them, which is a vital aspect of the vividness definition. In addition, many researchers have connected movement to attention in maps which suggests that animation is an important aspect of a vivid map. Finally, my participants noted the popularity of animation and the ability of these moving maps to grab attention of readers in social media feeds.

3.6.3 Color use in maps: Connection to vividness definition

It is clear that color and emotion are connected. To some extent, it appeared that my participants drew from their own experiences in deciding what colors evoke particular emotions, but in other cases it was also clear that they thought about when colors made sense for their data; both for the structure and cultural connections. Emotional interest is one of the key components of the vividness definition, and both the interviews and literature in the psychology and visualization fields illustrate that colors do have affective connections which may lead to emotional interest (e.g., Valdez and Mehrabian 1994, Suk and Irtel 2010, Bartram et al. 2017). While research in cartography has tested the connection between affect and color in maps recently (Anderson 2018), the color practices noted by my participants can serve as useful guides for making vivid maps, along with the already established literature for color best practices (e.g., using ColorBrewer).
3.6.4 Cartographic best practices: Connection to vividness definition

The aspects of cartographic best practices which my participants mentioned have been explored in the cartographic literature; however, practicing cartographers also draw from their own intuitions about what makes a map understandable and aesthetically appealing to readers. For a map to be emotive and bring a topic to life, as a vivid map should, it first must be understandable. Indeed, Tyner’s work on persuasive cartography nearly 45 years ago noted that maps must be pleasing to look at to be persuasive. I argue that while “pleasing” may not be the best word, maps which are vivid must be understandable. Making maps which are understandable should draw on the 70 years of cartographic research which has resulted in a set of best practices. Indeed, this key link between understanding and persuasion was made in the early days of cognitive cartography. Robinson (1952), viewed as the father of academic cartography in the United States, drew from research related to advertising and psychology and called for research in cartography to build from these domains. The results of this extensive research form the basis for the contents of major textbooks in cartography which the designers at these organizations draw upon for their designs (e.g., Slocum et al. 2009, Brewer 2016). Finally, this link between best practices and bringing topics to life connects to Kent’s (2005) call for more research on aesthetics in cartography which he believes, and I agree, has been overlooked due to the focus on cognitive cartography.

3.6.5 Novel designs in maps: Connection to vividness definition

Vivid information has been argued to have more impact on judgements because it is more available in memory (Nisbett and Ross 1980). In information visualization, novel designs have been shown to be interesting and more memorable (Borkin et al. 2013, Borkin et al. 2016), and when used with cartographic best practices are comprehensible. These types of designs stand out in our minds. In the same way, novel designs in maps are perhaps more memorable, and allow map readers to immerse themselves in a place which provokes imagery in the map reader or makes the topic more proximate by bringing a topic closer to a map readers lived experiences. Finally, some of these new technologies (e.g., AR/VR, drones, etc.) also provide more concrete images of these distant and abstract concepts related to a changing climate. While in some literature vividness and novelty are defined separately (e.g., Stroebe and Fennis 2015), I argue linking these concepts is key for map design since these types of designs do stand out to readers when used in concert with the other four aspects of vividness in maps.
3.7 Conclusions

This chapter reported on an interview study conducted with elite mapmakers at media organizations and government agencies who design climate change maps that matter. The result of this study was a set of cartographic aspects which together are needed to make a map that matters, in other words, a vivid map.

The concept of vividness has not been mentioned in cartographic research; however, it has potential as a way to allow cartographers to create influential maps that are not necessarily overtly propagandist. Cartographers now can incorporate these aspects of a vivid map to create maps that matter. Previous research on vividness lacked a clear definition which made extending this concept to a new domain difficult. The final set of vivid map aspects will allow cartographers to create emotional interest and bring distant topics to life. These aspects are also supported in the cartographic literature and align with the current definition of vividness in other domains.

These aspects are:

1. Visual salience
2. Visible change over time
3. Color use with aligns with cultural and emotional connotations
4. Cartographic best practices
5. Novel designs

A vivid map balances the art and science of cartography to create a compelling means by which to convey information about a changing climate. Maps are vivid when use the aspects of vividness listed above. These maps need to follow cartographic conventions, illustrate change over time, make key data salient, use color which is emotive and follows best practices, and incorporate novel designs to make the map memorable. While novel designs often break the rules of best practices, I argue there are some novel designs which still follow best practices and it is these designs which are vivid. Vivid maps may be particularly important when the topic of the map is abstract and potentially confusing to readers, such as in climate change. Readers will not only be able to understand complex topics through the use of cartographic conventions, but these maps will also be memorable through novel designs. In this way, vivid maps can be persuasive towards action, even if that action might simply start with sharing the map on social media. In addition, a map which uses all of the vividness aspects are not simply click-bait since they do not only use novel designs to attract attention without regard for empirically tested cartographic best practices. Finally, in the cartographic domain, vividness is a term which can be used to describe maps in a holistic way, which has not, to my knowledge, been done in cartography before in this way.
This research built from previous research to evaluate maps that matter (Robinson et al. 2017). Future research would benefit from empirically testing the impact of vivid map designs. One way in which to understand potential impacts of vivid maps would be through a survey where participants view a variety of maps and are asked whether they would be likely to share the map on social media. Since a map that matters is one that is disseminated widely, understanding whether a map has potential to be viral is a first step in understanding its impact.
Chapter 3 References


NOAA’s Climate.gov. 2016. “Stunning Arctic Warmth in Fall 2016.”


https://doi.org/10.1080/23729333.2016.1278151.


Chapter 4
Cartographic analysis of compelling climate change communication

4.1 Introduction

Climate change is a multidimensional and complex issue which has significant and unpredictable impacts on the environment and society (IPCC 2014). Communicating this issue is necessary for better understanding of the causes and impacts of a changing climate. In public communication of climate change, maps have become a common graphic used to communicate information about climate change. The geographic nature of climate change due to the spatial homogeneity of the causes, impacts, public opinion, and mitigation and adaptation strategies means maps are an effective visual representation for climate change.

Maps of climate change are designed and used by climate scientists, government agencies, as well as journalists in the media, albeit with different audiences in mind. While the specific goals of the maps designed by these groups are different, the overarching goal of these maps remains the same: to make this complex issue relatable, tangible, and understandable for a broad audience (see Chapters 2 & 3). However, little research has assessed the content of these maps and the aspects of these maps which attract readers, reduce complexity, and make the issue of climate change tangible, and tell a story to their readers.

One way to evaluate maps of climate change is through the concept of vividness. A term used to describe content that is “likely to attract and hold our attention and to excite the imagination to the extent that it is (a) emotionally interesting, (b) concrete and image provoking, and (c) proximate in a sensory, temporal, or spatial way” (Nisbett and Ross 1980, 45). The term vividness was a popular term used in the fields of advertising, media, and psychology in the late 1970s and 1980s. Vivid content in this prior research often referred to written or spoken content and was theorized to have a “significant impact on message success” (Guadagno et al. 2011, 636).

Vividness offers a means of examining the power in maps to influence thinking about an issue. In mapping climate change, journalists have goals of illustrating the changing climate with influential visuals, often maps. But who creates these maps and how influential are they? This article examines the vividness of maps of climate change and answers three core questions:

1. Which media organizations created and shared these maps and were they produced in-house or reproduced from other sources?
2. What aspects of climate change did these maps portray and what aspects of cartographic design did these maps employ?

3. Did these maps convey climate change vividly and which organizations produced vivid maps?

4.2 Climate change communication and vivid maps

The invisible causes, distant impacts, delayed or absent gratification for action, complexity and uncertainty of the science and the impacts, and our own self-interests toward the status quo all pose challenges to communicating climate change (Moser 2010, Nerlich et al. 2010). Much of communication and education literature related to this topic posits a progression from information, to awareness, to concern, and finally to a response or action. As long as people still fail to act, communication is needed to inform about causes, impacts, public opinions, and mitigation and adaptation strategies. For someone to engage in an action to mitigate or adapt to climate change, the person must first have information and be aware of the issue. However, research has illustrated that information alone to raise awareness about climate change is not always sufficient for behavior change, but it is still a necessary component (Chess and Johnson 2007). The effectiveness of climate change information is limited by the quality of the information and how it is framed (O’Neill and Nicholson-Cole 2009), the person’s emotions (Joffe 2008, Otieno et al. 2014, Swim and Bloodhart 2015) and connection to the environment (Schultz 2002), as well as their stage of knowledge or behavior change (unawareness, awareness, concern, and response) (Chess and Johnson 2007, Nerlich et al. 2010).

Much of the research in climate change communication has focused on the media as the primary actor for communicating climate change (Weingart et al. 2000, Boykoff and Boykoff 2007), and indeed, the media is one of the key ways in which information about climate change is communicated to the public (Hannigan 2014). In addition, visual communication research has illustrated that graphics and pictures are vital components of this communication (van der Linden et al. 2014, Harold et al. 2016). Visuals can both reduce complexity and help the public understand climate change (Weingart et al. 2000, Boykoff and Boykoff 2007, Smith and Joffe 2009, DiFrancesco and Young 2010, Manzo 2012), and some recent research has even established guidelines on effective visual communication of climate change (Harold et al. 2016).

While visuals have been shown to be important for climate change communication, and despite that geographers have focused extensively on climate change in other sub-fields, only a small set of research has focused on map design related to climate change. The majority of this research has focused on identifying best practices for displaying uncertainty (Kaye et al. 2012, Retchless and Brewer 2016, Johannsen et al. 2018). In addition, other research has
critiqued map design used in the IPCC reports (McKendry and Machlis 2008) focused on map design principles, while other more recent research has connected other topics common in climate change communication, such as motivated reasoning and spatial optimism bias, to how map readers viewed risks to sea level rise (Retchless 2017).

Information presented in different ways may have an influence on the persuasiveness of a message and how lasting the persuasive content is with the reader. Vivid information is content which is “likely to attract and hold our attention and to excite the imagination to the extent that it is (a) emotionally interesting, (b) concrete and image provoking, and (c) proximate in a sensory, temporal, or spatial way” (Nisbett and Ross 1980, 45), and has been theorized to be persuasive. One reason might be that vivid information is more influential when viewers are forming associations between prior knowledge and new knowledge, known as cognitive elaboration (McGill and Anand 1989). Other reasons include that vivid content is memorable and thus more cognitively accessible (Shedler and Manis 1986, Eaton 2011), meaning readers can incorporate the content into inferences and decisions they make. Vividness may also increase a readers’ ability to construct mental images and recall information through its emotional interest. Indeed, vividness has been shown to increase comprehension (Kelley et al. 1989) and with its ability to attract attention may also lead to greater motivation. In other words, vivid content brings concepts to life. Communicators often use vivid content with the goal of influencing their readers. While it is not completely clear why or how this information leads to changes in attitudes and behaviors, a necessary first step is to understand what content is vivid and who is creating this content to later test its potential for persuasion.

While the term vivid is rarely, if ever, used in the cartographic realm, visual hierarchy, attention, emotion, salience and persuasion are common themes within the cartographic literature (e.g., Fabrikant and Goldsberry 2005, Fabrikant et al. 2012, Griffin and McQuoid 2012, Muehlenhaus 2012, 2013, 2014). Maps are vivid through their cartographic design and through the emotions they evoke in their readers (see Chapter 3). The use of the visual variables (Bertin 1983), interactive primitives (Roth 2013), and dynamic variables (DiBiase et al. 1992), well known in cartographic literature, can influence the aesthetics of the design and readers’ reactions to the display. Through its potential to influence attitudes, vividness is also aligned with persuasiveness, a focus of some cartographic research in the late 1970s and early 1980s (Tyner 1982) and again more recently (Muehlenhaus 2012, 2013, 2014). Additionally, the design of graphics has been shown to influence whether a reader reacts with a greater willingness to engage or disengage in a behavior or attitude (Lang et al. 1993, Joffe 2008). Vividness may provide a connection between the design of the map, emotion, attention, and persuasion.
4.3 Methods

This study employed quantitative content analysis to answer the posed research questions from Section 4.1. I assessed the design of 242 maps of climate change. I present the methods of data collection and analysis in this section.

4.3.1 The sample

Between early 2015 and late 2017, a group of four undergraduate interns under my direction collected maps of climate change. The goal was to find maps in the print and online media published between January 2012 and December 2017 that illustrated climate change causes (e.g., CO₂ production and movement), impacts including everything from temperature and precipitation changes to glacial melt and sea level rise, as well as maps which illustrated the geographic disparities in public opinions about climate change. To be included in the sample of maps, the map needed to clearly indicate that it illustrated climate change in the title, legend, or map notes, or the article needed to mention the term climate change in the text.

The print and online media included in the search did not include maps on personal blogs, maps from peer-reviewed articles, maps in reports for lawmakers (e.g., the IPCC reports), or government agency maps unless these were reproduced in print or online media sources. The sources that were included were newspapers (e.g., The New York Times and The Washington Post) and magazines (e.g., National Geographic Magazine), as well as new digital media (e.g., Buzzfeed, Mashable, etc.) The sample did not include maps on TV because these maps are often not thematic and instead are simple locator maps with little climate data. These restrictions also limited the volume and complexity in locating and archiving these sources.

The maps were located through Internet searches (Google and Twitter), National Geographic Magazine repositories, The New York Times website, The Washington Post website, The Los Angeles Times website, the PressReader database, the Associate Press (AP) Image Database, and The New York Times Historical Database. I used the following search terms across all of these websites and databases: “climate change,” “climate change map,” and “global warming,” as well as more specific terms such as: “sea level rise,” “sea ice,” “glaciers,” “flooding,” “temperature change,” and “precipitation change.” I also used more general search terms including “climate” and “environment.”

PressReader, The New York Times Historical, and the Associated Press (AP) Image databases were available through my university library subscription. PressReader is a subscription based service to which libraries can subscribe and allows patrons to browse in full-color the past 90 days of over 6,000 periodical publications from around the globe. Within PressReader I
focused on publications in English from the United States from cities with major
newspapers. Since this resource only contains the previous 90 days of content, I looked at

The New York Times Historical database contained every article from The New York Times
from 1851 to 2013 in full print page form including graphics. However, this database only
contained the high contrast black-and-white (no greyscale) versions of the print articles. In
this database, I only looked at articles and maps from 2012 and 2013 because the database
did not contain articles after 2013 during the data collection period. From the identified
articles, I searched for the full color images online on The New York Times website since
often the pure black-and-white scans of the maps were unreadable.

The AP provides news stories to other news organizations. Generally small local newspapers
do not produce their own stories and graphics on larger international topics, such as climate
change. Instead these smaller outlets rely on the AP for broad non-local stories because the
AP has the resources to write these stories with the goal of dissemination through smaller
local news organizations. Thus, the graphics from the AP database served as a representation
of a wider range of sources.

I also had access to every map published in National Geographic Magazine during the time
period of interest, and I identified the maps during that period which illustrated climate
change.

Finally, after the initial set was compiled, maps within the same article which had the same
design and topic and only illustrated different geographic areas were only coded once in the
analysis. For instance, if one website contained maps of sea level rise for five US cities, this
was coded as one map because the topic and map design was the same, even if the geographic
area of interest in the five maps were different. The final set of maps amounted to 242.

4.3.2 Content analysis

I analyzed the maps with content analysis. Content analysis is a systematic method for
examining and comparing symbols of communication (Rose 2012). A set of codes is
identified and these codes offer a systematic lens by which to examine themes (Krippendorff
2013). This type of analysis has typically been used for analysis of text, but has recently been
expanded to maps to derive common themes (Muehlenhaus 2011, 2013) as well as best
practices (Kessler and Slocum 2011, Roth et al. 2015).

The goal of this content analysis was to understand who produced the maps, where they
were reproduced, what aspect of climate change they illustrated, what types of design they
used (type of map and visual variables used), what location and extent they showed, and the
extent to which each map was vivid through a Likert scale rating by two coders (see Table 4.2).

Once the full set of 242 maps was compiled, I established a coding scheme. The coding scheme consisted of general codes (Table 4.1) and vividness codes (Table 4.2). The general codes were important for understanding the content included in the maps related to: 1) the publication location, 2) producer, 3) date of publication, 4) use of dynamic map designs, 5) type of map design. The vividness codes were established to analyze for the aspects of the maps which aligned with the aspects of vividness from Chapter 3 which are: 1) visual salience 2) visible change over time, 3) color use which aligns with cultural and emotional conventions, 4) best practices for cartographic design, and 5) novel designs. These aspects of vividness were based on themes from a series of interviews conducted with media cartographers and graphics editors at major media organizations and government agencies who produce maps of climate change (see Chapters 3). I divided the best practices aspect from Chapter 3 into 1) projections, 2) legend design, and 3) layout to make the aspect more specific for the task of coding. I also added one additional code to the vividness codes called topic. This code was used to identify maps which illustrated a topic relevant to society. Since the relevance to society and the environment is key to “maps that matter” (Robinson et al. 2017), it made sense to include this in the coding scheme.

I first coded the maps based on the general codes using a Google form. I typed in responses for the short answer codes (Location and Producer), and selected from a set of potential answers for the multiple-choice codes. For the date code, I entered a six-digit date. I coded based on the vividness codes in a second round of coding.

<table>
<thead>
<tr>
<th>Code</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Short Answer</td>
</tr>
<tr>
<td>Producer</td>
<td>Short Answer</td>
</tr>
<tr>
<td>Date</td>
<td>Date</td>
</tr>
<tr>
<td>How dynamic is the map?</td>
<td>Multiple Choice</td>
</tr>
<tr>
<td>Type</td>
<td>Multiple Choice</td>
</tr>
</tbody>
</table>

*Table 4.1. List of the general codes and how they were collected.*

The vividness scores were coded on a 5-point Likert scale where the highest score was assigned if the map fully implemented a particular vividness aspect, and the lowest score was assigned if the map did not engage with a particular aspect. The resulting table from the vividness scores looked similar to Table 4.3.
<table>
<thead>
<tr>
<th>Codes</th>
<th>Ratings (5-point Likert Scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Salience</td>
<td>Is the important thematic data made salient in the map?</td>
</tr>
<tr>
<td>Change over Time</td>
<td>Does the map show change over time to make climate change tangible?</td>
</tr>
<tr>
<td>Novel Design</td>
<td>Does the map use a novel design style?</td>
</tr>
<tr>
<td>Color Use</td>
<td>Does the map use saturated colors that align with color connotations?</td>
</tr>
<tr>
<td>Projection</td>
<td>Does the map use an appropriate projection for the data?</td>
</tr>
<tr>
<td>Symbolization</td>
<td>Does the map use visual variables that are appropriate for the data?</td>
</tr>
<tr>
<td>Legend Design</td>
<td>Is the legend clear?</td>
</tr>
<tr>
<td>Layout</td>
<td>Is the layout design balanced?</td>
</tr>
<tr>
<td>Topic</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 4.2. List of the vividness codes and explanations.

<table>
<thead>
<tr>
<th>Map</th>
<th>Salience</th>
<th>Change</th>
<th>Novelty</th>
<th>Color</th>
<th>Projection</th>
<th>Symbol</th>
<th>Legend</th>
<th>Layout</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 4.3. Example output data table of vividness coding.

4.3.3 Non-metric Multidimensional Scaling (nMDS)

Because the result of the vividness ratings was a combination of the nine vividness aspects, it was important to analyze these codes with a method designed for analyzing multidimensional data. I used non-metric multidimensional scaling (nMDS) in the \textit{vegan} package in the \textit{R} statistical package to identify clusters of maps based on vividness codes. nMDS is a visual ordination method used for understanding and explaining the interaction between variables. It is often used by ecologists for understanding species distributions (McCune et al. 2002). As a visual ordination method, nMDS graphics are meant to be read and interpreted visually. The multidimensionality of the input data is scaled to reduce the dimensions, and the resulting dimensions in the nMDS plot are arbitrary. In this case, the nine vividness attributes were scaled to 2D space. This type of analysis does not show the most and least vivid maps, instead it allows readers to see how maps cluster.
4.4 Results and discussion

This section includes the results of the map collection and archiving, the content analysis coding, and non-metric multidimensional scaling of the content analysis results. The results indicated there was a wide variety of final publication outlets, with a smaller set of original producers. The majority of maps from this small set of producers were republished across media outlets. In addition, an even smaller subset of the publication outlets produced their own maps. Most of the maps in the sample were thematic, and illustrated a wide variety of different climate change related topics. Finally, some of the maps in the set were highly vivid and were rated high on all of the vividness codes, many of the maps were rated highly on some vividness codes and were rated low on other codes, and a few maps were rated low on all of the vividness codes.

4.4.1 Interrater reliability

The maps were coded by two coders trained in the coding scheme. Both coders coded every map for the general codes and the vividness codes. I measured Cohen’s Kappa and percent agreement to assure interrater reliability. Percent agreement accounts for the differences in coding, while Cohen’s Kappa accounts for agreement that could be expected by chance (Landis and Koch 1977). The results from the interrater reliability measures are illustrated in Table 4.4. Many of the codes had very high interrater reliability agreement in the Landis and Koch (1977) “Almost Perfect” range. Other codes had lower interrater agreement because there was more variability because the categories had more potential options (e.g. Type) or because the code was more subjective (e.g. Visual Salience).
<table>
<thead>
<tr>
<th>Code</th>
<th>Kappa</th>
<th>Percent Agreement</th>
<th>Mismatches (n=242)</th>
<th>Landis &amp; Koch Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>0.98</td>
<td>0.98</td>
<td>3</td>
<td>Almost Perfect</td>
</tr>
<tr>
<td>Producer</td>
<td>0.75</td>
<td>0.76</td>
<td>44</td>
<td>Substantial</td>
</tr>
<tr>
<td>Date</td>
<td>0.95</td>
<td>0.91</td>
<td>13</td>
<td>Almost Perfect</td>
</tr>
<tr>
<td>Dynamics</td>
<td>0.60</td>
<td>0.94</td>
<td>12</td>
<td>Moderate</td>
</tr>
<tr>
<td>Type</td>
<td>0.57</td>
<td>0.66</td>
<td>64</td>
<td>Moderate</td>
</tr>
<tr>
<td>Visual Salience</td>
<td>0.60</td>
<td>0.48</td>
<td>123</td>
<td>Moderate</td>
</tr>
<tr>
<td>Change over Time</td>
<td>0.74</td>
<td>0.53</td>
<td>11</td>
<td>Substantial</td>
</tr>
<tr>
<td>Novel Design</td>
<td>0.56</td>
<td>0.55</td>
<td>107</td>
<td>Moderate</td>
</tr>
<tr>
<td>Color Use</td>
<td>0.82</td>
<td>0.71</td>
<td>69</td>
<td>Almost Perfect</td>
</tr>
<tr>
<td>Projection</td>
<td>0.87</td>
<td>0.90</td>
<td>23</td>
<td>Almost Perfect</td>
</tr>
<tr>
<td>Symbolization</td>
<td>0.85</td>
<td>0.96</td>
<td>9</td>
<td>Almost Perfect</td>
</tr>
<tr>
<td>Legend Design</td>
<td>0.89</td>
<td>0.76</td>
<td>58</td>
<td>Almost Perfect</td>
</tr>
<tr>
<td>Layout</td>
<td>0.90</td>
<td>0.75</td>
<td>59</td>
<td>Almost Perfect</td>
</tr>
<tr>
<td>Topic</td>
<td>0.90</td>
<td>0.81</td>
<td>45</td>
<td>Almost Perfect</td>
</tr>
</tbody>
</table>

Table 4.4. Interrater reliability scores for content analysis, including vividness codes and general codes

### 4.4.2 Publications and map producers

Of the 242 maps in the sample, there were a wide variety of different final outlets of publication, (n=45, Table 4.5), but less diversity in which organizations produced the maps initially (n=40, Table 4.6). Many of the reproduced maps were originally produced by government agencies, published in peer-reviewed articles, or taken from scientific visualization tools designed for use by other scientists. These graphics were reproduced directly by media organizations without any edits or updates. Finally, a small group of maps were produced in-house by media organizations who designed their own maps or updated the design of maps from peer-reviewed articles or government agencies. A Sankey diagram illustrates the interconnectedness between producer and final publication location for maps that were produced by producers with more than one map (Figure 4.1).
<table>
<thead>
<tr>
<th>Final Publication Location</th>
<th>Count (n=242)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Geographic Magazine</td>
<td>35</td>
</tr>
<tr>
<td>The New York Times</td>
<td>26</td>
</tr>
<tr>
<td>Washington Post</td>
<td>25</td>
</tr>
<tr>
<td>Texas Climate News</td>
<td>19</td>
</tr>
<tr>
<td>Climate Central</td>
<td>13</td>
</tr>
<tr>
<td>Business Insider</td>
<td>11</td>
</tr>
<tr>
<td>Huffpost</td>
<td>11</td>
</tr>
<tr>
<td>Minnesota Public Radio</td>
<td>11</td>
</tr>
<tr>
<td>National Geographic Website</td>
<td>11</td>
</tr>
<tr>
<td>Vox</td>
<td>11</td>
</tr>
<tr>
<td>Mother Jones</td>
<td>6</td>
</tr>
<tr>
<td>Salon</td>
<td>6</td>
</tr>
<tr>
<td>Mashable</td>
<td>5</td>
</tr>
<tr>
<td>Minnesota Star Tribune</td>
<td>5</td>
</tr>
<tr>
<td>Mashable website</td>
<td>4</td>
</tr>
<tr>
<td>Texas Tribune</td>
<td>4</td>
</tr>
<tr>
<td>The Atlantic</td>
<td>4</td>
</tr>
<tr>
<td>Mic</td>
<td>3</td>
</tr>
<tr>
<td>NPR</td>
<td>3</td>
</tr>
<tr>
<td>Associated Press Image Database</td>
<td>2</td>
</tr>
<tr>
<td>LA Times</td>
<td>2</td>
</tr>
<tr>
<td>Mother Jones Website</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>23</td>
</tr>
</tbody>
</table>

**Table 4.5.** Counts of maps by final publication outlet. Outlets with only one map were combined into an “other” category.
<table>
<thead>
<tr>
<th>Producer</th>
<th>Count (n=242)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Climate Assessment</td>
<td>44</td>
</tr>
<tr>
<td>National Geographic</td>
<td>37</td>
</tr>
<tr>
<td>The New York Times</td>
<td>27</td>
</tr>
<tr>
<td>Peer reviewed article</td>
<td>23</td>
</tr>
<tr>
<td>Climate Central</td>
<td>13</td>
</tr>
<tr>
<td>NOAA</td>
<td>13</td>
</tr>
<tr>
<td>Minnesota Public Radio</td>
<td>11</td>
</tr>
<tr>
<td>NASA</td>
<td>11</td>
</tr>
<tr>
<td>Independent cartographer</td>
<td>7</td>
</tr>
<tr>
<td>Not listed</td>
<td>6</td>
</tr>
<tr>
<td>Texas Tribune</td>
<td>4</td>
</tr>
<tr>
<td>Washington Post</td>
<td>4</td>
</tr>
<tr>
<td>Climate Reanalyzer</td>
<td>3</td>
</tr>
<tr>
<td>IPCC</td>
<td>3</td>
</tr>
<tr>
<td>National Audubon Society</td>
<td>3</td>
</tr>
<tr>
<td>Notre Dame Global Adaptation Index</td>
<td>3</td>
</tr>
<tr>
<td>Yale Climate Change Communications</td>
<td>3</td>
</tr>
<tr>
<td>Associated Press</td>
<td>2</td>
</tr>
<tr>
<td>Google</td>
<td>2</td>
</tr>
<tr>
<td>National Snow and Ice Data Center</td>
<td>2</td>
</tr>
<tr>
<td>Standard and Poor’s</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 4.6. Counts of maps by map producers. Producers of only one maps were combined into “other” category. All maps from peer reviewed articles were combined into a “peer reviewed article” category. Maps by independent cartographers were combined into an “independent cartographer” category.
Figure 4.1. Sankey Diagram illustrating connections between map producers and final publication outlets. The left side of the diagram is the original producers, and right side indicates where the maps were published. The width of the line illustrates the volume of maps produced and then reproduced by the various outlets.

4.4.3 Government entity maps

Of the government-sponsored entities who produced many of the maps in the sample, the primary entities were NASA, NOAA, and the United States Global Change Research Program (USGCRP). Within NASA and NOAA, in particular, there are groups which focus on the public communication of the science of climate change research and specifically on publicly communicating research funded by these agencies. At NASA, this includes the NASA Scientific Visualization Studio and the NASA Earth Observatory. At NOAA, the public outreach group for information and data on climate is Climate.gov. While these public outreach groups exist, graphics were often picked up by the media from groups throughout these climate focused agencies, not just the public outreach groups, and sometimes these graphics were not designed for public communication. For instance, at NOAA many of the maps which were picked up by the media are those from Climate.gov, however maps of weather sometimes slipped in and were used by the media to make points, sometimes incorrectly, about warming (e.g., Beauregard 2014).

Different from NASA and NOAA, the maps from the USGCRP were originally published in the National Climate Assessment (NCA), a report produced through the work of a group of climate scientists in the United States. This report is published every few years and is designed to communicate to policy makers about the state of the climate and the potential
impacts on the United States. These maps in the sample were in the public domain and were reproduced by new digital media (e.g., Vox, Mashable, Buzzfeed) often with article titles such as, “8 charts that show the terrifying reality of how climate change is affecting the U.S.” (Abrams 2014). These maps were originally designed for policy makers and thus often illustrated topics representing impacts on agriculture as well as other issues important to constituents.

4.4.4 Peer-reviewed article maps

Maps were also reproduced directly from peer-reviewed academic articles. Overwhelmingly, these maps were designed to work best in their original publication. These maps often did not have titles and used acronyms not understood without reading the original article. For the example shown in Figure 4.2, the map was originally published by Melia et al. (2016) and then was republished on National Geographic’s website without any changes. This map included acronyms and graphs with little explanation on the National Geographic caption. Readers on the website, for instance, might have wondered why there are two different colored lines, and what the percentages labeled on top of Greenland meant. No explanation was provided on the reproduced map or its caption. In these cases, these maps were not designed to be picked up by the media or used for a more general audience.
Figure 4.2. Maps from Melia et al. (2016) republished on the National Geographic Website (Mason 2017). This map was not updated for a general audience and contains legend items and symbols which are not understandable without explanation on the final publication website. 

As sea-ice declines, Arctic shipping routes will open up. Estimates for both a low future greenhouse-gas emissions scenario (left) and a high emissions scenario are that more routes will be open to more types of ships for more months of the year in the coming decades.

PHOTOGRAPH COURTESY MELIA ET AL, GEOPHYSICAL RESEARCH LETTERS

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1 The pink lines refer to routes usable by Polar Class 6 (PC6) vessels which are able to maneuver through medium first-year ice. The cyan lines refer to routes usable by Open Water Vessels (OW) with no specific ice strengthening. The percentages over Greenland represent the trans-Arctic potential for the two vessel classes (Melia et al. 2016).
4.4.5 In-house media map productions

While the majority of media outlets republished maps from other sources, a small subset of outlets produced their own maps in-house. Those most common in this category were: National Geographic Magazine, The New York Times, and Climate Central. The New York Times and National Geographic Magazine specifically produced maps which were often multivariate, and in the case of The New York Times, often interactive and/or animated. Unsurprisingly, these two outlets also employ a large number of cartographers and data visualization journalists. For example, in an interview I conducted with a group of graphics editors at The New York Times, they noted that the graphics desk employed around 40 graphics editors (Buchanan et al. 2016, personal communication).

4.4.6 Topics, geographic location, extent, and scale

There were a wide variety of climate change impacts, causes, and mitigation strategies illustrated across the sample. Primarily, however, the maps focused on impacts and causes, and a few of the maps illustrated public opinions about climate change in the United States and the world (Table 4.7). Overwhelmingly, the maps showed temperature (n=51) more than any other type of impact.

The maps also tended to focus on the United States, the globe, or the poles, but few maps focused on inhabited places outside the United States. While this made sense, since the sample was from American media, it raised questions about the portrayal of climate change beyond U.S. contexts. Within the United States, some maps focused on individual cities or states, while other maps focused on larger regions (Table 4.8).
<table>
<thead>
<tr>
<th>Topic</th>
<th>Count (n=242)</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>51</td>
</tr>
<tr>
<td>sea level rise</td>
<td>19</td>
</tr>
<tr>
<td>water resources</td>
<td>16</td>
</tr>
<tr>
<td>glacial melt</td>
<td>13</td>
</tr>
<tr>
<td>sea ice</td>
<td>13</td>
</tr>
<tr>
<td>precipitation</td>
<td>12</td>
</tr>
<tr>
<td>public opinion/awareness</td>
<td>12</td>
</tr>
<tr>
<td>wildlife</td>
<td>12</td>
</tr>
<tr>
<td>vegetation</td>
<td>11</td>
</tr>
<tr>
<td>carbon (emissions, storage, credits)</td>
<td>9</td>
</tr>
<tr>
<td>insects</td>
<td>8</td>
</tr>
<tr>
<td>severe weather</td>
<td>8</td>
</tr>
<tr>
<td>vulnerability/risk</td>
<td>8</td>
</tr>
<tr>
<td>combination of many</td>
<td>7</td>
</tr>
<tr>
<td>coral reefs</td>
<td>6</td>
</tr>
<tr>
<td>permafrost</td>
<td>5</td>
</tr>
<tr>
<td>agriculture</td>
<td>4</td>
</tr>
<tr>
<td>economic</td>
<td>4</td>
</tr>
<tr>
<td>soil moisture</td>
<td>4</td>
</tr>
<tr>
<td>flooding</td>
<td>3</td>
</tr>
<tr>
<td>health impacts</td>
<td>4</td>
</tr>
<tr>
<td>human degradation</td>
<td>3</td>
</tr>
<tr>
<td>sea surface temperature</td>
<td>3</td>
</tr>
<tr>
<td>shipping</td>
<td>3</td>
</tr>
<tr>
<td>policy/agreements</td>
<td>2</td>
</tr>
<tr>
<td>conservation</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 4.7.** Counts of maps by topic illustrated.
<table>
<thead>
<tr>
<th>Place</th>
<th>Count (n=242)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>126</td>
</tr>
<tr>
<td>Global</td>
<td>51</td>
</tr>
<tr>
<td>Arctic</td>
<td>21</td>
</tr>
<tr>
<td>Antarctic</td>
<td>10</td>
</tr>
<tr>
<td>Hemispheric</td>
<td>8</td>
</tr>
<tr>
<td>North America</td>
<td>7</td>
</tr>
<tr>
<td>Brazil</td>
<td>4</td>
</tr>
<tr>
<td>Australia</td>
<td>2</td>
</tr>
<tr>
<td>Peru</td>
<td>2</td>
</tr>
<tr>
<td>Caribbean</td>
<td>1</td>
</tr>
<tr>
<td>Europe</td>
<td>1</td>
</tr>
<tr>
<td>Ecuador</td>
<td>1</td>
</tr>
<tr>
<td>Greenland</td>
<td>1</td>
</tr>
<tr>
<td>China</td>
<td>1</td>
</tr>
<tr>
<td>Middle East</td>
<td>1</td>
</tr>
<tr>
<td>Philippines</td>
<td>1</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>1</td>
</tr>
<tr>
<td>Kiribati</td>
<td>1</td>
</tr>
<tr>
<td>Canada</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4.8. Counts of maps by geographic locations illustrated.

4.4.7 Map design

The set included many different types of map symbolization: choropleth, isoline, proportional symbol, multivariate, as well as maps that did not fit in any single category. Within the set of maps, the majority of the maps were multicolored and used hue and lightness to convey information to the map readers. These maps were primarily raster, filled isoline, or choropleth maps.

Most of the maps were static (n=204). However, many of the maps produced by The New York Times, NASA, and a few independent cartographers were animated and/or interactive (n=38). Often these maps did not use templates or standard default designs, but instead illustrated custom multivariate and dynamic design. National Geographic, which primarily designs static maps, did introduce more complexity to their maps by creating multivariate maps. These maps were designed to allow the reader to explore the geographic phenomena for an extended period of time and have less similarity with the single-variate maps found on
many of the newer online media websites where publishers compete for the attention from the viewer with the rest of the Internet and often only have a few fractions of a second to communicate information to the reader.

4.4.8 Vividness results

One way to evaluate the results of the vividness analysis is to sum the scores of the coding. The most vivid maps were typically those which were produced by National Geographic and The New York Times with one exception. Those which scored the lowest on the vividness analysis were those produced by government agencies and academics. Figure 4.3 a-d illustrates the top four most vivid maps in the set based on the coding, and Figure 4.4 a-d shows the lowest rated maps in the set. The highest rated maps often shown the dynamics of climate change through well designed maps, while the least vivid maps often were difficult to understand in the context in which they were published. Sometimes this was because the maps were not produced with the specific purpose in mind and thus were not adequate representations of the dynamics of climate change, e.g. Figure 4.4d. This specific example is a tool used to look at atmospheric circulation, not specifically climate change. Others were deemed non-vivid because they did not follow cartographic conventions (e.g. Figure 4.4b).

![Figure 4.3a](image)

Figure 4.3a. This is the most vivid map (White 2017). More information on why this map was rated as highly vivid in Section 4.5.
Figure 4.3b. The second most vivid map shows the dynamics of the melting of the Arctic ice caps (James et al. 2016).

Figure 4.3c. This is the third most vivid map and creates emotional interest by showing the detail of the buildings in New York, with which map readers can connect (Morris et al. 2013).
**Figure 4.3d.** This is the fourth most vivid map and is an animation of the increase in global temperatures over the 20th century (Mashable 2017).

**Figure 4.4a.** This is the least vivid map and fails to follow some cartographic conventions and does not employ any novel designs or data (United States Global Change Research Program 2014).
Figure 4.4b. This is the second least vivid map (United States Department of Agriculture, Forest Service 2012). These maps do not follow cartographic conventions in terms of color and projection use. In addition, the title of the maps and the legends are not helpful to the map reader.

Figure 4.4c. This is the third least vivid map (NASA Scientific Visualization Studio 2017). The text on this map is difficult to read making it confusing to understand.
Figure 4.4d. This is the fourth least vivid map (Beccario 2016). This map was reproduced as a static screenshot with little context. The original tool is a dynamic map which shows current atmospheric circulation not the changing dynamics of climate change.

The nMDS plot of this data allowed for the visual analysis to see similarities and differences in the maps based on the vividness codes. On the nMDS plot (Figure 4.5), the points illustrated the maps in the set, and thus there were 242 points on the plot, one for each of the maps. Points closer to each other were those maps which had similar ratings on the vividness codes. Those that were farther apart from each other had more diversity in the ratings assigned based on the vividness codes. The vectors in the plot were the vividness attributes. The longer vectors were the vividness attributes which were more important in explaining the variance between the maps.

The primary attributes which accounted for more of the variance were: *legend design, novelty,* and *topic* which had the longest vectors which can be identified visually. Vectors which pointed in the same direction illustrate the aspects which were more correlated. For instance, *symbolization* and *legend design* were correlated, but *legend design* accounted for more of the variance noted by the length of the vector. *Color use* and *layout* pointed in opposite directions which indicated that these attributes were not correlated.
There were four primary vectors in the nMDS plot: 1) *legend design and symbolization;* 2) *novelty, layout, salience, and projection;* 3) *topic and change over time;* and 4) *color use.* *Legend design,* *novelty,* and *topic* dominated by accounting for a larger portion of the variance. *Color use,* on the other hand, while it did not correlate with any of the other attributes, also did not account for as much of the variance in the sample, and was illustrated by a shorter line. It was rare that a map was rated highly on *novelty, legend design,* and *topic.* Points for maps at the center, instead, illustrated maps which had similar ratings across the aspects of vividness, but the nMDS plot did not illustrate whether the ratings were all high or all low.

![nMDS plot of the maps produced by the top producers plotted based on the ratings of vividness.](image)

**Figure 4.5.** nMDS plot of the maps produced by the top producers plotted based on the ratings of vividness.

When viewed in a matrix of small-multiple graphs, as in Figure 4.6, it was clear map producers focused on different aspects of vividness in their designs. In this case, there were clusters related to the producer. For instance, The New York Times and National Geographic maps clustered on the left-side of the plot, while the National Climate Assessment (produced by USGCRP) maps and NOAA maps were primarily located on the upper-right-side of the plots. This was because the maps at National Geographic and The New York Times used more novelty (an attribute which explained a large portion of the
variance) such as 3D designs and interactivity. The National Climate Assessment and NOAA produced static single-variate maps which used color which aligned with connotations, showed topics which were more relevant to people, and had understandable legend designs. In contrast, the “Other” category of maps were spread out across the space. This made sense, since being in the “Other” category, meant these maps were heterogeneous in both their producer and their designs.

It was clear that vivid maps were often those designed in-house by media companies who knew more about their audiences than maps designed by government agencies whose maps were republished in a multitude of other outlets. For instance, NASA and NOAA published maps for their own audiences who tended to be the science-interested public, but these maps were also picked-up by many other media sources whose audiences differ. For instance, new digital media like Vox, Mashable, and Buzzfeed catered to a typically younger tech-savvy audience than NASA or NOAA’s general audience.

There were also patterns when comparing the use of dynamics (interactivity and animation) and the type of map design (Figures 4.7 and 4.8). Maps which were animated and interactive were those which fell on the novel side of the graphic, while static maps were spread across the nMDS space. In Figure 4.8, it was clear that certain types of maps accounted for more of the maps in the sample. These were: choropleth, filled isoline, point symbol, proportional symbol, raster, and reference. Choropleth maps tended to be less novel and the points were primarily located on the right side of the nMDS space where legend design and topic dominated explaining a large portion of the variance. Similarly, filled isoline maps were also located toward one side of the nMDS space. Line symbol maps, on the other hand tended to be more novel as did some of the point symbol maps. Raster maps, perhaps because they accounted for most of the maps in the set, did not have any particular pattern in the nMDS space.
Figure 4.6. Matrix of nMDS plots for each of the major producers who produced more than three maps. The longest vectors, or those which explain more of the variance, are labeled.
Figure 4.7. Matrix of nMDS plots by the use of dynamics. The longest vectors, or those which explain more of the variance, are labeled.
Figure 4.8. Matrix of nMDS plots for different map types. The longest vectors, those which explain most of the variance, are labeled.

4.5 A vivid map

The most vivid map in the set was a map titled “Alaska’s Permafrost is Thawing.” To identify this map from the set, I summed the scores from the vividness coding, and this map had the highest total score. This map was published in The New York Times in August 2017.
(White 2017, Figure 4.9). This interactive/animated map used scrolling to juxtapose the extent of permafrost in 2010 with what could be lost in the future as the reader scrolled down the page. In Figure 4.10, a radial chart illustrated how this map was rated on the nine vividness attributes. All but the topic and change over time categories were rated with the highest scores possible for the vividness ratings. Topic and change over time were given scores of 4/5 instead of 5/5. Finally, Figure 4.11 illustrated where this particular map fell in the nMDS space. This map fell on the left-side of the nMDS space because compared to the other maps in the total set of 242 it was more novel.

This map used *scrollly-telling* which allowed readers to use interactivity to understand more about the place than possible through a single static map. This design made this map novel since few other maps have employed this type of design. The cartographer limited what readers saw as they scrolled down the page and avoided overwhelming audiences by creating visual salience in each scene in the map. This map was simple enough that even a very novice user could engage and have fun. The map and article also incorporated photos which added to making the topic of climate change tangible for a general audience.
Alaska’s permafrost, shown here in 2010, is no longer permanent. It is starting to thaw.

This is what may be lost.

**Figure 4.9.** Screenshots from “Alaska’s Permafrost is Thawing” (White 2017) which was one of the highest rated maps on the vividness ratings.
Figure 4.10. Radial chart which illustrates how Figure 4.9 was rated on the vividness ratings.

Figure 4.11. The nMDS plot indicates where Figure 4.9 falls in the nMDS space.
4.6 Conclusions

In this chapter, I reported on an empirical study which used content analysis to understand what media organizations produced and published maps of climate change, what topics were illustrated in their maps, and the extent to which these maps were vivid (see Chapter 3). I asked three questions for this study:

1. Which media organizations created and shared these maps and were they produced in-house or reproduced from other sources?

This research showed that the producers of maps of climate change are often not the publishers of this same content. Only a few sources produced their own maps for publication, primarily The New York Times and National Geographic. A majority of the maps were produced by government entities: NASA, NOAA, and the USGCRP. These maps were republished across a wide range of sources from prestige media to new digital media. In addition, maps from peer-reviewed articles also found their way to the media. These maps were often republished without any updates to the design and thus often were missing information key for the map reader’s understanding.

2. What aspects of climate change did these maps portray and what aspects of cartographic design did these maps employ?

These maps primarily showed topics which were relevant to audiences in the United States. Primarily these maps illustrated either the United States or the globe, and usually did not illustrate places outside the United States except at a global scale. Temperature was the most common topic (n=51), followed by topics related to sea level rise, water resources, and glacial melt. The maps primarily were multicolored raster maps, although other types of thematic maps, such as choropleth and isoline were also common.

3. Did these maps convey climate change vividly and which organizations produced vivid maps?

Vividness is a concept from the communication literature and was extended to the cartographic domain (see Chapter 3). Maps which were vivid were those which employed the nine aspects of vividness presented in this chapter. These aspects included: cartographic best practices (legend design, symbolization, layout, and projections which were appropriate for the data), visual salience, visible change over time, color use which aligned with color connotations, topics which are meaningful, and novel design styles. Across the set of maps, most of the maps followed cartographic best practices, but few added novelty to stand out to readers. Primarily The New York Times, National Geographic, and The Washington Post
created vivid maps by adding novelty which included the use of scrolly-telling, animation, and other interactivity to make these maps memorable and stand out to readers.

4.6.1 Significance and future research

Identifying maps that have vivid attributes will allow for future research to evaluate the effectiveness of vivid maps for grabbing attention and persuading audiences. If these maps do indeed impact message effectiveness, as has been shown in other contexts (e.g., Guadagno et al. 2011), vivid map attributes will be those that can add to the wealth of cartographic principles we instill in new mapmakers. Vividness provided one way in which to identify those maps which did more than follow current cartographic conventions to expand beyond those principles to bring the nature of geographic change to life through novelty, visible change over time, visual salience, and emotional uses of color. There have always been vivid maps, but like fashion, what is novel is ever-changing. What might be considered vivid now may be passé in the future. By evaluating maps in this way, cartographers now have a means by which to identify what types of maps are vivid or pallid for map readers. While this study focused specifically on climate change, future studies could extend this work beyond the domain of climate change to other contexts where maps have implications for translating knowledge to the public or for policymaking.

Future research could expand on some of the limitations of this study, specifically related to coding, and the presentation of the results of the nMDS. Future studies would be well served to have two coders who did not take part in the development of the coding scheme as has been suggested by Krippendorff (2012). In addition, I imagine another study building on this in which the coding is completed by expert cartographers in the form of a survey. While nMDS was an interesting and effective way in which to understand the differences in the vividness ratings for the maps, the presentation here in a static form has some limitations. Ideally, an interactive nMDS plot would allow users to mouse-over a point on the plot and see a visual of the associated map. This type of visual analytics may lead to some more interesting discoveries of patterns in this and other datasets.

In the set of maps, a few maps stood out as employing designs which were vivid in that these maps drew attention, brought climate change to life, made it tangible, evoked emotion, were memorable, and made climate change feel proximate in a temporal, sensory, or spatial way. These often were maps designed by elite media organizations, and not only followed cartographic conventions but incorporated novel designs like dynamic and interactive displays. This research leaves open questions about whether vivid maps are persuasive to readers, what types of design lead to greater sharing and re-sharing of these types of maps, and what aspects of the design and content lead to different emotional responses. Future
research should test the effectiveness of vivid climate change maps, and expand the concept of cartographic vividness beyond the context of climate change.
Chapter 4 References


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https://doi.org/10.1179/1743277412Y.0000000032.


Chapter 5
Conclusion
Cartography: a translational science for the Anthropocene?

5.1 Introduction

This dissertation research investigated the connections between the science of climate change and how it was translated to the public by the media through maps. Climate change is arguably one of the most important environmental crises our world will face in both the short and long term. In focusing on “maps that matter,” this research answered calls for maps and geographic information to be studied, designed, and used in conjunction with the UN 2030 Sustainable Development goals (ICA 2016, Robinson et al. 2017). Specifically, this research helped address UN Goal #13 to “take urgent action to combat climate change and its impacts” which includes the goal to “improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning” (United Nations 2016). I argue in this final chapter that this dissertation research illustrated that cartography can be a compelling form of translational science that creates a bridge between scientists and the public. As a translational discipline for the Anthropocene, cartography can integrate between science and the public for a wealth of topics, of which climate change is just one.

In this chapter, I first describe what translational research is in other academic domains. In the third section, I describe the main findings from this research and continue in the fourth section to describe three cross-cutting themes in the dissertation. Finally, I conclude with a description of how cartography can and has been translational.

5.2 What is translational research?

Science is striving to find its footing in a new political and social climate. Scientists are rethinking their fields to create products which are directly useable by society. Domains of science are now using the term “translational” to describe research which bridges between science and stakeholders to translate outcomes into meaningful products which directly address societal challenges (Schlesinger 2010). Some scholars argue that many questions in basic science have been answered, and current research should focus on questions the public cares about (Anbar 2018). These questions are often tied to how we manage the planet and require interdisciplinary research (Anbar 2018). Additionally, science and scientists are increasingly under pressure to defend research to the public due to societal shifts in how
science is perceived, and because science is often funded by taxpayer dollars. Thus, the push to make science meaningful to the public is of increasing importance.

The idea of translational science was first used in medicine as a way of connecting real-world patients with life-changing research. Researchers identified a disconnect between basic science, clinical testing, and the creation of usable drugs and treatments to solve human medical problems. Often this translational link was referred to as “bench-to-bedside” to describe the connection between science and the people for whom science asks and answers its questions (Woolf 2008). Recently translation has been extended to other fields, including ecology (Hallett et al. 2017, Schlesinger 2010), and now is a growing term in the geography domain used to describe a renewed focus on tangible outcomes for public stakeholders.

Translational research requires building community partnerships, creating cross-cultural relationships, and focusing on projects which are designed and conducted at scales needed for decision making. Suggestions have been made for this type of research to be place-based and focused on case studies (Hallett et al. 2017). In addition, this type of research is only possible through innovative collaborations (Mauser et al. 2013) which push the bounds of current academic disciplines. For some, this means collaborating with the design fields to help create usable outputs which draw from research in the fields of cognitive science, engineering, and design. Because cartography draws on many of these disciplines, it is here that cartography can play a part in a future translational research endeavor.

5.3 Summary of main findings

In this section, I summarize the main findings from the three empirical chapters and illustrate that maps can be translational as persuasive tools to convey science.

5.3.1 Chapter 2

Based on a series of interviews I conducted with expert mapmakers at media organizations and government agencies who produced the majority of maps of climate for the public, I found these mapmakers followed a similar process which focused on the decision-making structure of story development. This process started with developing ideas as a team and then making contact with scientists who shared data and collaborated with mapmakers to distill the information into a meaningful story. The mapmakers then reduced complexity in the science during design, and finally, mapmakers got feedback from colleagues to help improve future designs. It was clear from this research that these mapmakers were translating knowledge from scientists to the public and they followed insights from climate change communication research unlike what has been implied by other communications scholars.
5.3.2 Chapter 3

Additional results from the interview study, presented in Chapter 2, were used to put forth a set of map design aspects for creating a vivid map. Vividness, a concept from the communication literature, describes emotionally interesting and concrete image-provoking content which brings concepts to life through making this content proximate to readers in a number of ways to readers (Nisbett and Ross 1980). In this chapter, I extended this concept to the cartographic literature and connected the main themes of the interviews related to emotion, persuasion, and memorability to key components of the vividness definition (Nisbett and Ross 1980). The aspects of a vivid map were: 1) visual salience, 2) visible change over time, 3) color use which aligns with cultural and emotional connotations, 4) cartographic best practices, and 5) novel designs. Through using these aspects in map designs, future cartographers can make a vivid map which has potential to influence audiences while accurately presenting information through well-established guidelines based on empirical research. It is through using these vivid cartographic aspects that these maps can serve as useful devices for translating science to the public.

5.3.3 Chapter 4

Chapter 4 was based on a content analysis study for which I led the collection of 242 maps of climate change across United States’ print and online media. In this chapter, I showed that there were fewer producers of maps of climate change than publishers, and illustrated that few publishers produced their own maps of climate change. Using non-metric multidimensional scaling (nMDS), I illustrated that elite media outlets often produced maps in-house which were rated highest on the vividness aspects from Chapter 3. On the other hand, government entity maps and maps from peer-reviewed articles were those which were more widely republished across a range of different media outlets and were generally less vivid. This research showed that vivid maps were more often interactive and/or animated, and sometimes used “scrolly-telling” to tell complex stories as the map reader scrolled down a map on a webpage.

5.4 General themes across this dissertation research

There are several cross-cutting themes in this research which I discuss briefly here: cartographic best practices, vividness, and storytelling with maps. These themes represent both a call for continued research, in the case of cartographic best practices, and future research, as we reimagine cartography as a translational discipline.
5.4.1 Cartographic best practices

As noted in the preface of Brewer (2008), it makes sense to look to good design, as opposed to poor design, when making our own maps. It was clear from my interviews that experts did look to each other’s designs. Notably, in nearly every interview where I asked what other maps they look at as guides, participants expressed trying to copy The New York Times design. In addition, they shared best practices and designs with each other within their organizations. For instance, at National Geographic cartographers had access to past designs at the Magazine in their archives, and at NASA and NOAA there were style guides which helped cartographers maintain consistent good design in their maps. In this way, maps by expert cartographers are beginning to look similar. This has advantages and disadvantages. As designs coalesce, map readers may become more adept at reading these designs due to their familiarity which allows similar designs to better translate knowledge to a wider range of readers. This overt consistency also could be potentially problematic given the focus on the greater democratization of mapping. This greater democratization of mapping means a more diverse set of topics can be represented in maps, welcomes more diverse mapmakers into the field of elite mapping, and can lead to a larger diversity in designs which can be more inclusive. Finally, diversity in mapmakers may lead to illustration of topics and aspects of data which have remained silent on maps given cartography’s homogeneity (Harley 1989).

Cartographic best practices were presented throughout this dissertation. The majority of these best practices were derived from a long history of cognitive cartography research (Montello 2002). Novice and expert cartographers can benefit from employing these practices in their map designs. A few of the more recent texts on cartographic best practices are Slocum et al. (2009), Brewer (2016), and Field (2018). Drawing from the fields of data visualization and information visualization can also provide helpful practical advice which can be extended to map design. Books by Edward Tufte (1983, 1990, 1997), Stephen Few (2009, 2012), and Alberto Cairo (2013, 2016) are good places to start.

5.4.2 Vividness

Vividness is a new term for cartographers. I elaborated on this specifically in Chapter 3, and I think it deserves repeating here. Vividness can be a useful way to create and evaluate maps which are potentially persuasive. The vividness definition is tied to having a cohesive design based on the story the cartographer is trying to tell. This allows the cartographer to focus on creating visual salience and using best practices and colors which are emotive and align with color connotations. However, an emphasis on novel designs and mapping visible change over time in conjunction with cartographic best practices as a holistic way to view mapping is a new call in cartography. Maps need to stand out to influence readers. This is only possible if they are memorable and different from other maps. Some ways in which to add novelty are
through incorporating interactivity and animation when useful and necessary. Mapmakers should move beyond defaults in GIS software by using color schemes and symbols which still follow cartographic conventions for a good map but also provide less common designs to make maps stand out to readers. Most importantly, vivid maps combine empirically evaluated effective design best practices and new and novel designs.

Organizations that created vivid designs have focused on hiring talented graphic artists, cartographers, data visualization experts, and interaction designers and programmers to add depth to their reporting that has now largely moved from print to digital. The publisher of The New York Times wrote at the end of 2017 that this has been a period of innovation and growth in media and he listed interactive graphics as a part of what has made a strong and innovative news reporting agency (Sulzberger 2017). These new and novel designs were also only possible at organizations which had the capital to invest in these experts. As is clear through this research, these particular media sources were anomalies in the world of newspaper and magazine journalism and notes a need for increased investment in cartography across a wider range of media outlets.

5.4.3 Storytelling with maps

Finally, storytelling was a theme across the three chapters. This connection between cartography and storytelling is one that recently has gained momentum in the cartographic research realm (e.g., Caquard and Cartwright 2014, Song 2017, Landaverde Cortés 2018), as well as in information visualization (e.g. Gershon and Page 2001, Kosara and Mackinlay 2013). In this way, storytelling in maps also connects to emotions and maps, another recent call in cartographic research (Griffin and McQuoid 2012).

Communicating climate change relies on both information and emotional connection to the topic (Moser 2007). Thus, the story told through a map may be the vital aspect of emotional connection to the topic of climate change that makes a vivid map key to changing attitudes and behaviors. Cartographers at the elite organizations who have created vivid designs focused on integrating text, photos, and other graphics in a way that told a story, and also related the story to the larger topic and science of climate change. These maps did well by making climate change tangible in a way that other types of maps did not.

Finally, audience and purpose are also aspects of storytelling as well as map design. While breaking news stories still are the most read and shared of the content, the focus on creating in-depth stories with interactive maps and graphics has become an important aspect of journalism and storytelling at many of these media organizations. Across the organizations who created maps of climate change, those that told vivid stories were those who had clear ideas about their audiences. With the change in how maps are shared across the web,
however, creators of these graphics need to reevaluate who they assume their audience to be. In the scientific domain and in the creation of maps for peer-reviewed publications, scientists now need to assume that their map could be republished across the Internet. Clearly these maps have been shared and re-shared across social media platforms. Often these maps were reproduced across the web under violation of copyright, and sometimes these maps were used in ways that were counter to the original goal.

5.5 The future of cartography as a translational discipline

Cartographers are particularly well suited to take on the endeavor of making science more translational. Cartographers are typically housed in geography departments where a wide variety of research is conducted across different subfields. These physical surroundings lend themselves to identifying new research questions which integrate across geography and with other related fields. Additionally, within many geography departments, GIS and cartography are often used as research methods, and thus cartography and GIScience scholars are already aware of how they can connect with other researchers.

Calls have been made to explore aspects of cartography related to emotion, aesthetics, and storytelling (Kent 2005, Griffin and McQuoid 2012, Caquard 2013) which are important in translating knowledge. For instance, in November 2017, I had the opportunity to observe the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP23) held in Bonn, Germany. Fiji, the current president of the UNFCCC and host of COP23, focused on the idea of Talanoa. This is a concept from Fiji and the Pacific Islands used to describe dialogue which is inclusive, participatory, and transparent. “The purpose of Talanoa is to share stories, build empathy and to make wise decisions for the collective good. The process of Talanoa involves the sharing of ideas, skills and experiences through storytelling” (UNFCCC 2018). Talanoa could be used to describe maps which tell diverse stories, connect with audiences, evoke emotions, and lead to better decision making for the common good, and it may serve as a useful framework for research on these topics in cartography as they relate to solving some of society’s biggest problems in a translation way.

Critical cartographers, in addition, have also been successful in efforts such as community mapping, which has focused on more local scales (e.g., Boll-Bosse and Hankins 2017). The success of critical cartography in community mapping argues for future efforts to better connect between critical cartography and cognitive cartography. This would help to make research more community oriented at scales which are appropriate for decision making as is called for in the translational science literature (Hallett et al. 2017).
Finally, cartographic scholars could improve how they disseminate their own research to other scientists. Across science, often cartography is seen as the last step in the creation of graphics which convey some of the most important scientific findings related to topics such as climate change. For instance, in 2017, I was asked to make a map for Penn State News (Messer 2017) of the results of a climate science study which had been published in PNAS (Garner et al. 2017). The original study did not include maps, but the communications staff at Penn State wanted a graphic to accompany the announcement about the publication. On a more anecdotal note, climate scientists have repeatedly asked me for information about how to create better graphics. Cartographic researchers should try to follow the examples of some by publishing in outlets where their work will be seen by scientists in other academic disciplines (e.g., Retchless and Brewer 2015).

There are some clear successes of the cartography discipline reaching beyond its academic bounds. This dissertation research made clear that translational cartography is possible. There is a connection between the science of cartography and conveying best practices to communication practitioners. As Chapter 2 noted, these practitioners are clearly drawing from work in the academic domain, and they use this knowledge to provide useful outcomes for the public to understand the science of climate change. Though this research did not investigate the connection between the media and policymakers, my participants did describe that some of their maps may be used for policy. Social media has also been a particularly powerful tool in disseminating many of these maps beyond their original intended audiences. In this way, maps can serve as the bridge between science and the public.

The connections and open dialogue that my participants described with scientists exemplifies how cartographers can act as translators. Future research should investigate this in other contexts beyond climate change related to how cartographers can foster better translation and communication between science and the public. I envision a future research project which uses a series of workshops to bring together scientists, visual journalists, communication practitioners, and cartographic researchers to develop new ideas on the future of creating maps which are more useful to the public. Indeed, maps are powerful in connecting people through a common language which can help solve some of the biggest problems our society has ever faced.
Chapter 5 References


Appendix A

Interview Questions

I want to thank you for taking time out of your busy day to meet with me and answer my questions. Some of my questions may seem a bit repetitive, but the goal for me is to understand how and why you design climate change maps, the goals, workflow, politics, and processes of the development of climate change maps here at [media company/gov’t agency]. I am going to be recording to help me transcribe and code these interviews. If there is a question you do not want to answer, we can skip it. If you want to end the interview at any time just let me know. Let’s get started.

1. Ice Breaker:
   1.1. Walk me through the general workflow you use to design a map.

2. Opening Questions
   2.1. What is the goal of the maps you make about climate change?
       2.1.1. In terms of audience, purpose, format (media), and dissemination
   2.2. Who is your target audience? Are there other audiences?
   2.3. What is the main purpose of your maps about climate change?
   2.4. How do you/media organization want to disseminate your maps of climate change?

3. Design
   3.1. Are there consistent design choices you make for climate change maps that are not necessarily applied to maps of other types of content? E.g. color, symbolization, scale, typography etc.
   3.2. Is there any particular style that you use for climate change maps?
   3.3. How do you balance style and substance? Pushing the bounds of cartographic and graphic design with conveying the message of the map.
   3.4. To what extent do existing maps by [gov’t/other] agencies or other media outlets including the AP impact your design of climate change maps? Do you ever decide to use those maps (AP, NOAA)? Do you ever copy particular designs? And why?

4. Data
   4.1. How do you balance the complexity of the science of climate change with the making maps and stories understandable for your audience? (Complexity vs. communication)
   4.2. Are there differences in how data are prepared and analyzed for climate change maps as opposed to other types of maps included in stories by [media organization]?
   4.3. What challenges are there to working with climate data? E.g. complex climate data, uncertainty, etc.
5. **Integration with stories**
   5.1. What determines whether you use a map (versus a photo or graphic) in a story about climate change? How is it decided that a map is needed?
   5.2. How do you work together with editors and writers to determine the design of the maps included with a story about climate change?
   5.3. Have there been times when you decided not to use a map?
   5.4. What is the process and connection between the development of the cartographic design, the headline or story title, and the story itself? Does this process change with or without a map?
   5.4.1. Can you talk about a particular story where you were part of the process to create the headline, story, and map, and how did that work?
   5.5. What role do maps play in stories about climate change? Are they often viewed as the central piece or do they serve as attention grabbing devices?

6. **Climate change stories**
   6.1. What determines whether you/media company decide to write or run a story on climate change?
   6.2. When does climate change become “breaking news” and is shown on the front page (or online equivalent)?
   6.3. What is the timing for the development and publication of climate change stories and maps? (i.e. this is a slow moving phenomena, it is rarely breaking news)
   6.4. Do stories and maps about climate change have a particular tone? Are they designed to be emotional or a call to action?
   6.5. How are decisions made about the types of headlines used for climate change stories that include maps?

7. **Audience/Dissemination**
   7.1. Who is your main audience? (might skip if already answered)
   7.2. What types of response do you want from your audience?
   7.3. How do those media get disseminated?
   7.4. What are your dissemination goals? (just look and or reshared?)
   7.5. How does your audience primarily consume these maps? E.g. print, online via your website, online via Twitter, Facebook shares and retweets?
   7.6. How does knowledge about your audience and their views of climate change influence your design?
   7.7. Do you look and use the comments from readers to drive design decisions on future maps?
   7.8. What climate change maps have worked for your audience vs. haven’t worked? Or were successful towards your goal vs. unsuccessful? Effective vs. ineffective? How do you decide that?
8. Science of Climate Change
   8.1. What types of scientific findings do you map?
   8.2. How do you deal with findings that aren’t compelling?
   8.3. Do you ever create maps of lesser compelling findings or more mundane scientific findings on climate change?
   8.4. Do you feel that the media overemphasizes/emphasizes dire findings and does not include less interesting/less compelling findings?
   8.5. How do decide when to make connections between certain weather or climate events and climate change? (attribution to climate change)
      8.5.1. Tell me about a time when you connected between weather or a particular climate anomaly and climate change
      8.5.2. If no… Have you ever considered connecting particular weather or climate anomaly events with climate change?

9. Politics and climate change
   9.1. How policy relevant are the maps you design of climate change?
   9.2. Are the maps of climate change ever meant to be policy prescriptive?
   9.3. Do you feel the political contention surrounding climate change has an impact on the maps you make and on the stories in which they are a part?
   9.4. Do you ever think about portraying climate change in maps in a way that leans toward a particular political viewpoint?
   9.5. Our political situation has changed specifically in respect to climate change with our president-elect being the first president to deny climate change. Do you think this will affect how you will portray or continue to write about climate change?
Appendix B

Consent for Exempt Research
The Pennsylvania State University

Title of Project: Cartography of climate change: The media and cartographic design for climate change communication

Principal Investigator: Carolyn Fish
Advisor: Cynthia A. Brewer, PhD
Telephone Number: [redacted]
email: fish@psu.edu

Advisor Telephone Number: [redacted]
email: cbrewer@psu.edu

You are being invited to volunteer to participate in a research study. This summary explains information about this research.

• As part of my dissertation research I am investigating how maps of climate change are designed by the media, how stories about climate change are developed with maps as a component, and how political contention around climate change might impact design of those maps and stories. This research will form the basis of my dissertation and will help future cartographers understand how the media designs these types of maps for communication towards the development of best practices.

• For this project, I will be conducting semi-structured interviews with cartographers, editors, and writers at media organizations and government agencies. Each interview will be 1-2 hours depending on your availability. During this time, I will be asking about the workflows you use, how you map climate change maps or write stories about climate change. Finally, I will be asking you about how you feel the political aspect of climate change impacts your maps and stories.

• I would greatly appreciate being able to use your real name in my research. I understand if you do not want your name linked to your comments, and if you are not comfortable with me using your name in my research let me know, and I will assure you that your comments will not be attributed to you in any analysis and publication. In this case, only non-identifiable data will be used in the research. Any data collected throughout the duration of this research will be stored in a computer accessible by a password only known by me.

• I will be recording our interview. The recording will be used to create a written transcription of our conversation so I can use quotes from our conversation in my
research and compose a thoughtful narrative about the cartography of climate change. Please let me know if you do not want to be recorded, and I will only take hand-written notes. If you have questions or concerns, you should contact Carolyn Fish at [redacted] or fish@psu.edu. If you have questions regarding your rights as a research subject or concerns regarding your privacy, you may contact the Office for Research Protections at 814-865-1775. Your participation is voluntary and you may decide to stop at any time. You do not have to answer any questions that you do not want to answer. You may withdraw from participation at any time without repercussions. Tell the researcher your decision regarding whether or not to participate in the research.
## Appendix C

### Interview Code List

<table>
<thead>
<tr>
<th>Theme</th>
<th>Code</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Affect</strong></td>
<td>Emotion (either yes/no)</td>
<td>map described with emotional language (either positive or negative)</td>
</tr>
<tr>
<td></td>
<td>Memory</td>
<td>map described as memorable</td>
</tr>
<tr>
<td></td>
<td>Sensationalizing</td>
<td>map or story described as sensationalized or not</td>
</tr>
<tr>
<td><strong>Audience/Purpose</strong></td>
<td>Audience</td>
<td>participant described map audience, but not for scientists or policymakers specifically</td>
</tr>
<tr>
<td></td>
<td>Goals</td>
<td>participant described audience and purpose goals</td>
</tr>
<tr>
<td></td>
<td>Government maps for scientists</td>
<td>map audience was scientists</td>
</tr>
<tr>
<td></td>
<td>Op Ed</td>
<td>audience and purpose were opinion pieces</td>
</tr>
<tr>
<td></td>
<td>Policymakers</td>
<td>audience was policymakers</td>
</tr>
<tr>
<td><strong>Authority</strong></td>
<td>Linking to source</td>
<td>authority implied through providing a link to source</td>
</tr>
<tr>
<td></td>
<td>Source</td>
<td>authority implied because of source’s authority</td>
</tr>
<tr>
<td></td>
<td>Through design</td>
<td>authority implied through design choices of map</td>
</tr>
<tr>
<td><strong>Background</strong></td>
<td>About Nat Geo</td>
<td>participant talked about National Geographic history</td>
</tr>
<tr>
<td></td>
<td>Participant</td>
<td>participant gave their background</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>Scientists use graphic</td>
<td>scientists used map later to communicate their own research</td>
</tr>
<tr>
<td></td>
<td>Translators</td>
<td>cartographer acted as a bridge between scientists and public</td>
</tr>
<tr>
<td><strong>Complexity</strong></td>
<td>Abstract/tangible</td>
<td>participant described how they made abstract tangible</td>
</tr>
<tr>
<td></td>
<td>For a reason</td>
<td>complexity was left in map for a reason</td>
</tr>
<tr>
<td></td>
<td>Metaphors</td>
<td>map or story used metaphors for communication to reduce complexity</td>
</tr>
<tr>
<td></td>
<td>Reducing complexity</td>
<td>cartographers reduced complexity through design</td>
</tr>
<tr>
<td></td>
<td>Complexity</td>
<td>participant described difficult balance between simplicity and complexity</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>Data</td>
<td>participant talked about data used</td>
</tr>
<tr>
<td></td>
<td>Metadata</td>
<td>participant talked about metadata</td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td>Animation</td>
<td>design used animation</td>
</tr>
<tr>
<td>Attention/salience</td>
<td>design aimed to grab attention through making important data salient</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>-----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Cartographic conventions</td>
<td>participant described following cartographic conventions</td>
<td></td>
</tr>
<tr>
<td>Color Schemes</td>
<td>participant described color schemes used</td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td>participant described constraints on design</td>
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</tr>
<tr>
<td>Data classification</td>
<td>participant described data classification</td>
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<tr>
<td>Generalization</td>
<td>participant described using generalization in map</td>
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<tr>
<td>Interactivity</td>
<td>participant described using interactivity</td>
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<tr>
<td>Labeling</td>
<td>participant described labeling decisions</td>
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<td>Layout</td>
<td>participant described layout design</td>
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<tr>
<td>Marginalia</td>
<td>participant described marginalia</td>
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<tr>
<td>Novelty</td>
<td>participant described using novel design/data</td>
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</tr>
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<td>Projection</td>
<td>participant described projection choices</td>
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</tr>
<tr>
<td>Rainbow Color Schemes</td>
<td>participant described problems with rainbow color schemes</td>
<td></td>
</tr>
<tr>
<td>Scale</td>
<td>participant described scale of map</td>
<td></td>
</tr>
<tr>
<td>Style guide</td>
<td>participant described style guide or a consistent style was used at an organization</td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>maps were included in video</td>
<td></td>
</tr>
<tr>
<td>Visual hierarchy</td>
<td>visual hierarchy was described</td>
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</table>

<table>
<thead>
<tr>
<th>Dissemination</th>
<th>map was behind a paywall</th>
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</thead>
<tbody>
<tr>
<td>Dissemination</td>
<td>participant described general dissemination via their own procedures, but not social media or other media</td>
</tr>
<tr>
<td>Media redissemination</td>
<td>goal for when media redisseminated map</td>
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<tr>
<td>Social media</td>
<td>social media was used to disseminate</td>
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<tr>
<td>Viral</td>
<td>participant described a map going viral</td>
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</table>

<table>
<thead>
<tr>
<th>Other Sources</th>
<th>participant criticized other sources</th>
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</thead>
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<tr>
<td>Criticism of other maps</td>
<td>participant used other sources as inspiration</td>
</tr>
<tr>
<td>Looking at other sources</td>
<td>participant used new york times as inspiration</td>
</tr>
<tr>
<td>New York times look</td>
<td>participant used new york times as inspiration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Politics</th>
<th>answers to last interview question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divorced from policy</td>
<td>participant described map design as divorced from policy</td>
</tr>
<tr>
<td>Facts/truth</td>
<td>participant talked about &quot;facts&quot; or &quot;truth&quot;</td>
</tr>
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<td>Fox influence on Nat Geo</td>
<td>participants at Nat Geo described influence of Fox</td>
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<tr>
<td>Policymaker use of maps</td>
<td>participants spoke about policymakers using maps</td>
</tr>
<tr>
<td>Political situation changes mapping?</td>
<td>participants described political situation changing mapping</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
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<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
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<tr>
<td><strong>Scientific consensus</strong></td>
<td>participants described scientific consensus of human caused climate change</td>
</tr>
<tr>
<td>Social media cherry pickers</td>
<td>participants described audiences’ cherry picking information on social media</td>
</tr>
<tr>
<td>Science</td>
<td>Attribution to climate change an event was attributed to climate change</td>
</tr>
<tr>
<td>(Not) compelling/interesting</td>
<td>what was shown in a map was either compelling or not</td>
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<tr>
<td>Geographic focus</td>
<td>geographic location of a map was described</td>
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<tr>
<td>Breaking news</td>
<td>map of climate change was described (or not) as breaking news</td>
</tr>
<tr>
<td>Comparison to &quot;normal&quot;</td>
<td>map was described as a comparison to normal</td>
</tr>
<tr>
<td>Human impact</td>
<td>participant described a map that shows human impact</td>
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<tr>
<td>Show What</td>
<td>Mixing graphics and maps participant described mixing graphics and maps</td>
</tr>
<tr>
<td>Story</td>
<td>Storytelling participant described role of map in storytelling</td>
</tr>
<tr>
<td>Titles</td>
<td>participant described how titles are determined</td>
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<td>participant talked about integration of maps and words</td>
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<td>Timing</td>
<td>News cycle timing of a graphic was described within content of other events</td>
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<tr>
<td>Uncertainty</td>
<td>Uncertainty participants describe illustrating uncertainty</td>
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<td>Workflow</td>
<td>Colleague criticism/review process participant described internal review process for maps</td>
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<tr>
<td>Pitching stories</td>
<td>participant described how stories are pitched</td>
</tr>
<tr>
<td>Planning graphic</td>
<td>participant described planning out graphic</td>
</tr>
<tr>
<td>Researching for story</td>
<td>participant described researching for story and graphic</td>
</tr>
<tr>
<td>Timing</td>
<td>participant described timing or time allocated for a story</td>
</tr>
<tr>
<td>Workflow for story</td>
<td>general workflow of a story (when workflow was too general for any other code)</td>
</tr>
<tr>
<td>Collaboration</td>
<td>participants described collaborating with coworkers</td>
</tr>
<tr>
<td>Deciding on graphics</td>
<td>participants described deciding on what graphics to include in a story</td>
</tr>
<tr>
<td>Design decisions</td>
<td>participants described making decisions about design</td>
</tr>
<tr>
<td>Personal evaluation</td>
<td>participant described their own personal evaluation of graphic</td>
</tr>
<tr>
<td>Pull in for graphics</td>
<td>participant described being pulled in to work on graphics for a story that was already developed/developing</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Connections with scientists</td>
<td>participant described connections and conversations between scientists and journalists</td>
</tr>
<tr>
<td>Map reader feedback</td>
<td>participant described getting feedback from map readers</td>
</tr>
<tr>
<td>Redesign for next graphic</td>
<td>participant described changing designs over time, retrospective analysis</td>
</tr>
</tbody>
</table>
Vita
Carolyn S. Fish

Carolyn Fish received her Bachelor of Science from The Pennsylvania State University in 2008 and her Master of Science from Michigan State University in 2010. She continued working for Michigan State in late 2010 which included, among several odd jobs, GPSing thousands of street signs in Appleton, Wisconsin. In 2011, she started as a Cartographic Product Engineer at Esri, the makers of ArcGIS, where she created map templates for a variety of GIS user communities. Carolyn returned to graduate school in 2014 for her Ph.D. where her research and teaching interests lay at the intersection between cartography and environment-society geography. She has enjoyed her return to Central Pennsylvania through a renewed sense of exploration with friends by car, kayak, and on foot. She looks forward to beginning a new adventure in Eugene, Oregon in September 2018 where she will start as an Assistant Professor at the University of Oregon.