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REFEREED PAPER



Elements of Vivid Cartography

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ABSTRACT

As maps become more common and popular in the media to illustrate large social and environmental problems such as climate change, cartographers who are given this task are searching for ways to present information to persuade readers to care and take action. Research has shown that simply presenting facts is often not enough for someone to take action to solve these types of socio-environmental problems; information must not only be presented accurately but also must connect with readers' emotions. Indeed, cartographers have increasingly been interested in understanding not just the cognitive implications of map design but also both the persuasive nature of and affective responses to map design. Here I present the term *vividness*, a term used in other communication domains to describe content which attracts attention, evokes emotion, and makes distant topics proximate to readers. While this term is new to the cartographic realm it provides a framework by which to evaluate maps for their persuasiveness based in both cognitive map design research conducted since the middle of the last century and newer research in cartography on maps and emotion. Through semi-structured interviews with experts I illustrate how cartographers create persuasive maps that align with the definition of vividness and I argue that vividness is composed of the following elements in maps: (1) visual salience, (2) visible change over time, (3) congruent colour use, (4) projection choice, (5) symbolization, (6) legend design, (7) layout, and (8) novel designs.

KEYWORDS

Map design; cartography; vividness; salience; novelty; colour

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 aim to make climate change information clear and persuasive for audiences in the hope that the public take action toward mitigation or adaptation efforts. One way in which to describe maps that both present facts accurately but are also persuasive through their ability to connect with map readers' emotions is using the term *vividness*. This term originated in advertising and social psychology to describe 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). Indeed, research on climate change communication describes that simply presenting facts without making emotional connections with readers does not lead to a change in attitude (Chess and Johnson, 2007). Vividness describes content, in this case maps, which present facts in a way that connects with readers to make distant, complex, and contested topics real, and is vital in an age of disinformation campaigns where science is being questioned. Vividness can add to the literature on map design by providing a set of elements which cartographers can incorporate to create compelling designs especially of complex and contested topics like climate change, and a way to evaluate, and even rate, maps holistically informed by best practices from cognitive research in cartography and newer research on maps and emotion.

In this paper, I describe an interview study with expert cartographers who make maps about climate change. These cartographers at major news organizations and government agencies in the United States aim to follow cartographic best practices to present the facts clearly through maps, but also want to persuade audiences by connecting with map readers' emotions that they hope will lead to changes in attitude or behaviour without being propagandist. I argue that this compelling map design which is designed to persuade through the incorporation of best practices and creating emotional interest is what communication experts have called vividness. Based on the interviews, I demonstrate that the elements of vividness in maps are: (1) visual salience, (2) visible change over time, (3) congruent colour use, (4) projection choice, (5) symbolization, (6) legend

design, (7) layout, and (8) novel designs. Using semi-structured interviews with expert cartographers I illustrate the elements of cartography used to create vivid designs which are compelling to wide audiences and then I connect each of these elements to the definition of vividness.

In the next section, I review the literature on vividness. Then I describe how maps can be a type of vivid content through reviewing the cartographic literature on persuasion, emotion, and attention. I follow by describing the methods of the interview study, the results, and discuss how the elements used to create vivid designs connect to the vividness literature. I conclude with an overview of how vividness adds to the cartographic literature and present an idea for future directions.

Vividness

Vividness was defined in 1980 as 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). In the advertising realm the content might be a print or TV advertisement. In cartography, the content is the map. In this section, I describe vividness research in psychology and advertising and the controversy surrounding its impact on persuasion.

Vividness describes content which is designed to persuade readers (Eaton, 2011). Earlier research in the field of vividness focused largely on the disconnect between the theory that vivid information should be persuasive with the lack of empirical evidence for its effect on persuasion (see Taylor and Thompson, 1982). However, more recent research has shown that vividness has an effect on persuasion (Reyes *et al.*, 1980; Kisielius and Sternthal, 1984; Shedler and Manis, 1986; Kelley *et al.*, 1989; Smith and Shaffer, 2000; Guadagno *et al.*, 2011; Bailey *et al.*, 2015; Blondé and Girandola, 2018). Taylor and Thompson (1982) suggest that the disconnect between theory and evidence (what they call 'elusiveness') is because: (1) vividness has relied on measuring attitudes as compared to perceptions through the use of between-subjects methodologies (as opposed to within-subjects), and (2) because it was ill-defined. I describe both of these problems here.

First, Taylor and Thompson (1982) argue that elusiveness due to measuring attitudes as compared to perceptions was evident when comparing studies of vividness versus studies on salience. Salience studies have not suffered from an elusiveness of effect because those studies tended to use within-subjects testing to measure perceptions. They also argued that there is no good reason to separate vividness from salience. Guadagno *et al.* (2011) recently illustrated that the vividness effect on persuasion was clear (and not elusive) when the key point of an advertisement was made vivid, in other words, when the most salient part of the advertisement was vivid. In their study, they implicitly linked the concept of salience with vividness by illustrating that vividness had an effect when the key elements of the content were vivid, not the background.

Second, Taylor and Thompson (1982) also argued that vividness was sometimes elusive because it was ill-defined. 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 visually represented, which makes this type of content more likely to influence decisions or attitudes. However, despite many descriptions, what is considered vivid in advertising has not been clearly delineated. If researchers had a clearer idea of what was considered vivid versus pallid, studies could test more effectively whether this content was persuasive. In this paper, I aim to articulate what aspects of map design make them vivid to readers so cartographers can incorporate these aspects into their designs and so researchers can better test and understand whether these designs make a map more persuasive.

The case of maps

Vividness is not a term used in cartographic literature. However, vividness is connected to literature on persuasion, attention, and emotion, which are common topics in the field of cartography. How these concepts are addressed in cartographic literature will now be reviewed.

Persuasion and map design

Judith Tyner, Mark Monmonier, and Ian Muehlenhaus have made explicit connections between map design and persuasion. Monmonier's (1996) *How to Lie with Maps* provides an overview of the ways in which cartographers can manipulate maps and also how sometimes they have to tell 'white lies' because not everything in a single map can accurately represent the real world completely.

Tyner and Muehlenhaus' research both focus on developing categorizations and ordering of persuasive maps. Tyner (1974) categorized maps based on the type of persuasion (e.g. journalism, advertising) and identified that some maps are more persuasive than others (e.g. propaganda maps versus real estate maps) but also noted that some maps are unintentionally persuasive. Muehlenhaus (2013) used content analysis to categorize and develop a taxonomy of the composition of persuasive maps. His analysis resulted in a list of map elements that can be altered to impact the persuasive capabilities of maps. Results from Muehlenhaus' work specifically separates the two map types of rhetorical and rational maps and implies a continuum between the two. He lists political propaganda maps as the most persuasive maps (rhetorical) and scientific visualizations as being objective (rational) (Muehlenhaus, 2014). His continuum implies that there can be a purely objectively designed map and that these objective maps do not persuade and never aim to persuade.

Emotions and maps

Propaganda and persuasive maps, of course, are designed to play on human emotion, and beyond propaganda. Research on emotion and maps has risen in prominence. Caquard and Griffin (2019) identified three themes related to maps and emotion: (1) emotions can be placed on maps, (2) emotions can shape the map and mapping process, and (3) maps can influence emotional responses. I describe these three themes below.

One way in which emotions are placed on maps is through the use of narrative or storytelling to explicitly embed the human experience, including emotions, within a map. Mapping stories can include emotions, dynamic scales, fiction and non-fiction (Caquard and Cartwright, 2014). Pearce (2008), for instance, used the diary of an early explorer in the Canadian frontier to design a map where each day used colours based on the explorer's emotions written in his diary. Map stories can also be created with the use of dynamic online tools to connect geography through geometry and time (Caquard and Fiset, 2014). Likewise, Esri's StoryMaps support the development, sharing, and diversity of many different stories in a user-friendly way.

The stories behind the map, so-called 'meta-narratives', draw on post-representational cartography, the crux of critical cartography (Caquard, 2011). Critical cartography emerged with Harley's (1989) research to deconstruct the map to better understand the power dynamics and biases of both the cartographer and the impetus behind the development of a map.

The third theme – how maps affect emotions – is interesting here because it implies that maps, even those that are *not* explicitly propagandist, affect our emotions. Griffin and McQuoid (2012) describe the potential impact of aesthetics (2012), specifically drawing upon Kent's (2005) work. Others have theorized that default designs in GIS software are less emotive than custom designs. Fabrikant illustrated how colour had an impact on emotion measured through skin conductance Fabrikant *et al.* (2012). Anderson (2018) demonstrated that map readers have can unexpected emotional reactions when the colours used on maps are not 'congruent' with the topic. For instance, when bright 'happy' colours are used to show morbid topics, map readers were confused and uncomfortable with the map design. Through the use of methodologies similar to those of cognitive map design researchers, Fabrikant and her colleagues and Anderson make connections between the well-established field of cognitive map design and the newer domain of interest: emotion and maps. Similar to the cognitive map design research of the past these newer studies aim to understand how the map's design influences interpretation.

Attention

Drawing and directing attention is one of the goals of cartographers as they guide a map reader through a map (Lloyd, 2005). Research on attention in maps draws from Gestalt principles, specifically figure-ground, for describing which aspects appear more salient in map designs (MacEachren, 1995). Within cartography, recent research related to attention has focused on salience, visual contrast, visual hierarchy, and motion. Salience has largely been tested using eye-movement analysis to understand what draws attention in the visual field (Itti *et al.*, 1998; Itti and Koch, 2001). Research has shown that the primary theme of the map should align with the aspects which draw the most attention and eye fixations (Fabrikant and Goldsberry, 2005). Cartographers can make parts of a map more salient through visual hierarchy and contrast. Visual contrast, which is sometimes referred to as visual differences (Dent, 1972), uses the visual variables (Bertin, 1967) to show difference between elements on a map. 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).

Finally, research in psychology has shown that motion attracts attention (Franconeri and Simons, 2003; Abrams and Christ, 2006). In cartography, much of this research has focused on animated maps. Cartographers use moving or flashing symbols to direct attention to areas in an animated map display (e.g. DiBiase *et al.*, 1992). 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.

The research in this paper extends the term vividness into the cartographic realm by drawing connections between 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. These interview conversations centred on how to make climate change maps which are compelling to map readers from a wide audience. 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.

Methods

The goal of this research was to develop a set of elements of a vivid map. Vividness is a new way of understanding map design that (1) gives cartographers a set of elements to include in a map to make it compelling, and (2) gives researchers a means to evaluate the aspects of a map which may make it persuasive, incorporating well-known aspects of cartographic best practices derived from cognitive map design research as well as aspects of research on emotions and maps.

To understand the way in which vividness is already being used, even if the term is not, this research relied on semi-structured interviews with 16 expert cartographers, graphics editors, and managers at The New York Times, National Geographic, NASA, and NOAA to identify themes related to creating maps of climate change which they felt influenced their audiences. In this research study I was interested in climate change communication through maps, however, the elements of vividness in maps could be extended to other topics which are relevant to society and the environment. In this way, the concept of vividness is a larger and more holistic way to view maps which extends beyond just climate change maps.

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 vividness is not a term known to cartographers or graphics editors. The interview questions were designed to investigate how design decisions were made in regards to making maps of climate change which were effective for audiences. 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, the elements of vividness were common in the conversations and follow-up questions helped participants to elaborate on how these were important for their design process.

I connected and organized interviews with participants email, personal connections, and snowball sampling. The interviews were conducted in-person, via GoToMeeting, or via telephone, 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. Some of the interviews were conducted in a group setting due to availability of the participants. In all of the interviews, the maps the participants had created served as stimuli for conversation. This was a useful process and allowed participants to avoid speaking in abstract terms by allowing them to directly point out aspects of the design.

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 towards a final set of codes ($n = 82$) and 17 major themes. The 'design' theme contained 18 codes which describe how the elements of vividness were used by my participants (Table 1). I describe these in the next section and connect each of the elements to the vividness definition.

Results and discussion

There are 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. Through the interviews it was clear that there were eight themes which were important for creating compelling persuasive maps of climate change: (1) visual salience, (2) visible change over time, (3) colour use, (4) legend design, (5) projections, (6) symbolization, (7) layout, and (8) novel design styles which I determined were the key aspects of a vivid map. In this section I

Table 1. Codes, explanations, and quote counts for 'Design' theme.

Theme	Code	Explanation	Count
Design	Animation	design used animation	15
	Attention/salience	design aimed to grab attention through making important data salient	21
	Cartographic conventions	participant described following cartographic conventions	2
	Colour Schemes	participant described colour schemes used	39
	Constraints	participant described constraints on design	3
	Data classification	participant described data classification	6
	Generalization	participant described using generalization in map	8
	Interactivity	participant described using interactivity	21
	Labelling	participant described labelling decisions	4
	Layout	participant described layout design	4
	Marginalia	participant described marginalia	4
	Novelty	participant described using design novelty	35
	Projection	participant described projection choices	4
	Rainbow Colour Schemes	participant described problems with rainbow colour schemes	10
	Scale	participant described scale of map	7
	Style guide	participant described style guide or a consistent style was used at an organization	10
	Video	maps were included in video	6
	Visual hierarchy	visual hierarchy was described	3

illustrate how these are used in mapping climate change and connect them to the vividness definition. For the sake of brevity here, I describe legend design, projections, symbolization, and layout as 'cartographic best practices' since these do not require the same amount of explanation as the other four elements due to their familiarity within the cartographic literature.

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. 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.

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 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 (Nelson, 2012). 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.

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 dataset that will capture all of this?"'

I argue that salience is connected to the concept of vividness through Guadagno *et al.*'s (2011) study which showed that vividness did have an effect on persuasion when the central figure (i.e. the most salient part of the content) was made vivid. Salience is also already an established term within cartography and is widely used to make maps which resonate with audiences. It describes how the visual variables are manipulated to give thematic data visual meaning in cartographic design through the use of contrast and hierarchy. Salience guides readers' attention in a way that the cartographer is able to then make a map and its content emotionally interesting, proximate, and concrete.

Visible change over time

Across the interviews, it was clear that visually representing change over time was a key component to making maps of climate change that were accurate and had an impact on audiences. While illustrating change over time is of course important to climate change, as one group of participants noted – a map of climate change

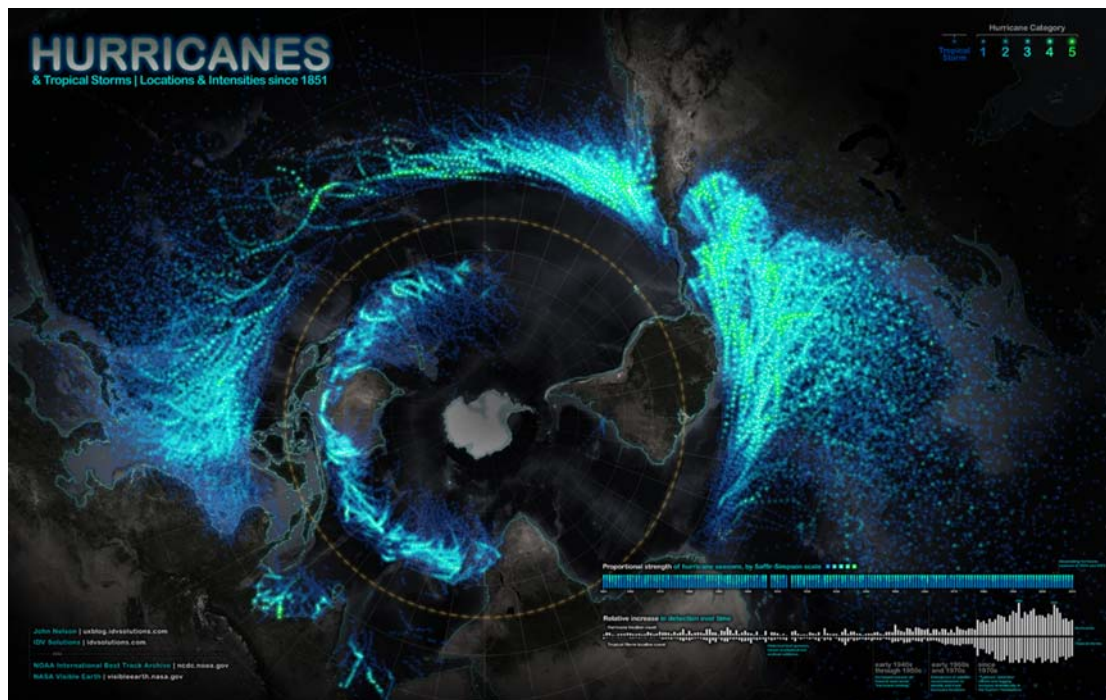


Figure 1. Map of hurricane and tropical storm locations and intensities since 1851 (Nelson, 2012). These data and a similar design were featured in the July 2013 issue of *National Geographic Magazine*. This map illustrates how cartographers elevate the thematic data in maps and push the basemap information back in the hierarchy.

must show change over time, I would also argue that most maps which matter need to illustrate time to make clear to audiences how our world is rapidly changing both socially and environmentally.

Maps which showed change over time as it relates to climate change illustrated (1) anomalies, or differences from 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 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.

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

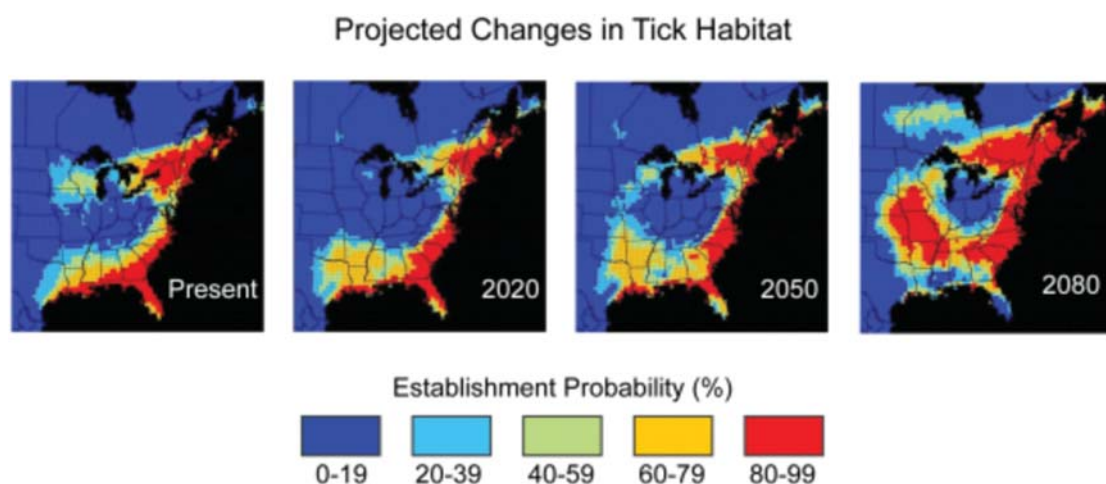


Figure 2. Map of a tick establishment probability in the eastern United States for the present and in 2080 (United States Global Change Research Program, 2014, Brownstein *et al.* 2005). This map illustrates one way in which to show change over time by illustrating potential future scenarios compared to the present situation as a set of small multiples.

single climate variables, such as precipitation and temperature (Figure 3). My participants did not spend much time describing these map designs, although nearly all of the organizations did make this type of map. They account for a larger percentage of the maps at government agencies than at media organizations.

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 2). These maps show snapshots of a location with an identical basemap design where the overlaying data illustrate 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]’.

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 Saunder 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.

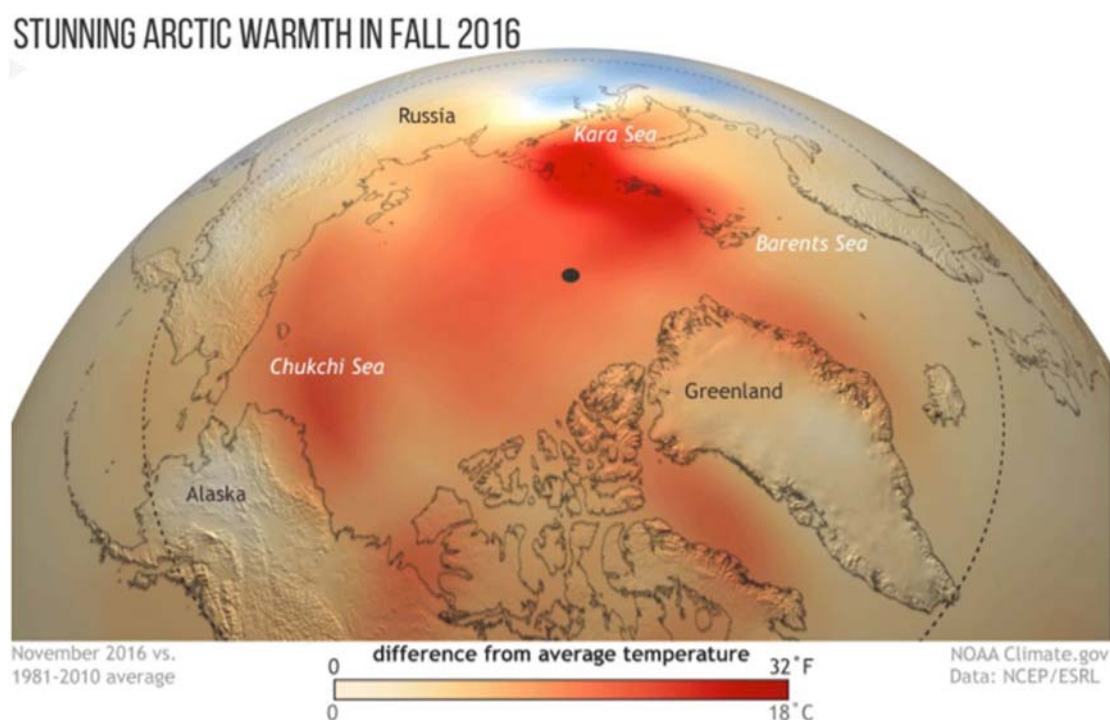


Figure 3. A change map which illustrates difference in average temperature by comparing the November 2016 average with the 1981–2010 average (NOAA Climate.gov, 2016).

Across the other organizations, 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 (NOAA's Climate.gov, 2016).

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 displays of change. At NOAA, interactivity in the form of time sliders were used extensively to allow map readers to interact with animations (e.g. Figure 4; NOAA's Climate.gov, 2018). 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. Nadja Popovich, graphics editor at The New York Times, also described making these decisions. She focused on one example, a piece called '95-Degree Days: How Extreme Heat Could Spread Across the World' which included two animated GIFs which illustrated the increase in 95-degree days around the globe under two scenarios: following the Paris pledges and if no action was taken (Plumer and Popovich, 2017). She said,

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.

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.

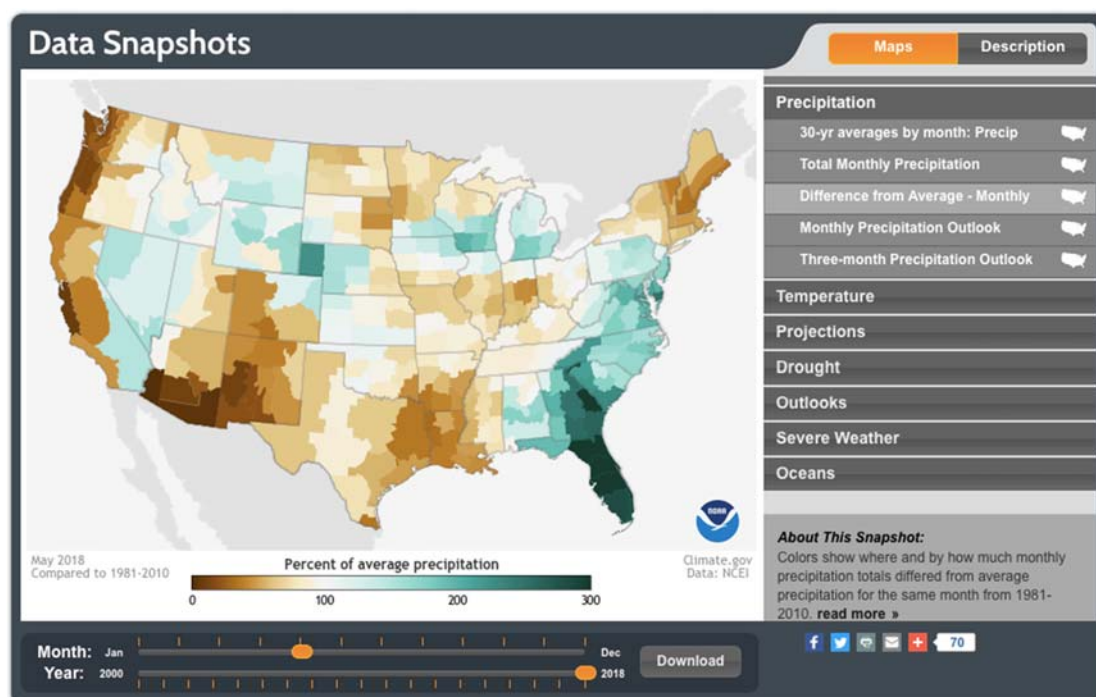


Figure 4. Map illustrating difference from average precipitation with a time slider at the bottom allowing the user to view change over time (NOAA's Climate.gov, 2018).

A key piece of the vividness definition relates to directing attention, exciting the imagination, and making topics proximate and concrete. Visibly illustrating change over time is one way in which to create this effect in maps and graphics. 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 (Fabrikant *et al.*, 2008). 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. In addition, many researchers have connected movement to attention in maps which suggests that animation is an important aspect of a vivid map.

Colour use: congruency and connotation

Across all of the interviews there were consistent comments about the use of colour. The general consensus was that the use of colour in the maps needed to align with the data in the map in two ways, by using colours schemes which aligned with (1) data measurement and structure ('analytic congruence'), and (2) connotations and emotion of the dataset ('affective congruence') (Anderson, 2018).

Analytic congruence

Participants often commented about 'analytic congruence' – the use of colour schemes and sequences which aligned with the underlying data and how it was structured. This aspect of the use of colour for statistical data has been tested empirically in cartography (Brewer, 1994; Olson and Brewer, 1997). My participants often talked about the three types of colour schemes established in this literature: sequential, diverging, and qualitative. They illustrated that this categorization was important for providing guidelines for the types [...] of colour schemes which are appropriate for different types of data, e.g. sequential colour schemes made sense to use when the data were ordinal, interval, or ratio, and diverging colour schemes were ideal when the data had a structure which diverged or had a meaningful midpoint.

Many of the participants spoke about making decisions about breakpoints in multi-hue (often diverging) colour 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 colour 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 colour 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 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 colour 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 colours,

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 colour ramps that have as many colours as you need to cover all seasons of the year into the past and the future.

Colour connotations and affective congruence

Participants also focused on the connotations of colour and the affectively congruent use of colour (Anderson, 2018). 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 colours which aligned with these colour 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 colour because that's a colour 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 colour and design and drive home that key point of this is warming up, this is melting.

Participants also spoke about 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, and 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 colour in an op-ed piece by Heidi Cullen titled ‘Think It’s Hot Now? Just Wait’ which showed a set of small multiples of three maps of the contiguous United States; the first map showed 1991–2010 temperature averages above 100 degrees, the second showed the same variable by 2060, and the third by 2100 (Wallace and Marsh 2016). The map used a colour scheme which started with a light grey and progressed through orange to red. In the 2100 map much of the southern part of the country was covered with the darkest red. Tim Wallace described how colour potentially played a part in the map’s going viral,

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 other cases, participants commented about how red was problematic. Meteorologists have been adding more colours 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 colours’ (Torregrossa, 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 colours 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 [*sic*] 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 [colour] palettes on top of [colour] palettes making these maps look really extreme [...]. They make their map look more extreme and it gets picked up [by other media]. Maybe those colours mean something to somebody, but it seems like the number of colours used has grown over time.

Colour is one of the key ways in which cartographers create emotional interest which is a key aspect of the vividness definition. Literature in the psychology and visualization fields illustrate that colours do have affective connections which may lead to emotional interest (e.g. Valdez and Mehrabian, 1994; Suk and Irtel, 2010; Bartram *et al.*, 2017). Cartographers have the opportunity to both align the data with a colour scheme (analytical congruence) as well as with colour connotations (e.g. blue for water, green for parks, and so on) and affective congruence, which is when colours in the map match the emotion inherent in the data (Anderson, 2018).

Cartographic best practices

My participants commented extensively on the use of cartographic best practices. The use of these best practices was intended to allow map readers to easily understand maps designed by my participants. Specifically, legend design, projections, symbolization, and layout were common themes. In this section, I briefly review how these conventions came up in conversations with participants.

Most of the government agency cartographers I interviewed described using style guides or templates to create consistent designs. The consistency across their maps made it obvious that the map had authority in its familiarity, similarity to other maps by the same source, and credibility in the data. One NASA visualizer described their style guide:

We have a style guide that describes our font, what size to use, colours 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, we have very specific settings for those. We have a section on establishing a visual hierarchy [...].

At media organizations, one might describe their use of best practices as ‘once you know the rules, you know how to break them’. Following a particular style was less consistent than at government agencies. Layout, for instance, 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, were mentioned as a way to reduce complexity for the reader at both media and government agencies. Cartographers worked with copy editors to identify wording for the title and symbol 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.

Participants described projections as not being obtrusive or in any way taking away from the design of the map. 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 highlight the data in a particular way.

Tyner's work on persuasive cartography 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 past 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 (e.g. Slocum *et al.*, 2009; Brewer, 2016) which drives the usage of these cartographic best practices described here.

Novelty

Finally, my participants 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. One notable exception was the NASA Scientific Visualization Studio group which used 3D and oblique views along with animation to create compelling videos. Figure 5 is a screen capture of one of their most republished animated maps (Putman *et al.*, 2014). In contrast, the Earth Observatory group members I interviewed shied away from these novel designs because they had to produce maps and graphics quickly, wanted their maps to be shared easily and needed all their maps to have a similar design.

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 moulds 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 and in comparison, to most media and government agencies, human and financial resources were less constrained at The Times. 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

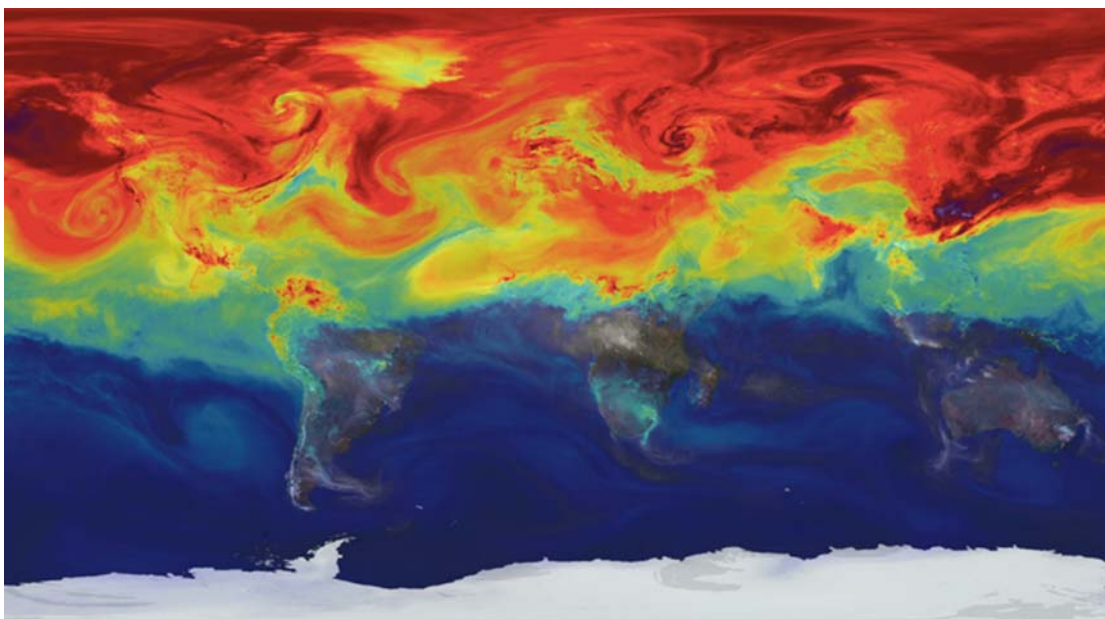


Figure 5. Screenshot of circulation of carbon dioxide in the atmosphere (Putman *et al.*, 2014). This is an animated map which shows how, over the course of a year, CO₂ circulates around the globe.

used to dip below cloud cover to collect data previously unavailable following climate-related disasters, or to create cinematic shots by doing dives or quickly zooming out from a location to give geographic context of a place. 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, [Haner, the photographer] is 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 (Figure 6; Buchanan and Watkins, 2015). In this particular map, by scrolling the reader is zoomed closer and closer to areas of melting on the Greenland ice sheet. As Derek Watkins explains:

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. Drawing from Archie Tse (2016) who called for simplifying interactions for users, this piece removed complicated interactivity to creating interactive maps which relied only on user scrolling. 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 these interactive graphics. In addition, increasingly articles and graphics are explored on smartphones and other touch-screen devices. The scrolly-telling design allowed mapmakers to grab attention by adding transitions to their designs without asking their audiences to search for buttons.

Graphics editors at The Times used these novel designs 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'. Her piece titled, 'Mapping 50 Years of Melting Ice in Glacier National Park' (Popovich, 2017) simply showed polygons of the glaciers in Glacier National Park in 1966 overlaid by polygons of the glaciers' extent in 2015 (e.g. Figure 7). While the actual design was simplistic and required less data, Popovich indicated that it 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 than they might normally see.

On the more complex and novel technology side of mapmaking, 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 focus 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 specific audiences are perhaps looking for these types of highly interactive and immersive experiences. Other climate change communication groups such as the Computational and Information Systems Lab (CISL) at the National Center for Atmospheric Research (NCAR) have also investigated how to make science accessible through AR as this technology becomes more affordable.

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.

In information visualization, novel designs have been shown to be interesting and more memorable (Borkin *et al.*, 2013; Borkin *et al.*, 2016). These novel designs stand out in our minds. In the same way, novel designs in maps are perhaps more memorable through their distinctiveness (Tom and Tversky, 2012), and allow map readers to immerse themselves in a place which provokes imagery in the map reader or makes the topic more

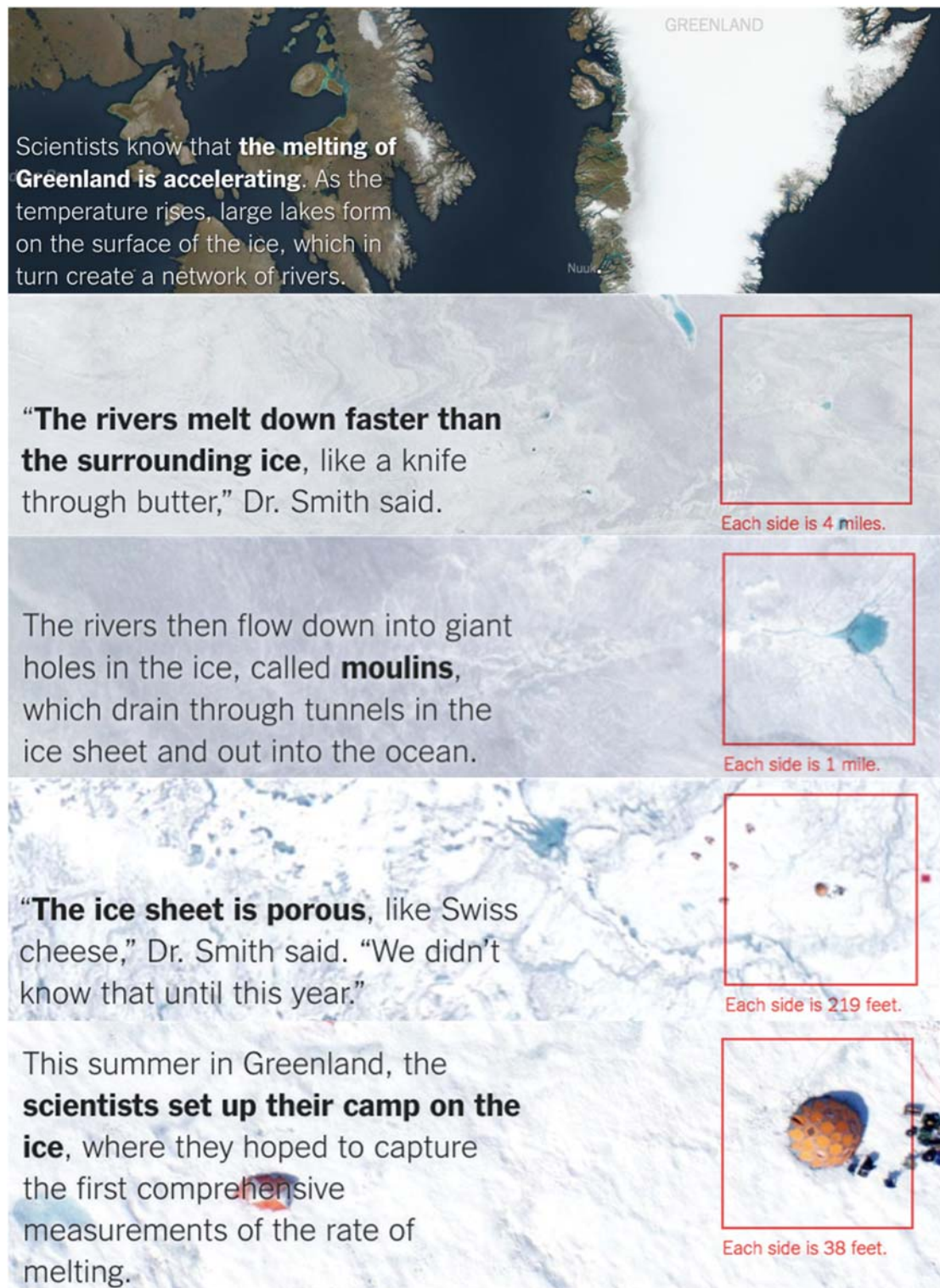


Figure 6. Screenshots from the Greenland is Melting Away interactive map piece (Buchanan and Watkins, 2015). Map readers scroll down the page and are zoomed closer to the ice sheet. From *The New York Times*. © 2015 The New York Times Company. All rights reserved. Used under license.

proximate by bringing a topic closer to a map reader’s lived experiences. Finally, some of these new technologies (e.g. AR/VR, drones) also provide more concrete images of these distant and abstract concepts to bring topics to life.

Conclusions

In this paper, I have presented elements of a vivid map. The concept of vividness adds to cartographic literature and expanding research on persuasion in cartography by creating a set of elements to employ in map design to create a



Figure 7. Approximation of the way Nadja Popovich created the graphics for 'Mapping 50 Years of Melting Ice in Glacier National Park' (map design by the author).

compelling map. These elements can be used by cartographers to create a vivid map and by researchers to evaluate a map for potential persuasiveness. The vividness definition by Nisbett and Ross (1980) provided a format by which to evaluate elements of map design that cartographers are already using to create compelling potentially persuasive maps. These elements of a vivid map are: (1) visual salience, (2) visible change over time, (3) emotionally and data congruent colour, (4) legend design, (5) projections, (6) symbolization, (7) layout, and (8) novel designs which bring readers closer to far away topics. This concept of vividness allows us to identify maps which are potentially influential especially in an age where drawing attention to maps is vital for communicating complex topics such as climate change. The set of vivid map elements will allow cartographers to create emotional interest and bring distant topics to life.

A vivid map balances the art and science of cartography to create a compelling means by which to convey information about the dynamics of our environment and society. These maps need to follow cartographic conventions, illustrate change over time, make key data salient, use colour 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 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. I would also argue that vivid maps have always existed, but what makes them vivid changes over time as novel designs and fashions change within cartography.

Future research would benefit from evaluating the extent to which a larger array of maps used these elements and empirically testing the impact of vivid map designs on persuasion. The maps of climate change included in this study provide compelling examples of cartography designed to persuade a diverse audience. Subsequent research could evaluate the extent to which their salient elements are used in a wider range of maps and designers. Second, this study illustrated the elements of a vivid map, but a larger question remains about whether these maps are indeed persuasive as the vividness literature suggests. 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 or donating money towards the cause represented.

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