

ARTICLE

Storytelling for Making Cartographic Design Decisions for Climate Change Communication in the United States

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ABSTRACT

Recent research in cartography has described how maps can tell stories; however, little research has empirically evaluated how storytelling can guide how map design decisions are made. I argue that storytelling allows cartographers to decide on basic map design elements by narrowing the focus of a map. First, cartographers decide on the driving story. The story is then used as a guide for every design decision, from what data to search for and use to the design of symbolism within the map. This research focuses on the case of climate change communication in the United States. Empirical evidence based on interviews with map-makers at major media organizations and government agencies creating maps of climate change illustrates how storytelling as a process provided these cartographers with a way to effectively convey the multidimensional and complex impacts of climate change across multiple scales. It is this storytelling process that enables cartographers to better connect with readers to communicate the impacts of complex environmental problems such as climate change. The article concludes with implications for using storytelling as an alternative way to think about cartographic communication and the map design process.

Keywords: storytelling, map design, cartography, qualitative GIScience, climate change communication

RÉSUMÉ

Les chercheurs en cartographie se sont récemment intéressés aux propriétés des cartes de raconter des histoires ; peu d'études ont toutefois porté sur l'évaluation empirique de la façon dont la mise en récit peut orienter la prise de décisions quant à la conception des cartes. De l'avis de l'auteure, la mise en récit permet aux cartographes de prendre des décisions relatives aux éléments de base de la conception des cartes et de faire ainsi en sorte qu'elles soient davantage ciblées. D'abord, les cartographes décident du fil conducteur du récit. Le récit sert ensuite de guide dans toutes les décisions relatives à la conception, de la nature des données à étudier et à utiliser jusqu'à la conception de la symbolique à employer dans la carte. L'auteure se penche plus particulièrement sur le cas de la communication de l'information relative au changement climatique aux États-Unis. Les données empiriques tirées d'entrevues menées auprès de cartographes d'organisations médiatiques et d'organismes gouvernementaux importants ayant pour tâche d'élaborer des cartes du changement climatique illustrent comment le processus de mise en récit permet à ces cartographes de communiquer efficacement les conséquences multidimensionnelles et complexes du changement climatique, selon diverses échelles. C'est grâce à ce processus de mise en récit que les cartographes parviennent à mieux rejoindre les lecteurs afin de les renseigner sur les répercussions de problèmes complexes liés à l'environnement comme celui du changement climatique. L'auteure conclut en décrivant les retombées de l'utilisation de la mise en récit comme solution de rechange dans la réflexion sur la communication cartographique et le processus de conception cartographique.

Mots clés : cartographie, communication de l'information sur le changement climatique, conception cartographique, mise en récit, science des systèmes d'information géospatiale qualitative

Introduction

Stories are one way in which cartographers connect with the public to communicate complex, multidimensional, uncertain scientific topics such as climate change in a way

that makes them more real and personal. Recent research in cartography has identified how maps can tell stories ([Caquard 2011](#)) and has theorized on how maps can be improved to be more similar to text-based stories by incorporating more than a single map design ([Mocnik and](#)

Fairbairn 2018). These storytelling maps focus readers' attention and are more memorable than other ways of presenting information (Kosara and MacKinlay 2013). Stories guide readers to understand causality by making it explicit how one event has caused another (Phillips 2012). In this way, map-makers can explicitly make visual connections between causes and effects of changing climate. While organizations in the United States such as the *New York Times*, the *Washington Post*, and *National Geographic* have focused on rich narratives told through text supplemented with pictures, graphics, and maps; storytelling maps of topics such as climate change are now being created by some of these elite media organizations. Sometimes maps are simple designs that accompany written text. In other cases, maps are the centerpiece that draws readers in, takes them on an adventure, and shows them some aspect of climate change they have never seen before (e.g., Buchanan and Watkins 2015). Journalists and news organizations alike have seen how high the stakes are for conveying the potential effects of climate change, and maps that tell stories have become one way to illustrate these effects. Maps that tell stories can show the geographic effects of climate change while also connecting readers to people and places where climate change effects are happening. However, little research in cartography has investigated the process of map-making when the stakes are high, when map-makers need both to connect with the readers' emotions and to convey basic facts.

This research investigated how map-makers use "the story" they are trying to tell as a decision-making process to focus their cartographic design. I report on a series of semi-structured single and group interviews conducted with map-makers at major media organizations and government agencies in the United States to understand the process and design decisions for creating maps of climate change. It was clear from these interviews that telling stories was key to every aspect of the design process and that the story guided design decisions, including what data they chose, how they worked with scientists to identify and tell just one aspect of the story, how they symbolized the map and story layout, and what other graphics and pictures accompanied the map. Storytelling was a key factor that focused the map-makers, journalists, scientists, and readers, where implications for illustrating cause and effect were key.

This research was thus guided by the following questions:

- (1) What is the process of creating climate change maps that are designed to be understandable by a wide general audience, and how does this differ across organizations?
- (2) How do climate change map stories originate and develop over time at these organizations?
- (3) How does "the story" focus the map-maker on the process of making maps of climate change to reduce

complexity and make complex data meaningful to audiences?

The rest of this paper is organized in five sections. I begin by reviewing the relevant background literature in information visualization, cartography, and climate change communication to illustrate how storytelling has become important in these domains. The methods section describes the semi-structured interviews and analysis. 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.

Background

Graphic storytelling has gained popularity in the design of information graphics, interactives, and data journalism in publications such as the *New York Times*, the *Guardian*, the *Washington Post*, and *National Geographic*. These types of visualizations go by many names: storytelling visualizations, visual data stories, narrative visualizations, and storytelling maps. In addition, narrative and storytelling have become of increasing interest in the related research domains of information visualization, data visualization, scientific visualization, and geovisualization and cartography (Tong and others 2018). Presenting complex data as stories reduces complexity for readers, especially given the wealth of data we now have at our fingertips (Figueiras 2014). Narrative visualizations offer a way to illustrate when one action causes another (Kosara and Mackinlay 2013). In this way, stories tap into episodic memory, as opposed to semantic memory, by presenting information as a sequence of events instead of disconnected facts, which makes it easier to remember them and recognize patterns (Ma and others 2012). This section is divided into three subsections. First, I review narrative visualizations as they relate to the field of information visualization. The second subsection explores how storytelling has become of increasing interest in cartography and map design. Finally, I touch on how storytelling has been used to visually communicate climate change.

NARRATIVE VISUALIZATION AND STORYTELLING

Within the field of information visualization, many terms are used to describe graphics and visualizations that tell stories, including *narrative visualizations* or *visual data stories*. Along with the use of many terms to describe seemingly the same thing, there lacks a clear definition of these types of visualizations. Lee and others (2015) present a concrete definition of visual data stories as stories composed of pieces (1) backed up by data, (2) visualized to support one or more intended messages, including annotations or narration to highlight and emphasize the message, and (3) presented in a meaningful order or with a

connection between them to illustrate the communication goal. I argue that order is not important in narrative visualizations, since storytelling allows flashbacks and other ways of bending time to advance a narrative.

Narrative visualizations combine the advantages of the exploratory and communicative aspects of visualizations. While early calls for storytelling in visualization focused on how visualizations can serve as communication devices (Gershon and Page 2001), Segel and Heer (2010) and Hullman and Diakopolis (2011) identified that narrative visualizations combine exploratory and communicative visualization by incorporating author-driven stories with user-defined data exploration. To do this, these types of visualizations include well-defined and structured narratives that also incorporate limited interactivity through which the user can explore the data further. Researchers agree that the incorporation of storytelling into visualizations is useful when it can “allow the users to engage with the data, make the insight jump out, and helps users to cope with their short attention spans and lack of data literacy” (Figueiras 2014, 2). Wohlfart and Hauser (2007) note that one can do this by having *story nodes*, where the story pauses and allows the reader to explore the data, and *story transitions*, author-driven transitions that advance the story at the pace set by the author. Figueiras (2014) specifically set out to see how to balance narrative flow with the “experience of discovery” (1). In her work, Figuerias looked at three visualizations with the goal of identifying how to add more aspects of storytelling to the designs. Specifically, she identified how to incorporate aspects of context, empathy, and temporality.

More recent research has looked at the advantages and preferences of different designs in narrative visualizations. McKenna and others 2017 specifically looked at how the use of scrolling has increased in narrative visualization design. They evaluated the “stepper vs. scroller debate” among practitioners and creators of interactive stories. They attribute this to the increase in touch-based devices such as phones and tablets. Their results were mixed, with some preferences for the scroller, since it was easy to use on different types of devices, while also illustrating that different types of navigation had an impact on reader engagement (McKenna and others 2017).

While there now exists a body of research on storytelling and the types of graphic, rhetorical, and interaction design that can tell stories with visual data, less research has focused on the storytelling process, with only a few articles even giving a few sentences to describe it. Kosara and MacKinlay (2013) describe how journalists work. “They collect information through research and interviews, which gives them the key facts, and then they tie those facts together into a story” (44). They note that the material from the research phase might end up in the final story, but more often than not, that content serves only as background information. Unlike Hullman and Diakopolis

(2011) and Segel and Heer (2010), who see storytelling as a combination of exploration and communication, Kosara and Mackinlay (2013) see storytelling as purely a communication result, with exploration as a part of the process. Lee and others (2015), in contrast, offer what they describe as a more detailed description of the storytelling process. Their process moves from exploring and analyzing the data, to making a logical connection and ordering the story pieces, to building the presentation with the story material, to finally sharing the story, getting input, and responding to input. In this paper, I argue that the process of visual storytelling is more complex than this previous research notes.

CARTOGRAPHIC STORYTELLING

There is no doubt that maps, like graphics, can also tell stories. As Caquard and Cartwright note, “the potential of maps to both decipher and tell stories is virtually unlimited” (Caquard and Cartwright 2014, 101).

Narrative cartography has in some ways brought together the disparate subdomains of cognitive map design research and critical cartography. One way in which it does this is through the inclusion of emotion and personal experience in map design. Pearce’s work explored how narrative of a map can be produced through the graphic variables (Bertin 1983) to convey experience and sense of place (Pearce 2008). Her work was innovative in that it explored narrative in map design, the potential to embed emotional experience in a map, and illustrated a way to bridge design inspired by Western cognitive cartographic research while also incorporating non-Western ideas into a physical map. Pearce’s later work went further to explore mapping of indigenous stories and revitalization of indigenous languages through mapping (Pearce 2014). Caquard built on her work by exploring ontologies in GIS and mapping, and he critiques these as being Western and reductive (Caquard 2011). Caquard describes a movement from grid maps, such as those that often serve as basemaps or reference maps in the geoweb, to story maps. Grid maps do little to tell the stories of place, while story maps are defined by experience imbedded in the map (Caquard and Cartwright 2014). It is these metanarratives which have allowed map fiction to become reality – by simply drawing things on a map they become real (Caquard 2011).

Mocnik and Fairbairn (2018) take another approach to investigating maps as vehicles of narrative. Their work calls for a *story focus*, but also notes that maps are not nearly as good at telling stories as language (written or oral), but instead need to incorporate diagrams and other contrasting media. This call for multimedia is similar to those in information visualization, where one simple graphic may not tell a story, while a combination of graphics, interactives, and text can (Segel and Heer 2010). Caquard concludes his review of narrative cartography with this: “A theme that

appears consistently throughout this review is the trend toward a hybridization: between cartography and creative disciplines; between the grid map and the story map; between fiction and reality; between the map and the territory” ([Caquard 2011](#), 14). Technology allows users to easily create their own mapped stories using Esri StoryMaps and Tableau, which lend themselves to this hybridization, and open source libraries such as D3 allow cartographers to expand beyond the defaults in available GUI-based software.

Finally, critical post-representational cartography has explored the process of map-making and the political and power relations that become embedded in a map through its production ([Caquard and Cartwright 2014](#); [Harley 1989](#)). “From a post-representational cartography perspective, the map is less important than the process of making it and using it” ([Caquard and Cartwright 2014](#), 105). However, few have explored storytelling as a process for map design. One notable exception is Moore and others’ work, which explored the storytelling process as a way to demonstrate how the visual data storytelling process can generate new insights in environmental justice work ([Moore and others 2017](#)).

CLIMATE CHANGE STORYTELLING

Illustrating change is key to telling a story and vice versa. Climate change communication is fundamentally tied to making it clear that humans have burned fossil fuels, and this has increased atmospheric CO₂, which increases the greenhouse effect, leading to greater overall warming, which has led to a wide array of climate change impacts. And indeed, there are numerous articles on the use of stories for climate change communication. The goal of these studies has been to supplement and critique the large body of knowledge in traditional climate change and risk communication, which on its own often fails to incorporate “diversity, relationship, texture, or to provide sufficient information on whether and how to try to change things or even what might happen in the future” ([Moezzi, Janda, and Rotmann 2017](#), 4).

Additionally, there is a need for climate change communication to tell stories to make climate change real and understandable and connect with the emotions of readers (for review and introduction to a special issue on storytelling and climate change, see [Moezzi and others 2017](#)). Simply providing information about climate change is not enough to get people to act ([Moser 2007](#)). Instead, communicators need to connect with people’s emotions, which has been shown to increase action toward mitigation and adaptation ([Kollmuss and Agyeman 2002](#)). While research exists on using stories for climate change communication, only a small portion relates to the use of visuals. Stephen Sheppard is one exception. His work has explored using visual stories to communicate climate change at human scales for better communication to develop local solutions

Table 1. Insights and guidelines for creating accessible climate graphics

Psychological insights	Guidelines to improve accessibility
Avoid intuitive judgements	<ul style="list-style-type: none"> • Use empirically derived principles to inform design. Test graphics to determine viewers' comprehension.
Direct visual attention	<ul style="list-style-type: none"> • Present only the visual information necessary for the communication goal. • Direct viewers' attention toward the pertinent information for that goal. • Make important visual features of the graphic perceptually salient to capture attention. • Choose designs that are familiar to viewers and connect with their prior knowledge.
Support inference making	<ul style="list-style-type: none"> • Remove or reduce the need for spatial reasoning skills by illustrating inferences directly in the graphic. • Direct viewers to the most important relationships in the data. • Decisions to create animated graphics should be informed by cognitive principles. Consider providing user controls. • Match visual representation to metaphors that aid conceptual thinking.
Integrate text with graphics	<ul style="list-style-type: none"> • Keep the graphic and text close together by using text within a graphic when necessary. • Use text to help the viewer comprehend the graphic.

Source: [Harold and others \(2016\)](#).

([Sheppard 2012](#)). Finally, while not explicitly concerned with storytelling, [Harold and others \(2016\)](#) compiled a review of insights from psychological research to make climate change graphics more accessible. Their guidelines focused on (1) avoiding intuitive judgements, (2) directing visual attention, (3) supporting inference making, and (4) integrating text and graphics ([Harold and others 2016, Table 1](#)).

It is clear that storytelling, especially with visuals, data, graphics, and maps, is a growing field. In addition, as the field of data journalism grows, where journalists are using these devices to tell stories about the perils of the environment and society, it has become increasingly important for us to understand best practices to create effective, emotive, and beautiful visual data stories, especially with maps.

Methods

To answer the research questions, this study used semi-structured interviews with expert climate change map-makers in the United States.

RESEARCH PARTICIPANTS

Between 2015 and 2017, with the assistance of four undergraduate students, I collected 242 maps of climate change in US print and digital media. There were a variety of producers of climate change maps, but consistently NASA, NOAA, the *New York Times*, *National Geographic*, and the US Global Change Research Program (USGCRP), which produces the National Climate Assessment (NCA), produced many of the maps. Because these groups produced so many of the maps, I chose to conduct interviews with experts at these organizations, but excluded the USGRP, because it is an ephemeral group of individuals who serve during the production of the NCA every few years, but are primarily researchers housed at universities and national laboratories. In total, I conducted interviews with 16 individuals at four organizations (NASA, NOAA, the *New York Times*, and *National Geographic*; Table 2).

All of the participants did at least one of the following: represented climate data, managed employees who represented climate data, or wrote about climate change science and collaborated with map-makers. At government agencies, there are many groups that make maps. I only spoke to individuals in NASA's Earth Observatory group and NOAA's Climate.gov. These individuals are referred to as NASA and NOAA employees in this paper without

explicitly naming their groups within the organizations. Within these two agencies, these groups explicitly create maps to be read and understood by the public.

The research participants came from a wide variety of backgrounds, including science, journalism, and cartography. Many media organizations and government agencies have, in recent years, employed cartographers educated at universities with top cartography production labs. However, nine of my participants had other educational backgrounds. These individuals ranged from science experts who became communicators to 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.

INTERVIEW PROCEDURE

This research relied on semi-structured group and individual interviews. Semi-structured interviews rely on a set of questions predetermined for an interview. This format also allows researchers flexibility to ask follow-up questions, depending on the flow of each discussion (Dunn 2010, Monmonier and Gluck 1994, Robinson, Roth, and MacEachran 2011, Suchan and Brewer 2000). I developed a set of interview questions broadly focused on the workflow for creating maps of climate change. Subsets of questions focused on audience and purpose, data manipulation, design decisions, science representation, integration with written stories, and dissemination. Outside the scope of this research paper, I asked participants about the politics of climate change and its effect on their maps

Table 2. List of interview participants, affiliations, type of interview, job titles, and interview locations

Organization	Job title (gender)	Interview type	Interview location
NASA Earth Observatory	Senior data visualizer (man) Former science writer (woman)	Individual Individual	Office Common area
National Geographic	Former director of cartography (man) Former graphics editor (woman) Senior graphics editor (woman), maps and graphics research editor (man) Senior graphics editor (man)	Individual Individual Group Individual	Conference room Conference room Conference room Conference room
The New York Times	Three graphics editors (all men) and one section editor (woman) Graphics editor (man) Graphics editor (woman) Graphics editor (man)	Group Individual Individual Individual- follow up	Conference room Phone Phone Phone
NOAA Climate.gov	NOAA affiliate- section project lead (woman) NOAA affiliate- data visualization coordinator (woman) NOAA affiliate for climate.gov- section editor (woman)	Individual Individual Individual	Video conference Video conference Video conference

and reporting. Group interviews were conducted in cases where the agency, organization, or individual dictated that there were significant time constraints that made individual interviews impossible. In the group interviews, instead of asking specific questions from the predetermined list of interview questions, I asked one general question from each of the subsets above and used the more detailed interview schedule for follow-up questions. In this way, we covered all of the topics covered in the individual interviews, but there was less specificity in terms of questions asked. The group interview has been used in human geography to understand interactions across people. In many cases this is within the family group to understand marital dynamics or parent-child dynamics (Longhurst 2016). In this case, the group dynamics helped me understand the process of development of graphics, since in these cases individuals worked together as a team on projects.

I travelled to the *New York Times*, *National Geographic*, and NASA's Goddard Space Center between December 2016 and March 2017 and met with my interviewees in person. Interviews with individuals at NOAA's Climate.gov were conducted between September 2017 and June of 2018 with GoToMeeting video conferencing software which allows users to share screens. In addition, I conducted three interviews with graphics editors at the *New York Times* via phone in December 2017. Interviews lasted between 25 and 65 minutes.

Prior to conducting each interview, I collected 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. The maps provided opportunities for map-makers to point out examples of particular cartographic techniques and talk through specific design decisions. I recorded all of the interviews with a smartphone app, and the recordings were later transcribed by a service. I verified and edited the transcriptions, as needed, to ensure that the transcription was accurate. All of the quotations used were double-checked with the interviewees who asked to be consulted before their inclusion.

QUALITATIVE TEXT ANALYSIS

I followed 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 transcripts and created codes related to my research questions and unexpected themes in the interviews. This initial coding resulted in nearly 140 codes, far too many to be useful (Cope 2010). To reduce the number of codes, I identified codes that were similar or overlapping and combined these quotations into a single code to avoid overlap. Two themes emerged that aligned with the research questions posed here: "complexity" and "workflow" (Table 3). The complexity theme codes were drawn largely from Harold and

others (2016), while the "workflow" theme codes emerged through the interviews.

Results

The following subsections describe how the interview responses answer the research questions. First, I illustrate how "the story" served as a common way to make decisions across organizations, despite how audience and purpose differed. Second, I describe how stories originated and how "the story" developed over time through conversations with expert scientists. Finally, I illustrate the workflow and design decisions to make these maps understandable through creation of metaphors and by making key data salient.

THE "STORY" AS A DECISION-MAKING STRUCTURE

This research illustrates that across all four sources, storytelling was the guiding goal for writers, cartographers, and others at these organizations and that there was a common work flow to create the story (Figure 1). Participants noted that "the story" allowed the graphics and maps to be incorporated into the text. In this way, the map, through its design and layout, guided the reader on a journey through a narrative. My participants described using the story to allow the content to be more memorable and stick with the reader.

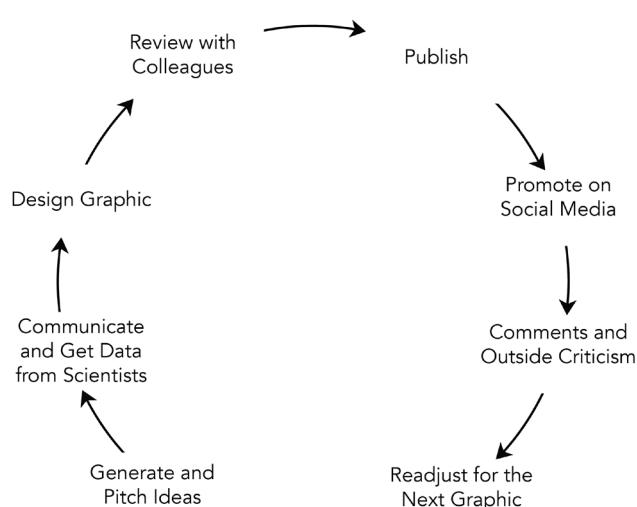
For example, in the map The Melting of Antarctica (Figure 2), the cartographer took readers on a journey to understand how the continent of Antarctica is changing over time. Through the integration of the title, text, locator map, and other graphics, this map illustrates the dynamics of a changing climate. The title and subtitle text set up the story to give context to how the current situation is different from before climate change. Areas of the map are made more salient through the use of the visual variables to create a visual hierarchy. Map tips also guide the reader to the 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.

It was through *the story* that cartographers and writers all had a common and easy decision-making structure to follow. 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. Table 4 provides numerous quotations across the four organizations to exemplify how important storytelling was for making design and writing decisions in the maps, graphics, and copy.

Table 3. Codes, explanations, quotation counts, extensiveness for "Complexity" and "Workflow" themes

Theme	Code	Explanation	Count	Extensiveness
Complexity	Abstract/tangible	Participants described how they made abstract tangible	25	11
	For a reason	Complexity was left in map for a reason	3	2
	Metaphors	Map or story used metaphors for communication to reduce complexity	6	3
	Reducing complexity	Cartographers reduced complexity through design	43	13
	Complexity	Participant described difficult balance between simplicity and complexity	10	5
Work flow	Colleague criticism/review process	Participant described internal review process for maps	22	11
	Pitching stories	Participant described how stories are pitched	14	8
	Planning graphic	Participant described planning out graphic	8	4
	Researching for story	Participant described researching for story and graphic	11	6
	Timing	Participant described timing or time allocated for a story	27	8
	Work flow for story	General work flow of a story	19	10
	Collaboration	Participant described collaborating with coworkers	6	3
	Deciding on graphics	Participant described deciding on what graphics to include in a story	5	4
	Design decisions	Participant described making decisions about design	27	10
	Personal evaluation	Participants described their own personal evaluations of graphic	2	2
	Pulled in for graphics	Participant described being pulled in to work on graphics for a story that was already developed/developing	4	3
	Connections with scientists	Participant described connections and conversations between scientists and journalists	54	11
	Map reader feedback	Participant described getting feedback from map readers	12	7
	Redesign for next graphic	Participant described changing designs over time, retrospective analysis	4	3

Notes: Count is the number of quotations assigned to a code. Extensiveness accounts for how many of the participants mentioned the code at least once.

**Figure 1.** The process of creating climate change graphics

AUDIENCE AND PURPOSE: GOVERNMENT ENTITY MAPS VS. MASS MEDIA

Across the four organizations, there were differences in the audience and purposes of the map designs; however the focus on "the story" remained. 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. Maps created by these government entities were more widely distributed



Figure 2. The Melting of Antarctica map exemplifies an intricate and detailed map design by *National Geographic*. Note: This design, though static, allows map readers both to get a general sense of the topic and to dig down to get more detailed information (Tierney, Treat, and Tyson 2017).

Source: Stephen Tyson/National Geographic Creative.

Table 4. Selection of quotations from participants across the four organizations to illustrate the reoccurring theme of "the story"

- | | |
|------------------------|---|
| NASA Earth Observatory | <ul style="list-style-type: none"> 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?" |
| The New York Times | <ul style="list-style-type: none"> 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. |
| National Geographic | <ul style="list-style-type: none"> 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. |
| NOAA Climate.gov | <ul style="list-style-type: none"> 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. |

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 the 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 their Web sites, or (3) explicitly viewing the agencies’ social media feeds. However, the overarching goal was for these maps to be 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 3). At NASA, one employee described the need to create images that could be reused across many different types of media. In particular, they noted that NASA’s Earth Observatory team provided both an annotated image and an image without labels so that other sources, such as TV production companies, could add their own text at an appropriate size for their audiences and purposes.

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 that do not have science experts on staff to use the content from these scientific-focused government agencies directly.

In contrast 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. These organizations have clear ideas of the demographics of their audiences. However, the purposes of their maps and graphics varied within their own publications which had implications for design. For instance, at *National Geographic*, some maps were those that accompanied a simple short story. The maps were designed quickly (less than a month). In other cases, such as Figure 2, the map accompanied a story that was the feature of an entire issue of the magazine. This project took the cartographer several months and numerous iterations. At the *New York Times*, participants described when graphics editors would be given just a few hours to put together a map to accompany a major news story. These stories sometimes were published on the front page. At other times, they described when the graphics department would drive a story. Graphics editors were given months to put together their own copy and graphics. These in-depth pieces were often published both in the static newspaper and in an online interactive feature, and graphics editors might work on these projects on and off for several months.

Across all of the organizations, participants spoke, in passing, about how audiences are changing. As social media dominate the ways in which people find and interact with information, it is clear that the graphics my participants were creating are also changing. The map often had to tell the story on its own, since viewers might be less likely to read a whole article that accompanied a map. Increasingly, map readers simply click on a graphic that appears in a

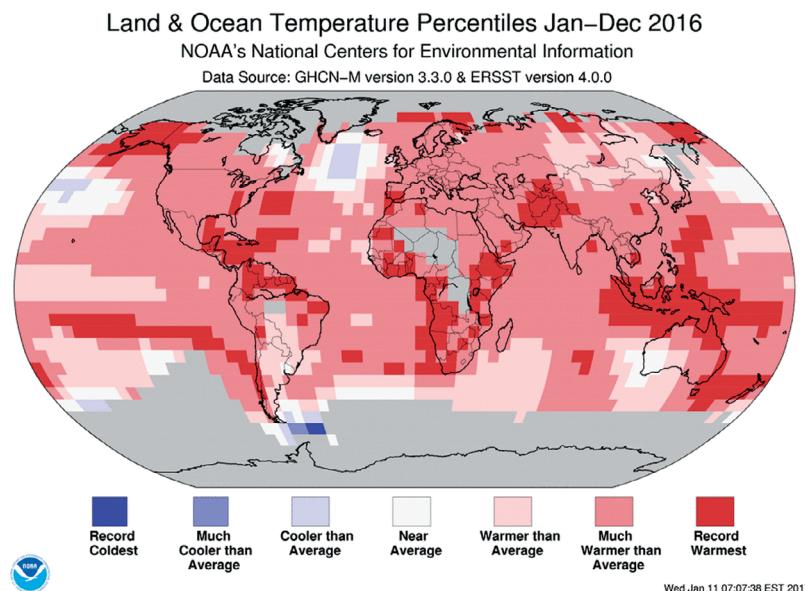


Figure 3. NOAA map of 2016 global temperatures compared to average ([NOAA National Centers for Environmental Information 2017](#))

Notes: 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*.

Source: NOAA Photo Library. The image is in the public domain.

social media feed while ignoring the accompanying written text. In addition, all of the organizations used social media as a way to increase traffic to their sites and to share their maps and graphics more widely.

Finally, while social media were used to promote and disseminate maps and graphics, my participants had a difficult time identifying why some stories went viral while others did not. A *New York Times* employee 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.” However, even when participants were able to identify which stories went viral, how or why it happened was less understood.

STORY ORIGINATIION: PITCHING AND DECIDING ON A STORY

Across the four organizations, participants described how stories originated. Specifically, they described pitch meetings where they identified interesting stories and brainstormed as a group how a story might be told. From the initial set of stories discussed, the map-makers flagged stories that they felt would be interesting and might have data available. Finally, data sets were identified to be used to tell the stories. It was at this point in the process that participants described how the integration of maps, graphics, photos, and copy was discussed to identify how to tell the story best.

The pitch meetings were sometimes composed of a diverse group of individuals from across the organization, while in other instances they were led by individuals within a “desk” that focused on a single topic. At NASA, pitch meetings happened every week via a conference call with employees at Goddard Space Flight Center (Maryland), Johnson Space Center (Texas), and the Jet Propulsion Laboratory (California) to identify as many story ideas as possible. At the *New York Times*, on the other hand, many stories were identified by specific desks and graphics staff were pulled in to work on graphics for the story. For instance, during the time in which I conducted interviews, the *New York Times* created a “climate desk” that focused on stories specifically about climate change. In their stories, they would often bring in graphics department staff to help create the graphics and maps, although they also employed one graphics editor who worked solely on climate desk graphics. My participants at the *Times* noted, however, that the graphics department was unique in that many times they would complete the whole workflow (pitch, story, graphics, etc.) within their single department. At *National Geographic*, on the other hand, often the pitch for the story was driven by the photography, for which the magazine is best known.

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 stories about climate change. In this way, my participants exemplified how academic publishing in high-impact journals such as *Proceedings of the National Academy of Science*, *Science*, and *Nature* has a compounding impact on the greater dissemination of scientific research. Journalists use these high-impact journals as fodder for scientific stories.

Once the story was decided, the participants described doing background research. A 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.” They further explained that this process allowed them to ensure that the data were available for the story. Participants at other organizations also described this aspect of the process. Sometimes research for a story was conducted entirely by the graphics staff and writers; in other cases, research editors or freelancers assisted. Together these individuals collaborated to research, write, gather data, and create a compelling story as a team.

STORY DEVELOPMENT: HONING THE STORY WITH EXPERT SCIENTISTS

All of my participants described in-depth conversations with scientists as they developed stories. Communication with scientists whose work they were representing in their publications also centred around *the story*. Through these conversations, my participants were able to decide on a story, hone a previously decided story, or tell the story better after having the scientist explain the story to them. In every interview, my participants described open dialogue 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 a story. In some cases, the scientist would provide his or her network of other researchers to help tell the story to my participants from multiple perspectives. My participants noted that all quotations and statements were checked, and often double-checked, with scientists to assure accuracy.

Scientists pointed out the most salient aspects of stories to the communicators. It was this process that my participants described as allowing them to hone their stories. One *National Geographic* employee described how

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.

In other cases, the scientists were there to help identify different ways of elaborating on complex topics. Participants repeatedly noted how they had scientists explain stories in multiple ways. This allowed my participants to drill down to what was interesting about the studies they were featuring and identify the best ways to convey the scientific information to non-scientific audiences.

REDUCING COMPLEXITY BY CREATING METAPHORS AND MAKING KEY DATA SALIENT IN VISUAL STORIES

To communicate climate change effectively, map-makers described a need to reduce complexity. Specifically, they described (1) using metaphors that have been described as effective ways in which to tell visual stories of climate change in the literature (Harold and others 2016) and (2) making key data salient to focus the story for readers.

Participants noted using points of reference 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 4). In other cases, they described trying to find more whimsical

comparisons that readers could connect with. For example, one *New York Times* graphics editor said of providing metaphorical context to the reader for maps of ocean temperature change,

I talked to several scientists to try to figure out what a zetajoule 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 graphics, 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 sea levels would rise given the melting of Antarctica (Figure 5). This provided a simple visual that was incorporated into the map design.

It was 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. A *National Geographic* employee described the 2.5D map of rising sea levels in New York City as follows (Figure 6): "when you are looking at little buildings [they] are going to be inundated with water. This



Figure 4. Graphic of the extent of major wildfires in 2017 compared with the size of Washington, DC

Note: This graphic is a good example of using comparison to a local geography to understand the extent of distant events.

Source: Tierney (2018).

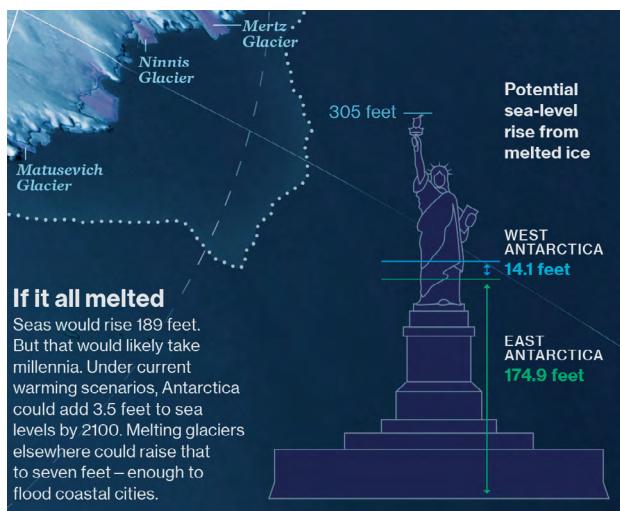


Figure 5. Section of the Melting of Antarctica map showing the use of metaphor to illustrate potential sea level rise if parts of Antarctica were to melt (Tierney and others 2017)

Source: Stephen Tyson/National Geographic Creative.

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 the importance of familiarity in their designs. One NASA employee said their goal was often "to be really familiar in our approach." At the government agencies, maps were designed with a particular look and feel and often used template designs. Map readers can pick up a government map and inherently understand it without a lot of additional cognitive effort.

Telling visual stories often requires directing readers' attention and directing them to relationships in the visual. One way in which my participants described this process was by removing all but the most salient aspect of the data. By adding salience to the key aspect of the map, my participants gave readers 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. To add salience and focus in the design, for example, NOAA affiliates described following

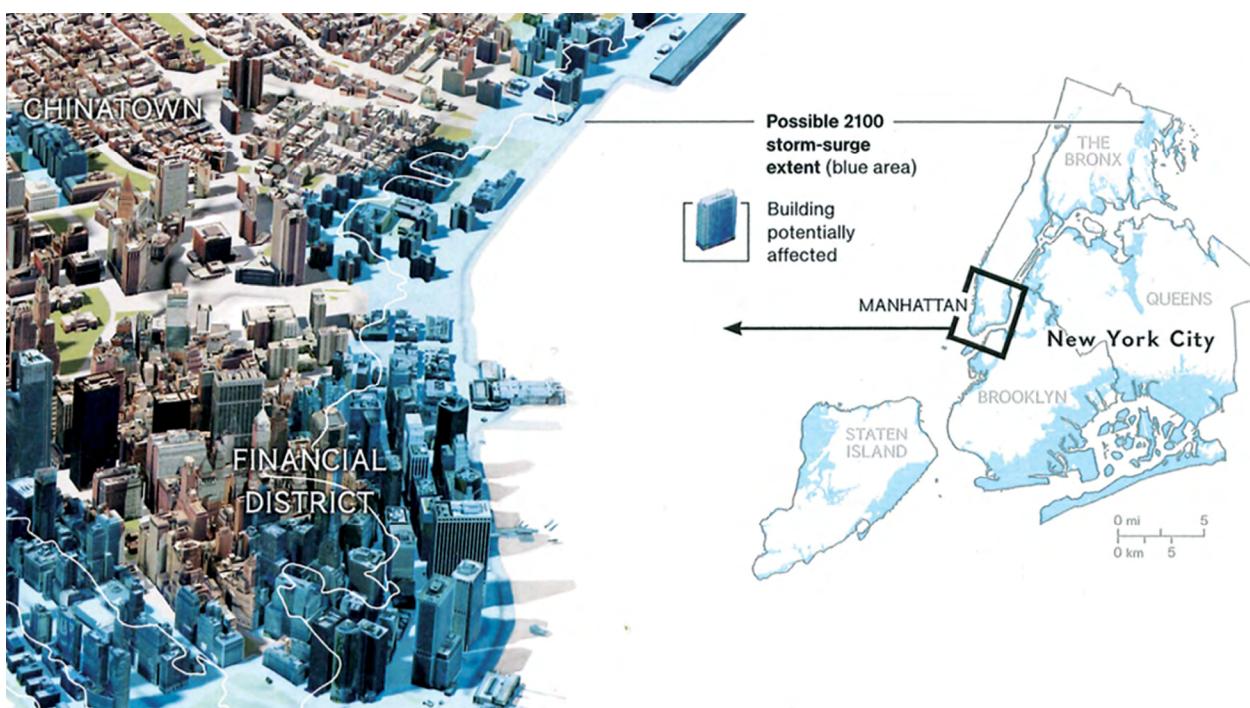


Figure 6. Map of sea level rise in New York City during a potential future superstorm in 2100

Note: The graphics editor who worked on this map noted the emotion he tried to impart in the map by illustrating New York City in such detail.

Source: Morris, Twombly, and Smith (2013). Ryan, Morris/National Geographic Creative.

Tufte's (1983) data–ink ratio rule to reduce complexity in the designs. The *data–ink ratio* describes the proportion of ink used for the actual data in a graphic vs. the ink used for the non-data aspects of a graphic. According to Tufte, graphics with high data–ink ratios are better designed, since all of the ink on the graphic is devoted to data, without unnecessary embellishments. NOAA affiliates noted that when they put minimalism at the forefront of their design decisions, they were able to create easy-to-understand graphics that focused on the most important data to tell the story.

My participants also described breaking down data into smaller chunks to focus their readers. 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 that use *scrolly-telling* to reduce complexity in their designs. Scrolly-telling, while adding interaction, allows a reader to simply scroll down a page through a story. 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.

Discussion

STORY FOCUS AS PROCESS

It was clear that “the story” served as a primary decision-making structure for map-makers and writers at all four of these organizations. By asking themselves “does this align with the story I am trying to tell?” my participants made decisions about how to reduce complexity in their designs. The story also provided a starting point for the entire team. The process across the four organizations followed a similar flow, which brought together a team of writers, graphics editors, scientists, and other researchers. Throughout the process, each individual continually asked whether adding or reducing content still allowed him or her to tell a coherent and cohesive story which a reader could follow. It was through this process that the cartographers focused the story through the use of metaphor and making key data salient in the design.

Despite calls to better understand how graphics and maps can tell stories, few papers elaborate on the *process* of storytelling with visuals, and in particular maps. The few papers that do mention the process simplify it to a few steps and imply that these steps are often conducted by one person who wears many hats. While this study only included 16 participants, it was clear that the process is

quite complex, involves many experts, and can take significant amounts of time and energy. As in the narrative visualization literature, I did see that storytelling allowed the combination of exploration and communication (Hullman and Diakopolis 2011; Segel and Heer 2010). As one of my participants said, it was through certain tools and guidance by the scientists that they were able to explore the data to identify the story, and then tell that story to their readers.

In their review of the psychological insights to improve climate change data visualization, Harold and others (2016) noted the need to reduce complexity to make climate change graphics accessible (Table 1). My participants, knowingly or not, followed nearly every aspect of the insights described by Harold and others (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. My participants also described making important visual features in the story salient. Sometimes they did this through the use of technology such as scrolly-telling or by reducing extraneous information by following Tufte's (1983) data–ink ratio. In addition, through the use of style guides and templates, my participants focused on keeping the design of the map familiar for audiences. My participants also used metaphors and text on the map in the form of map tips to direct attention and support inference making. They did this by adding text to the map, creating additional illustrations, and simplifying designs over time through feedback from readers, colleagues, and design competitions.

WHO IS TELLING THE STORY AND FOR WHOM?

Critical cartographers have asked us to consider post-representation, that is who is producing the map and what aspects of power relationships are reproduced in its content and design (Caquard 2011). Journalists are an elite group of individuals who are overwhelmingly white, male, and highly educated. As was expected, all of my participants had bachelor's degrees and many had post-graduate degrees, including many with PhD's; however, half of my research participants were women. While the journalism field and science fields have been male-dominated throughout much of modern history, it is clear that there are larger changes going on more recently related to gender balance in these fields. It was clear through my interviews that women are pushing the bounds of visual data journalism and climate change communication. This

research does, however, call attention to the lack of other types of diversity in who is telling the story of climate change visually.

In the past 20 years, there has been a greater democratization of mapping. Software and Web tools that are free or low-cost now allow non-experts to create maps without large up-front expenses or training. As storytelling with maps and other visualizations becomes more common, so do the tools to create these types of visuals. Esri's StoryMaps, in particular, are easy to use, relatively low-cost compared with desktop GIS software, and easily shareable. While these stories are not necessarily as polished as those created by the *New York Times* or *National Geographic*, they now allow a more diverse set of map makers to create maps that tell stories with data. It is my hope that other software and Web-based mapping companies will create products similar to and competitive with the Esri StoryMaps that allow this trend to continue.

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 map-makers to create maps that align with readers' goals. In this case, it was clear that media organizations had a better idea of their audiences than government agencies, which allowed media organizations to create more specific graphics that did not rely on templates. I argue, however, that government agencies that had less control over their maps have had a larger impact, because these maps were disseminated far beyond their own Web sites. This was 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 a map might serve for this growing set of viewers.

Finally, my participants spoke to where they found fodder for future stories – in the newest issues of high-impact scientific journals such as *Science*, *Nature*, and *Proceedings of the National Academy of Science*. While there is no doubt that some of the most innovative and ground-breaking science is published in these high-impact journals, such journals cater to a particular type of science that is predominately older, white, and male. Scholars are seeing the need to tell interesting stories with data in part because (1) the science cannot speak for itself and (2) qualitative information can add new perspectives and richness to the science and its communication. Journalists too need to look beyond these quantitative-based scientific journals to a more diverse

set of research studies that are found in other types of journals where there are more diverse voices in terms of authors and data.

Conclusion

In this paper, I reported on a study to understand the design decisions made by climate change map-makers in the media and at government agencies in the United States. Specifically, I asked three questions:

What is the process of creating climate change maps that are designed to be understandable by a wide general audience, and how does this differ across organizations?

The results of a series of semi-structured interviews with employees at NASA, NOAA, the *New York Times*, and *National Geographic* indicate that there is a common process in designing maps that tell stories to wide general audiences. This process is more complex than other scholars have noted in related work in information visualization. In particular, climate change map storytelling at these organizations involves multiple people who work toward a common goal to visual tell stories. It was also clear that this process centres on using “the story” identified in the data to make design decisions throughout the process, from which scientists to collaborate with, to what data are used and how they are displayed, to what types of metaphors to use to connect readers more clearly to complex and distant climate change effects. *The story* was the central way in which map-makers focused on a common theme and design strategy. In addition, it was clear that despite differences in audience and purpose at government agencies vs. media organizations, “the story” still guided decisions.

How do climate change map stories originate and develop over time at these organizations?

Participants in this study illustrated how stories are identified, how these stories are pitched in big meetings with many individuals across the organization, and then how they began initial research individually. I argue that focus is given to particular types of science, while others are ignored, since these stories are often identified through publications at major high-impact science journals. Once a story was identified, participants described constant back-and-forth with experts in the field to understand the science, get assistance on refinement for the story, and sometimes push a scientist to remove information from a graphic in order to tell the most easily understandable story. This open dialogue illustrates the connections that are built between science and the media through individual story development, even while the general trope in science is that the media often “get it wrong.”

How does “the story” focus the map-maker in the process of making maps of climate change to reduce complexity and make complex data meaningful to audiences?

Participants described how they reduced complexity in two ways: (1) by creating metaphors that helped readers with context and understanding of abstract and distant effects of climate change and (2) by making key data salient to focus the reader. To create metaphors, sometimes the map-maker described talking with scientists to better understand complex topics or big numbers to create context. In other cases, creation of visual metaphors relied on their own imagination and creativity. On the opposite side, however, was the push to make key data salient by removing all extraneous information in a methodical way by following suggestions from experts such as Tufte.

Map storytelling is an area of research ripe for investigation. While there is now a growing literature in this domain, there are still many unanswered questions: what types of these stories go viral? how can technology support development of stories while avoiding the lack of novelty that often comes with technology defaults? how can we encourage and continue to support more diverse voices to be part of this innovative way of illustrating data?

Understanding process is a key first step into understanding how we can leverage map storytelling to make “maps that matter” for the betterment of society (Robinson and others 2017). These maps have the potential to better connect with map readers, which may in turn lead to action to solve large social and environmental problems. This paper has explored how story maps of climate change are made at major organizations driving the visual and cartographic conversation on a changing climate.

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References

- Bertin, Jacques. 1983. *Semiology of Graphics*. Madison, WI: University of Wisconsin Press.
- Buchanan, Larry, and Derek Watkins. 2015. "Greenland Is Melting Away." *The New York Times*. Available at <https://www.nytimes.com/interactive/2015/10/27/world/greenland-is-melting-away.html>.
- Cauquard, Sébastien. 2011. "Cartography I: Mapping Narrative Cartography." *Progress in Human Geography* 37(1): 135–44. <https://doi.org/10.1177/0309132511423796>.
- Cauquard, Sébastien, and William Cartwright. 2014. "Narrative Cartography: From Mapping Stories to the Narrative of Maps and Mapping." *Cartographic Journal* 51(2): 101–6. <https://doi.org/10.1080/000870414Z.000000000130>.
- Cope, Meghan. 2010. "Coding Qualitative Data." In *Qualitative Research Methods in Human Geography*, 3rd ed., ed. Iain Hay, 281–94. Oxford: Oxford University Press.
- Dunn, Kevin. 2010. "Interviewing." In *Qualitative Research Methods in Human Geography*, 3rd ed., ed. Iain Hay, 101–38. Oxford: Oxford University Press.
- Figueiras, Ana. 2014. "Narrative Visualization: A Case Study of How to Incorporate Narrative Elements in Existing Visualizations." In *2014 18th International Conference on Information Visualisation*, 46–52. N.p.: IEEE.
- Gershon, Nahum, and Ward Page. 2001. "What Storytelling Can Do for Information Visualization." *Communications of the ACM* 44(8): 31–37. <https://doi.org/10.1145/381641.381653>.
- Harley, John Brian. 1989. "Deconstructing the Map." *Cartographica* 26(2): 1–20. <https://doi.org/10.3138/E635-7827-1757-9T53>.
- Harold, Jordan, Irene Lorenzoni, Thomas F. Shipley, and Kenny R. Coventry. 2016. "Cognitive and Psychological Science Insights to Improve Climate Change Data Visualization." *Nature Climate Change* 6: 1080–89. <https://doi.org/10.1038/nclimate3162>.
- Hullman, Jessica, and Nick Diakopoulos. 2011. "Visualization Rhetoric: Framing Effects in Narrative Visualization." *IEEE Transactions on Visualization and Computer Graphics* 17(12): 2231–40. <https://doi.org/10.1109/TVCG.2011.255>.
- Kollmuss, Anja, and Julian Agyeman. 2002. "Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-environmental Behavior?" *Environmental Education Research* 8(3): 239–60. <https://doi.org/10.1080/13504620220145401>.
- Kosara, Robert, and Jock Mackinlay. 2013. "Storytelling: The Next Step for Visualization." *Computer* 46(5): 44–50. <https://doi.org/10.1109/MC.2013.36>.
- Lee, Bongshin, Nathalie Henry Riche, Petra Isenberg, and Sheelagh Carpendale. 2015. "More than Telling a Story: Transforming Data into Visually Shared Stories." *IEEE Computer Graphics and Applications* 35(5): 84–90. <https://doi.org/10.1109/MCG.2015.99>.
- Longhurst, Robyn. 2016. "Semi-structured Interviews and Focus Groups." In *Key Methods in Geography*, 3rd ed., ed. Nicholas Clifford, Meghan Cope, Thomas Gillespie, and Shaun French, 143–56. Los Angeles: Sage.
- Ma, Kwan-Liu, Isaac Liao, Jennifer Frazier, Helwig Hauser, and Helen-Nicole Kostis. 2012. "Scientific Storytelling Using Visualization." *IEEE Computer Graphics and Applications* 32(1): 12–19. <https://doi.org/10.1109/MCG.2012.24>.
- McKenna, Sean, N. Henry Riche, Bongshin Lee, Jeremy Boy, and Miriah Meyer. 2017. "Visual Narrative Flow: Exploring Factors Shaping Data Visualization Story Reading Experiences." In *Computer Graphics Forum*, 36(3): 377–87. <https://doi.org/10.1111/cgf.13195>.
- Mocnik, Franz-Benjamin, and David Fairbairn. 2018. "Maps Telling Stories?" *Cartographic Journal* 55(1): 36–57. <https://doi.org/10.1080/00087041.2017.1304498>.

- Moezzi, Mithra, Kathryn B. Janda, and Sea Rotmann. 2017. "Using Stories, Narratives, and Storytelling in Energy and Climate Change Research." *Energy Research and Social Science* 31: 1–10. <https://doi.org/10.1016/j.erss.2017.06.034>.
- Monmonier, Mark, and Myke Gluck. 1994. "Focus Groups for Design Improvement in Dynamic Cartography." *Cartography and Geographic Information Systems* 21(1): 37–47. <https://doi.org/10.1559/152304094782563948>.
- Moore, Sarah A., Robert E. Roth, Heather Rosenfeld, Eric Nost, Kristen Vincent, Mohammed Rafi Arefin, and Tanya M.A. Buckingham. 2017. "Undisciplining Environmental Justice Research with Visual Storytelling." *Geoforum* 102: 267–77. <https://doi.org/10.1016/j.geoforum.2017.03.003>.
- Morris, Ryan, Matthew Twombly, and Maggie Smith. 2013. "A Superstorm in 2100." *National Geographic* 224(3): 40–41.
- Moser, Susanne C. 2007. "More Bad News: The Risk of Neglecting Emotional Responses to Climate Change Information." In *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*, ed. Susanne C. Moser and Lisa Dilling, 64–80. Cambridge, UK: Cambridge University Press.
- NOAA National Centers for Environmental Information. 2017. "Land and Ocean Temperature Percentiles Jan–Dec 2016." Global Temperature and Precipitation Maps. NOAA. Available at <https://www.ncdc.noaa.gov/temp-and-precip/global-maps/201613#global-maps-select>.
- Pearce, Margaret Wickens. 2008. "Framing the Days: Place and Narrative in Cartography." *Cartography and Geographic Information Science* 35(1): 17–32. <https://doi.org/10.1559/152304008783475661>.
- Pearce, Margaret Wickens. 2014. "The Last Piece Is You." *Cartographic Journal* 51(2): 107–22. <https://doi.org/10.1179/1743277414Y.0000000078>.
- Phillips, Jonathan. 2012. "Storytelling in Earth Sciences: The Eight Basic Plots." *Earth-Science Reviews* 115(3): 153–62. <https://doi.org/10.1016/j.earscirev.2012.09.005>.
- Robinson, Anthony C., Urška Demšar, Aileen Buckley, Silvana Philippi Camboim, Kenneth Field, Bin Jiang, Menno-Jan Kraak, Antoni B. Moore, and Claudia Robbi Sluter. 2017. "Big Data and Cartography: Research Challenges and Opportunities for Making Maps That Matter." *International Journal of Cartography* 3(Sup1): 1–29. <https://doi.org/10.1080/23729333.2016.1278151>.
- Robinson, Anthony C., Robert E. Roth, and Alan M. MacEachren. 2011. "Understanding User Needs for Map Symbol Standards in Emergency Management." *Journal of Homeland Security and Emergency Management* 8(1): 1–24.
- Segel, Edward, and Jeffrey Heer. 2010. "Narrative Visualization: Telling Stories with Data." *IEEE Transactions on Visualization and Computer Graphics* 16(6): 1139–48. <https://doi.org/10.1109/TVCG.2010.179>.
- Sheppard, Stephen R.J. 2012. *Visualizing Climate Change: A Guide to Visual Communication of Climate Change and Developing Local Solutions*. London/New York: Routledge.
- Suchan, Trudy A., and Cynthia A. Brewer. 2000. "Qualitative Methods for Research on Mapmaking and Map Use." *Professional Geographer* 52(1): 145–54. <https://doi.org/10.1111/0033-0124.00212>.
- Tierney, Lauren. 2018. "The Grim Scope of 2017's California Wildfire Season Is Now Clear. The Danger's Not Over." *Washington Post*. Available at https://www.washingtonpost.com/graphics/2017/national/california-wildfires-comparison/?noredirect=on&utm_term=.730e1aa020d5.
- Tierney, Lauren, Jason Treat, and Stephen Tyson. 2017. "The Melting of Antarctica." *National Geographic* 232(1): 35–38.
- Tong, Chao, Richard Roberts, Rita Borgo, Sean Walton, Robert Laramee, Kodzo Wegba, Aidong Lu, Yun Wang, Huamin Qu, and Qiong Luo. 2018. "Storytelling and Visualization: An Extended Survey." *Information* 9(3): 65. <https://doi.org/10.3390/info9030065>.
- Tufte, Edward R. 1983. *The Visual Display of Quantitative Information*. Cheshire, CT: Graphics Press.
- Wohlfart, Michael, and Helwig Hauser. 2007. "Story Telling for Presentation in Volume Visualization." In *Proceedings of the 9th Joint Eurographics/IEEE VGTC Conference on Visualization*, ed. Ken Museth, Torsten Möller, and Anders Ynnerman, 91–98. Goslar, Germany: Eurographics Association.