Advanced Review

Climate change and visual imagery

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Many actors—including scientists, journalists, artists, and campaigning organizations—create visualizations of climate change. In doing so, they evoke climate change in particular ways, and make the issue meaningful in everyday discourse. While a diversity of climate change imagery exists, particular types of climate imagery appear to have gained dominance, promoting particular ways of knowing about climate change (and marginalizing others). This imagery, and public engagement with this imagery, helps to shape the cultural politics of climate change in important ways. This article critically reviews the nascent research area of the visual representations of climate change, and public engagement with visual imagery. It synthesizes a diverse body of research to explore visual representations and engagement across the news media, NGO communications, advertising, and marketing, climate science, art, and virtual reality systems. The discussion brings together three themes which occur throughout the review: time, truth, and power. The article concludes by suggesting fruitful directions for future research in the visual communication of climate change. © 2013 John Wiley & Sons, Ltd.

How to cite this article:
WIREs Clim Change 2014, 5:73–87. doi: 10.1002/wcc.249

INTRODUCTION

Visual images are everywhere in the portrayal of climate change. They appear in the media, in scientific reports, and in NGO and governmental campaigns, and they are created by artists. Yet despite the ubiquitous nature of climate imagery, scholars in sociology,[1] geography[2] and communication studies[3] have all called attention to the lack of research investigating climate visualization. This is an area of nascent scholarly interest, which this article elucidates. This review examines image representations: visual images which have physical form (e.g., through television, adverts, Facebook pages, films, photographs, paintings, scientific figures) that act to shape the production and (re)making of meanings about climate change. This review does not focus on mental imagery, though this area is briefly outlined in Box 1.

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Conflict of interest: The authors have declared no conflicts of interest for this article.

Image Qualities

Images have several qualities that aid in information exchange: they can draw viewers in through vivid and emotive portrayals,[4] they aid in remembering information,[13] and (providing audiences share cultural references which allow them to decode the image), they can transcend linguistic and geographical barriers.[14] Images hold three communicative qualities which differ from text.[15] First, images are analogical—that is, images are interpreted based on similarity, whereas words rely on social convention. For example, the word 'sun' looks nothing like the sun. To be able to understand the (written or spoken) word 'sun' requires knowledge of the social conventions that make up the English language. But a photograph of the sun bears a close resemblance to the thing it represents. Second, images lack an explicit propositional syntax. Whereas verbal language uses precise syntactic devices to make propositions or connections, visuals cannot do this, so other (loose, imprecise and unsystematic) cues need to be used instead.[16] For example, a text can easily represent the sequence of an event: 'climate science projections predict hotter summers by 2050'. To communicate this in visual form may require a series of images (perhaps a scientist at a computer, a close-up of a scientific map of climate model output, an

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BOX 1

THE IMAGES IN OUR HEADS: AFFECTIVE IMAGERY

This review treats imagery as 'external': images are physical visual depictions. A growing body of work also investigates the representations and role of mental imagery of climate change—the visual imaginations people hold. These mental images can mirror common visual media representations of climate change, demonstrating the power visual imagery has to position peoples' engagement with climate change.[4,5]

Risk perception researchers have investigated the mental images people associate with climate change by focusing on the role of 'affect' (the emotional quality of 'good' or 'bad') to understand how people process information and make decisions about risk.[6] Affective imagery analysis has been employed to explore the affective dimensions of public perceptions of climate change risk. Affective images, defined as 'sights, sounds, smells, ideas, and words, to which positive and negative affect or feeling states have become attached through learning and experience',[7] are explored using word association tasks to identify the mental representations and associated feelings publics spontaneously associate with the issue.[8]

Nationally representative surveys in the United States indicate that common mental imagery associated with 'global warming' in the United States includes melting ice impacts, references to rising temperatures, and impacts on nonhuman nature.[9,10] This mental imagery has changed over time, with an increase in skeptical associations 2002 to 2010; and a decrease in associations between climate change and the hole in the ozone layer.[11] A similar study carried out in the United Kingdom (but using the term 'climate change' rather than 'global warming') found the most common mental imagery to be related to 'weather', rather than ice or increasing temperatures.[12] However, Common to all these studies was that image associations evoked negative affect ratings, indicating that the issue has negative connotations for both Americans and Britons.

image of the Sun) to imply a similar causality—though note how this image sequence may be interpreted in different ways (perhaps, 'science experiment will alter the Sun's output'), as the visual cues are loose and imprecise.

Last, images in general, and photographs in particular, are indexical—they come to be seen as a direct representation of reality, rather than viewed as a particular version of reality framed in a particular way. This can mean that images, and especially photographs, come to be seen as 'speaking the truth', rather than as normative statements portraying a particular way of seeing the world.[17] An example of how this can be easily forgotten is exemplified in the controversy over an editorial decision to display a (Photoshop altered) polar bear image alongside a letter from climate scientists ('Climate change and the integrity of science') in the journal Science. An outcry occurred following the finding of the Photoshop altered nature of the image, especially in juxtaposition to a letter about scientific integrity.

These qualities demonstrate that any image can be subject to multiple readings, and thus any one image can be subject to multiple (and potentially competing) understandings. For example, the famous Apollo space photographs have become iconic through two very different readings of the same images. 'Whole-earth' readings view the Apollo images as an environmentalist conception of quasi-spiritual interconnectedness between land and life; whereas 'one-world' readings see the images representing secular mastery of the world and the spread of a specific socio-economic order across space.[18] Even if visual meaning appears so self-evident as to be 'naturally' given, this is simply a product of the visual being so widely distributed and understood within a culture that it is no longer recognized as being socially constructed.[19] As Hall[19] says in discussing text, there is 'no degree zero in language', and the same can be said of visuals, however self-evident the visual reading appears to be.

Encoding and Decoding in Visual Communication

This review draws upon the encoding/decoding model of Stuart Hall.[19] Hall conceptualizes the communications process as an on-going circuit or loop, where three distinct but interlinked 'moments' can be described. There is no beginning or end to this loop; each moment is necessarily informed by and situated in what has gone before, both in terms of material artifacts and social relations. This review concentrates on part of the mediation of climate change: visual images (in their many forms), and their production and consumption. We therefore broaden the use the encoding/decoding model from its original televisual origins, to encompass all climate visual mediated interactions.

The review is structured around the three moments of the communications cycle. It draws from several sources[19–22] to examine:

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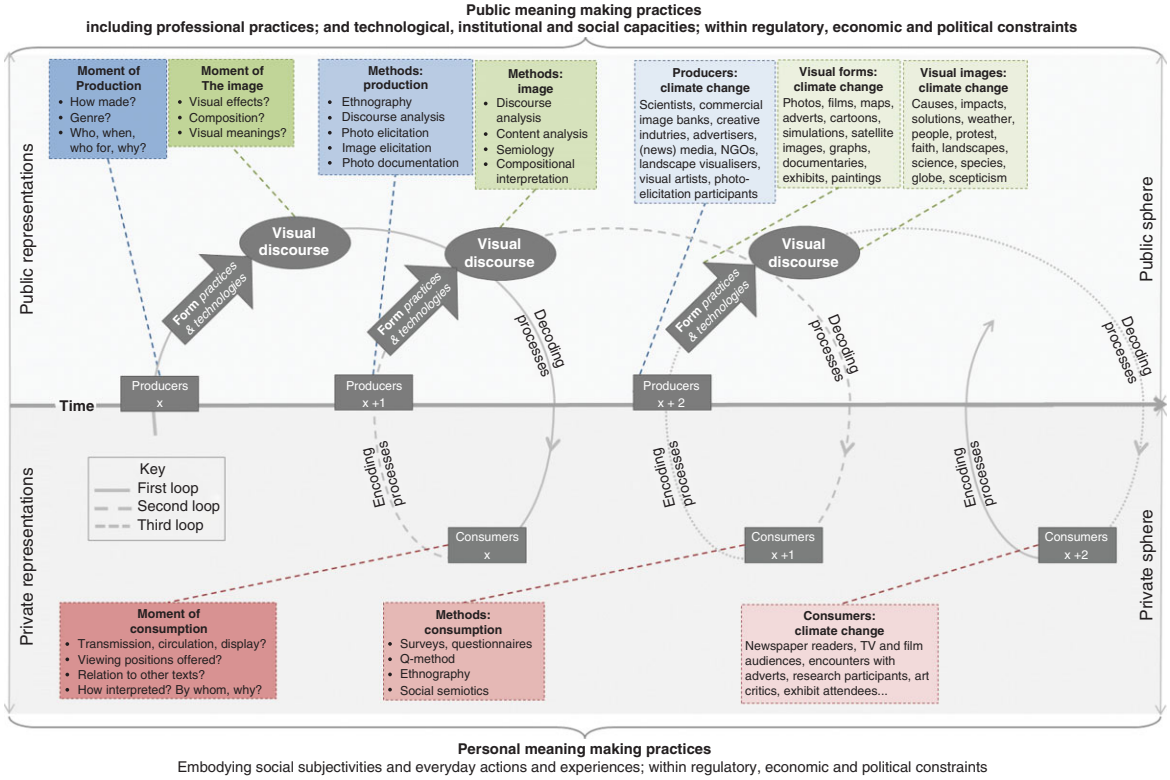

FIGURE 1 | The three 'moments' for climate visuals within the communications cycle: the moment of production (blue), the moment of the (visual) text (green), and the moment of consumption (red). Each loop describes a particular component of the cycle, with the first loop identifying the questions of the communications process that may be asked at each moment (darkest shade); the second loop outlining the methods that may be used to answer such questions (mid shade); and the third loop the types (of producers, visual images, consumers) that can be seen in each moment (lightest shade). Although the schematic starts with the moment of production ('producers x' box), note how any point on this circuit can be a starting point, informed of by what has previously occurred.

- the moment of production (the conditions and practices that lead to a form of visual appearance);
- the moment of the (visual) text (the particular construction and arrangement of the visual, itself the product of the practices and technologies employed: note the term 'text' is used to emphasize that images are actively read by consumers, even if their reading seems self-evident); and
- the moment of consumption (readers drawing upon available cultural competencies to 'make sense' of and realize into coherent meaning the visual image).

Figure 1 shows this cycle in schematic form. Although the schematic starts with the moment of production ('producers x' box), note how any point on this circuit can be a starting point, informed of by what has previously occurred. Each moment in Figure 1 has an attached color-coded descriptive box, so that boxes at the moment of production are blue, at the moment of the image are green, and at the moment of consumption are red. Each loop of the cycle starts (arbitrarily) at the moment of production, to encompass the moment of the image, through to the moment of consumption. Each loop describes a particular component of the cycle, with the first loop identifying the questions of the communications process that may be asked at each moment; the second loop outlining the methods that may be used to answer such questions; and the third loop the types (of producers, visual images, consumers) that can be seen in each moment. Note that each complete loop is shaded differently, with dark shades for boxes identifying the questions at each moment, mid-shades for the methods boxes, and light shades for type boxes.

Figure 2 focuses in on the three moments of the visual communication cycle, and places the literature drawn upon for the review within one (or more) of these moments. The color shading is as for Figure 1 (moment of production in blue, moment of the image in green, moment of consumption in red).

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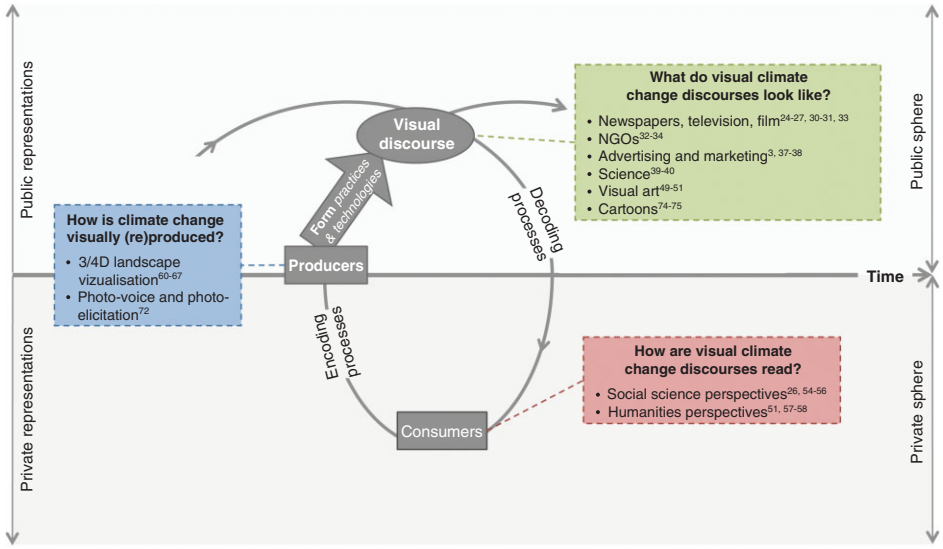

FIGURE 2 | A focus on the three moments of the visual communication cycle, placing the literature drawn upon for this review within one (or more) of these moments. The color shading is as for Figure 1 (moment of production in blue, moment of the image in green, moment of consumption in red).

This review synthesizes a diversity of work exploring climate change imagery—from corpora including the news media, NGO communications, advertising and marketing, scientific imagery, artist-created imagery, to landscape visualizations under climate projections. While some of these corpora overlap (e.g., advertising imagery can be found in newspapers; NGO imagery may be seen on television), we discuss image types based on how research projects to date have approached analysis (e.g., research on newspapers has so far only examined climate images attached to news stories, and not explored newspaper adverts; analysis of NGO imagery has focused on static campaign photography, and not televisuals). The review starts by exploring literature at the moment of the image, as there is a growing body of research emerging here (there is less research investigating the moment of climate image consumption, and still less at the moment of climate visual production). We then bring together the diverse literature examined with a synthetic discussion of three key themes (time, truth, and power) arising in all three moments. We conclude by suggesting a number of fruitful areas for further research in this rapidly evolving field.

THE MOMENT OF THE VISUAL TEXT

This section brings together research which has examined the moment of the (visual) text. The studies reviewed explore many of the components outlined in Figure 1—questioning the visual effects employed, image composition, and visual meanings within imagery. The studies generally use content analysis and/or (visual/critical) discourse analysis; some also draw on semiology and compositional interpretation. This section explores a diversity of visual forms and image types, including: the news media, NGO communications, advertising and marketing, scientific imagery, artist-created imagery, and landscape visualizations. It speaks to the green box in Figure 2, answering:

What Do Visual Climate Discourses Look Like?

Newspapers, Television, and Film

There has been a growth in scholarly interest in the visualization of climate change, particularly through the examination of visual images in newspapers and news magazines. Studies have examined newspaper imagery in the United Kingdom,[5,23] Canada[24,25] and the United States.[26] Comparative work examining imagery in US, UK, and Australian newspapers has also been carried out.[27] Many of these studies first use a content analysis to identify major thematic trends in the image data, before an in-depth reading of themes or iconic imagery is undertaken.

Several themes emerge from these content analyses. First, there is both a considerable quantity and a diversity of climate change imagery in newspapers. DiFrancesco and Young[24] identify 100 images from articles substantively about climate change over a six month period during 2008 from two Canadian newspapers; Smith and Joffe[5] analyze

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188 images taken from UK Sunday newspapers in their 2000–2006 sample; and O'Neill[27] analyses 1603 images from 13 Australian, UK, and US newspapers throughout 2010. These studies find that climate images depict identifiable people (most often politicians, but also scientists, citizens, business leaders, and celebrities), the causes of climate change (such as through iconic images of 'smokestacks'), climate impacts at home and abroad, and graphical or scientific representations of climate change.

Second, the personification of climate change is a major theme in climate visualizations. Both DiFrancesco and Young[24] and O'Neill[27] find images of people dominated coverage; with 66% and 48% of coverage respectively (though note O'Neill single-coded images, whereas the content analysis codes in DiFrancesco and Young are not mutually exclusive). Hespanha[26:340] comments that images focusing on people were 'unexpectedly common' in her US sample of newspapers and news magazines, accounting for around 30% of all images. Smith and Joffe[5] found reasonably high levels of imagery depicting people, with a statistically significant trend towards higher levels of people pictured in tabloid, rather than broadsheet, newspapers. Third, many of these images of people depict politicians, though this varies cross-culturally. The highest levels of visuals coverage of politicians is found by O'Neill[27] in Australian newspapers, at 43%. Considerable, though lower, levels of political figure visual coverage is also found in the United States[26,27]: 20% and 18%, respectively and the United Kingdom[27]: 13%.

Fourth, climate impacts are very visible, particularly in the United Kingdom. Smith found climate impacts gathered the highest coverage of any image type, at over 50%. O'Neill[27] found rather less impacts coverage in the United Kingdom, though still a reasonably large proportion at 23% of coverage. A diversity of impacts is featured by newspapers, including impacts on species, and for polar and glacial landscapes, agriculture, sea-level rise, drought, and forest fire. The United Kingdom is particularly interesting in featuring a significant proportion of visual coverage of polar or ice imagery, something not found in either the United States or Australia.[27] Much of the imagery depicts impacts on nonhuman nature, contributing to the perception of climate change as a remote issue unlikely to have personal implications.[26,27] Last, images of climate mitigation or adaptation are depicted only rarely, or are notably absent: less than 7% of coverage in UK, Australian, or US newspapers pictured adaptation or mitigation,[27] and only 5% of images depicted green technology in the Canadian study.[24]

Last, there appear to be differences in how particular newspapers visually frame climate change news. In UK newspapers, Smith and Joffe[5] found broadsheet newspapers were more likely to depict climate impacts, and use graphical representations, than tabloid newspapers. However, tabloid newspapers were more likely to feature images of people. In the comparative UK, US, and Australian newspaper study, no statistically significant relationship was found between broadsheet/tabloid newspapers, but a statistically significant relationship was found between newspaper ownership and the climate visuals portrayed[27]; with newspapers owned by News Corporation significantly more likely to use imagery of people ($P < 0.01$), and for the people portrayed to be political figures ($P < 0.05$, rather than scientists, celebrities, business leaders, or others). Newspapers under any other ownership were statistically more likely than those owned by News Corporation to use visuals of climate impacts ($P < 0.1$). Taking this evidence together with that from a frame analysis, O'Neill concludes that two visual frames are prominent, a 'contested' visual frame and a 'distancing' visual frame; with Australian newspapers, and those owned by News Corporation, particularly relying on the 'contested' visual frame.

Many of these newspaper image studies reported here take the individual image as their unit of analysis. While there are practical reasons for doing so, these types of analyses fail to account for other influences on how newspaper images may be interpreted. DiFrancesco and Young's Canadian study is particularly enlightening for the way it focuses on both imagery and texts, and the interplay and interactions between these two communication devices within a newspaper article. They find a 'profound disjuncture'[24:517] between images and text in climate change newspaper coverage, with visual and linguistic coverage pulling in different narrative directions.

Climate change is increasingly portrayed through visual means on television, with high-profile examples including the Hollywood blockbuster The Day After Tomorrow[28] and Al Gore's An Inconvenient Truth,[29] as well as more 'everyday' encounters through television news. The role of the documentary image is examined in the context of the documentaries An Inconvenient Truth and The Great Global Warming Swindle and their associated legal and regulatory challenges by Mellor.[30] This work sheds light on the problematic nature of indexicality[17] in climate change visuals. Mellor asserts that there is controversy over the perceived accuracy these films expressly because of the lack of attention paid to the films' visuals. Mellor explains how science documentary films specifically aim to persuade viewers by establishing trust through

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their indexicality in two different ways: first, through establishing a contract between viewer and filmmaker in which the viewer accepts the truthfulness of the films visuals—this event happened, in this way, in this place (even though they may dispute the filmmaker's overarching narration or argument); and second, through the acceptance of the subject matter as science-based and therefore grounded in scientific ideals of organized skepticism and empiricism.

Television news images are examined by Lester and Cottle,[31] using news broadcasts from the United Kingdom, United States, Australia, South Africa, India, and Singapore. This study is especially enlightening as it does not examine climate change in isolation, but instead compares climate representations to a broad range of risk issues including trade, migration, the war on terror, cultural identities, human rights, and broader (nonclimate change) environmental risk issues. Three categories of news visuals were found across the sample: iconic visuals purporting to represent what was discussed (e.g., an image of a flooded Pacific island reporting a story about the impacts of sea-level rise on a community); symbolic visuals representing broader themes beyond the literal meaning of the image (e.g., an image of 'smokestacks' when reporting news about industrial air pollution) ; and spectacular visuals which were seemingly deployed to encourage strongly affective responses such as awe and dread (e.g., visuals that focused on the destructive force of extreme weather events). Climate change visuals dominated over all the risk issues examined in terms of the symbolic and spectacular visuals deployed, with almost 52% of coverage falling in one of these categories. This was over 10% higher than any of the other global risk issues surveyed. So, little climate change coverage (compared to other global risk issues) used iconic visuals directly representing what was discussed.

Lester and Cottle also explored the visual rhetoric devices used to portray climate change, finding powerful symbolic messages of the seriousness and consequences of human-caused climate change prominent.[31] Television offers the opportunity to portray multiple visuals in sequence, which allows an element of storytelling and comparison (unlike static visuals, such as those in newspapers). So for example, Lester and Cottle found devices such as panning shots (from a crowded street outwards to a depleted glacier; or from a city street back to an industrial and urban landscape of smokestacks under a darkening sky) were used to locate viewers to places and peoples threatened by climate change under multiple spatial scales; and to emphasize the seriousness and consequences of climate change to everyday life.

Non-Government Organizations

Non-Government Organizations (NGOs) have long recognized the importance of visual images as communications tools. Dominant visual tropes in climate change campaigns include the documentation of environmental damage, and of nonviolent direct action[32] and the portrayal of development and vulnerability.[33]

Much of the in-depth analysis in this area has been carried out by media studies scholar Julie Doyle,[32,34,35] focusing on the visual portrayal of climate change by the environmental NGO Greenpeace in the United Kingdom. Doyle[34] documents the changing nature of environmental NGO communications through a detailed examination of the visual tropes employed by Greenpeace. She finds five distinct phases in evidence between the publication of the first Intergovernmental Panel on Climate Change (IPCC) report and 2007, illustrating an evolution of climate change campaigning imagery.

The first distinct phase began in 1994, as Greenpeace sought to endow climate change with symbolic meaning through its publication 'Climate Time Bomb: Signs of Climate Change from the Greenpeace Database'. This first phase is characterized by visuals which established the dangers of a warming world, by presenting the future as imminent catastrophe. Visuals borrowed from the visual lexicon of nuclear catastrophe (e.g., visualizing a rising sun in the form of a mushroom cloud atomic bomb shape), and used the color red to symbolize heat and danger. Phase two (1997) found Greenpeace shifting attention to the causes of climate change, and to its potential future solutions. Climate change was made more meaningful to a UK audience by depicting habitats and wildlife in the Atlantic as victims of climate change. Phase three (1997–1999) began with the publication of a photograph depicting a crack in the Larsen B ice shelf in Antarctica. Greenpeace used this image as a way of 'bearing witness' to climate change, and as visual evidence for a warming world. This period saw a focus on the fragility of the polar regions, though it also saw use of solutions imagery depicting renewable energy images. Phase four (2001–2003) saw another distinct shift in visual coverage, away from bearing witness of climate impacts, and towards a focus on the geopolitics of oil. For example, campaign images in phase four concentrated on making links between 'dirty oil and dirty politics', casting Esso and George Bush as villains. Last, phase five (2002–2007) saw a return to the visual trope of melting glaciers, and the (problematic) use of images to bear witness to climate change.

Greenpeace rely heavily on the indexical nature of photographic images as a way to bear witness to climate change, with photographs relying on a

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visual decoding which sees visualized landscapes as representations of (threatened) nature. This theme of 'bearing witness' is also found in other NGO imagery, where people are 'self-consciously' placed at the center of extreme weather events.[33] Doyle[32] describes the portrayal of time, and change, in Greenpeace visual campaigning, through the use of paired images of glacier (and their retreat). She maintains that these paired visuals are problematic, in that although they may provoke feelings of nostalgia, irretrievable loss, and shock, they also act as visual symbols of climate change made evident and thus a failure to prevent action.

Advertising and Marketing

From Toyota's Prius car, to Tesco's 'If it's not dirty, wash at 30' campaign, there is competitive advantage gained from being perceived as a company concerned about climate change.[36] A key element in such strategies relies on the use of imagery to engage the consumer. The ''Green Collection'' released by Getty Images in 2008, e.g., supplies stock photographs depicting green and environmental issues for use in advertising and promotional material. An online database allows customers to enter search terms and select images that best suit corporate needs and branding requirements. Hansen & Machin[3] conducted a content analysis of 600 images from this collection using search terms ''environmental and climate change''. Results revealed striking similarities between pictures. Locations were not specific, nor bound to a particular time period and people were portrayed as types rather than individuals. The authors argue that this attempt to recontextualize the issue away from naturalistic imagery towards conceptual imagery is unhelpful, in that it distances consumers from the everyday reality of the issue.[3]

Visual marketing strategy companies have used various visual devices to link their product with the issue of climate change. For example, energy and automotive companies run ad campaigns claiming to provide the highest fuel efficiency, by using images of green and scenic landscapes. Others take a more alarmist approach using a sense of urgency to engage consumers emotionally. One example the Yale Forum study provides is for an energy company who use the image of a globe encased within a stopwatch counting down time with tagline 'Global warming demands action: we're not waiting'.[37] Some companies have even used imagery to parody the issue. Linder[38] provides an illustration citing imagery a clothing company has used to advertise a winter coat. A male model with facial expressions of annoyance is depicted wearing the coat with tagline 'if the effects of global warming are everywhere, why is my flat so cold?' Research is required to test the efficacy of these various campaigns, but they demonstrate how climate change visuals can provide powerful visual tropes for marketing and advertising.

Science

There is a growing academic interest in the visualization of climate science, principally through the work of art historian Birgit Schneider.[39,40] Schneider notes the work of climate science cannot be done without the work of visualizations, as scientific images arising from climate model simulations (e.g., the maps, figures, and graphs used to illustrate the IPCC reports) are essential to be able to communicate climate data.[40] Scientific images have to act towards multiple goals—as mission statements, scientific evidence, guidelines for action and yet still appeal to esthetic values. Scientific visualizations of climate model data (e.g., the now iconic image of the globe turning red) can become banal, almost everyday images. And although scientific images may aim to 'follow the ethics of science', they also carry with them 'narratives of fear, symbolism, and common myth'.[40 :189] So the apparent simplicity of scientific images hides their immense complexity, not only in terms of data reduction, but it also by obscuring their position as value-laden objects which portray claims to truth.

The contestable nature of scientific images, despite their origins in positivist science, is illustrated with reference to the now iconic hockey stick graph image. This image plots 10 palaeoclimate record temperature reconstructions over the past millennium (Figure 3). The graph's name refers to the temperature projections which, after remaining relatively stable over the millennium, increase dramatically after the industrial revolution begins, like the blade of a hockey stick. This graph shape has the potential to induce a range of emotions; from punishment to impending apocalypse.[39] The image gained notoriety after it was printed in the 2001 IPCC Summary for Policymakers as climate scientists (particularly Michael Mann) clashed with those skeptical of anthropogenic warming about the presentation of the data in the graph (particularly Michael McIntyre[41]). The image became something of a synecdoche for the increasingly politicized nature of climate change science. The magazine Scientific American claimed 'take down Mann [via the disputed image], it seemed, and the rest of the IPCC's conclusions about anthropogenic climate change would follow'.[42:34] Controversy has also followed other ostensibly 'scientific' images, such as Al Gore's graphic representation of carbon dioxide emissions,[43] and of the IPCC's 'burning embers' diagram.[44]

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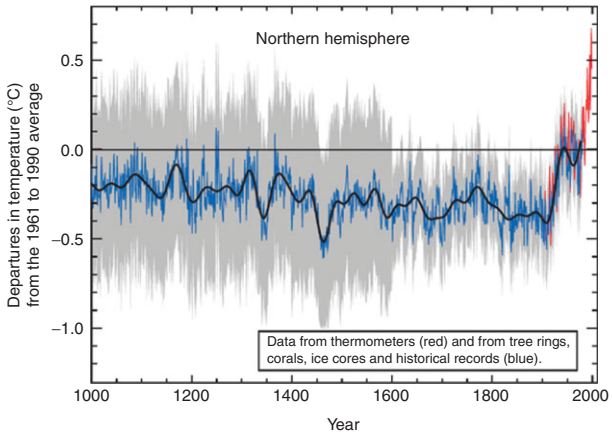

FIGURE 3 | Scientific images are not value free—this image has caused much controversy for the IPCC. © IPCC (2001:3). Original caption: Variations of the Earth's surface temperature for the past 1000 years. The year by year (blue curve) and 50 year average (black curve) variations of the average surface temperature of the Northern Hemisphere for the past 1000 years have been reconstructed from 'proxy' data calibrated against thermometer data (see list of the main proxy data in the diagram). The 95% confidence range in the annual data is represented by the gray region. These uncertainties increase in more distant times and are always much larger than in the instrumental record due to the use of relatively sparse proxy data. Nevertheless the rate and duration of warming of the 20th century has been much greater than in any of the previous nine centuries. Similarly, it is likely that the 1990s have been the warmest decade and 1998 the warmest year of the millennium. [Based upon (a) Chapter 2, Figure 2.7c and (b) Chapter 2, Figure 2.20, see http://www.ipcc.ch/ipccreports/tar/wg1/005.htm].

But scientific images do not only visualize the past. Climate science images, perhaps more than any other type of climate imagery, have the aim of projecting possible futures. In visualizing particular futures (using particular visual tools such as the use of the color red to indicate heat—but it is also a visual trope which implies danger and even apocalypse), scientific images create a contingent global reality. Climate science portrayed through images draw boundaries around what is normal,[39] and thus help to define what is seen as politically, socially, and economically acceptable.[45] As such, climate science images act as political objects. Schneider[40] concludes that the specific nature of climate science images is due to their intention to prevent what they show: while the creator of the image may intend to display rational, representative, and logical scientific data, such images also generate meanings and affective responses to the actual image portrayed.

Visual Art

Beyond scientific and mass media understandings of climate change, the issue has started to have influence within wider cultural and artistic spheres. Of course, such artistic representations range beyond the visual image, and so go beyond the scope of this review (Refs 46, 47 engage with some of these broader themes). Artistic endeavors are thus discussed briefly here.

There is an increasing number of artistic endeavors that seek to engage with climate change.[48] For example, the Cape Farewell project has brought together artists, scientists, and communicators to engage the public about the urgency of climate change.[49,50] The project leads expeditions to the Arctic to inspire invited guests to develop artwork representing a changing climate. TippingPoint is another international effort using art to promote engagement and awareness of the climate change. With the aim of 'energizing the creative response to climate change', TippingPoint organizes open space gatherings across the world for art and science to collaborate. Climate change has also been the focus of artistic exhibitions. 'Heat: Art and Climate Change' was an exhibition at the RMIT University art gallery in Melbourne, showcasing artists interpretations of climate change. 'Weather Report: Art and Climate Change' is another example where images have been used to explore potential climate change impacts. Housed at the Boulder Museum of Contemporary Art in Colorado, this exhibition included images of digital art that visualized extreme projections of climate impacts in the United States, Bangladesh, and Darfur. Dunaway argues that these sorts of visuals introduce questions of class, power, and justice that can be missing from mainstream climate discourse.[51] Last, some projects have used art as a form of creative activism or 'artivism'. For example, '350 Earth' (launched by www.350.org) uses art to generate support for a global climate movement. Creating artwork, large enough to be seen from space, 350 Earth calls on politicians to take action while demonstrating global public support and commitment for dealing with the issue. Little research has explored the types of visual discourse arising from these sorts of projects.

THE MOMENT OF CONSUMPTION

Social science and humanities researchers have both started to explore this area, though many research gaps remain. Social science studies have used surveys, questionnaires, and Q-method to empirically examine how particular audiences engage with particular visuals. Ethnography is another potential method at the moment of consumption (see Ref 22). Humanities researchers have critically engaged with climate change visuals, particularly in terms of artistic representations. They seek to answer:

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How Are Visual Climate Discourses Read?

Social Science Perspectives

Research in this area to date has largely focused on understanding peoples' engagement with mass media visual imagery. Visual representations arising from news media discourses represent an important part of how people construct meaning about climate change.[2,52] This is not to say that audiences act as a passive receptor on whom the media 'work their magic',[52,53] but that the media offers an array of interpretative packages, including through visual images, which help people conceptualize an issue.[52]

Research investigating how visuals arising from news media are read appears to show some consistency (at least in the US, UK, and Australian cohorts participating in research to date) in whether climate change images invoke negative or positive emotions. Hespanha[26] reports that climate images presented generally provoked negatively valenced emotions rather than positively valenced emotions. Images that most reliably invoked negative emotional response included a map of receding Arctic sea ice, and a scientific diagram of the greenhouse effect. The strongest negative reaction was found for a photograph of smokestacks. This result echoes the findings of O'Neill and Nicholson-Cole[54] and O'Neill et al.[55] who also find especially strong negative emotions attached to smokestacks imagery. Both these studies found that while dramatic and potentially fear-inducing images like smokestacks can successfully capture people's attention, they can also act to distance viewers, leaving them feeling overwhelmed, or helpless.

Positive emotions were associated with some of the images in the Hespanha study.[26] These included photographs of a climate protest, and a photograph of international political leaders signing an agreement. The image most consistently and intensely positive was a photograph of people installing solar panels. Again, this is echoed in the responses from US, UK, and Australian participants in the O'Neill et al. study,[55] where images evoking renewable energy futures and personal mitigative behaviors strongly promoted feelings of self-efficacy.

Particular types of visual discourse also appear to produce relatively homogeneous responses (again, at least in the Western, English-speaking countries surveyed). O'Neill et al. used a representative sample of individual visual images arising from newspaper stories about climate change (mainly photographs, but also a scientific figure and a map[27]) in a Q-method exercise. Participants were asked to rank climate change images on scales on salience ('this image makes me feel climate change is important') and efficacy ('this image makes me feel I can do something about climate change'). They found statistically significant relationships across participants ranking images of climate change,[55] indicating that there appears to be a dominant discourse about climate change visuals. The study has three key findings: first, images of climate impacts were found to promote feelings of salience, but undermine self-efficacy; second, images of energy futures appeared to promote self-efficacy; and third, images of politicians and celebrities strongly undermined feelings of saliency. The results suggest that climate images can either act to increase the sense of importance one may feel about the issue, or promote feelings of being able to do something about climate change. However, few images appeared able to promote feelings of both salience and efficacy.

There is little research exploring audience engagement with climate visuals on television. Lowe et al.[56] examine audience perceptions after viewing The Day After Tomorrow, though they do not focus on visuals specifically. However, their research echoes other work in climate change communication on the use of fear-inducing visuals[54]: Lowe et al. found that the abrupt and catastrophic transformation of the Earth's climate into a new ice age portrayed by the film made participants significantly more concerned about climate change, but also made them feel that extreme events due to climate change would be less likely.

Critical Reflections From the Humanities

The studies examined above explicitly measure how people engage with particular visual discourses. Such studies emerge from the social sciences. Humanities researchers have also explored readings of artistic representations of climate change (though, as previously mentioned, much of this goes beyond the visual image to examine artistic works more generally). A brief discussion is thus provided here.

Humanities researchers have explored the role of art and artists in responding to climate change, as well as whether art is (or should try to be) an effective mechanism for engaging people with the political and scientific dimensions of the issue. Critiques also examine how audiences may engage with climate visuals: whether art which represents climate change distances people from the issue, or normalizes the problem.[51,57,58] Much discussion focuses on the role of the apocalyptic in visually representing climate change. For example, 'Postcards from the Future'[59] transformed iconic locations around London by projecting visuals of potential climate impacts. These visualizations included paddy fields in Parliament Square, a shantytown outside Buckingham Palace and a frozen river Thames. Such visual artistic endeavors can offer exciting opportunities for engagement,[51]

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but many visualizations verge on the incredible, and may act to distance people from engaging with climate change.[54,58] Critique of the role of visuals in representing climate change remains an important site of climate visual research.

THE MOMENT OF PRODUCTION

This section critically reviews research investigating the moment of production. There is little work in this area, and so it is a key site for future research into the visualization of climate change. The moment of production in terms of climate visuals could look to examine how climate visuals are made, in which genre, by and for whom, when, and why. Methods that could be employed here include ethnography, discourse analysis, and innovative visual research techniques such as image- or photo-elicitation. This section draws on work examining image (re)production in the public sphere (participatory processes of 3D visualization production) the other in the private sphere (photo-elicitation). The contribution from these studies is not so much at the site of the visual text (though this could of course be explored), but their explicit concern with the process in which images are produced.

How Is Climate Change Visually (Re)produced?

3D Landscape Visualization

Artists are not the only actors visually portraying visions of climate futures. With the rise in climate science projections has come an increased desire to visualize climate futures. While in the past these projections have been visualized through maps, 2D, or 3D model representations, or GIS, these are often static, highly technical, and their engagement requires specialized knowledge. 3D landscape visualizations[60] such as VRGIS (Virtual Reality Geographic Information Systems), attempt to overcome these difficulties. Here, we focus on the innovative use of 3D landscape visuals when they are embedded in participatory processes of future climate change visioning in local and community planning,[61] as the participatory planning process itself feeds into the production of visual climate imagery.

3D landscape visualizations add a vivid virtual reality element to climate projections,[62] enabling participants to immerse themselves and interact in a dynamic 'fly through' experience of photo-realistic imagery of local landscapes visualized under future climate scenarios.[63] Sheppard sees this tool as a unique form of visual communication of climate information, 'conveying information in the dominant form to which the human species is genetically adapted (i.e., visual landscapes), but capable of showing future worlds as they would be seen if the viewer were actually there'.[61,64:638] The aims of 3D landscape visualization is a focus on the realistic and engaging visual depiction of scientific projections, embedded within community planning where local people can engage in dialog about planning options under climate futures.[63–66] Such climate change visualizations have represented land use change in agricultural landscapes,[62] coastal zone management options,[63] mountain snowpack depletion[66] and flood management.[67] As tools for encouraging discussion and dialog, visioning techniques such as VRGIS appear to be successful. Preliminary results evaluating engagement with these climate visualization techniques indicate that participants positively evaluate the visualization experience, they find the scenarios credible, and self-assessed knowledge of both climate change mitigation and adaptation increase.[66]

3D landscape visualizations rely on the indexicality of imagery. This may facilitate engagement, as images portrayed are of recognizably local areas. Yet the intensively visual experience of these visioning scenarios causes a number of its own issues. Depicting uncertainty can be problematic within the visualizations. Depiction of particular landscape elements appearing because of a particular management intervention (e.g., the visualization of one particular crop over another in response to a change in climatic regime) within the visual scene may be then perceived as being 'certain' to occur, when in fact they are contingent on many other circumstances.[63] Also, the creation of visualized landscapes from positivist scientific information necessarily involves value judgments through the creative process in order for participants to be able to effectively 'read' the landscape. For example, high-carbon worlds may be depicted by visualizing smokestack chimneys prominently beside residential houses, but those chimneys may be removed from a low-carbon world, where residential housing is instead displayed with discreet solar panels on householders rooftops, e.g., see Ref 64:643. The visual display of smokestacks in the high-carbon visualization would likely provoke strong affective reactions,[55] which might not necessarily reflect the full 'background' to the scenario (such as issues surrounding the construction of renewables, their energy storage capacity and other such issues). These issues are not necessarily problematic (indeed, an emerging literature seeks to provide ethical codes to address such issues[60,61]) but it should be emphasized through the participatory process through which the visuals are used that these visualizations are as

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contingent on values and norms in their construction as any other visual image.

PhotoVoice and Photo-Elicitation

Another way of investigating the (re)production of climate visuals is to place the image researcher and image producer together in a co-constitutive relationship, whereby visual images are actively produced in the context of a research project. While the images can still be examined (i.e., at the moment of the visual text), the aim of these projects is to explicitly explore and understand the moment of image production. Research participants use photography or image-making as a way of capturing events, problems, or concerns about a particular topic that may be otherwise difficult to convey. The resulting imagery, and the narratives surrounding these images, is then used as an empowering and powerful tool to spur discussion (for more details of this type of visual method, see Refs 22, 68–71). An example of this sort of research method is the 'At the Water's Edge' project,[72] where PhotoVoice was used to explore peoples' values and concerns about adaptation to sea-level rise in a coastal location vulnerable to inundation. Participants were instructed to create photographs that visualized what they valued about being at the water's edge, and the threats they perceived to this place in the context of sea-level rise. The images created by participants were then exhibited at an art symposium. The results provided insight into the social and cultural dimensions of adaptation to climate change, highlighting how sea-level rise poses a threat to things which people value.

DISCUSSION

This review began by outlining three qualities of images: their analogical quality, the lack of an explicit propositional syntax in visuals (and how this differs to the communication quality of text), and the visual image's indexicality. This review has touched on these qualities through many different forms of visual representation. In this section, they are brought together in a discussion of three major reoccurring themes that have emerged at the moment of the visual text, the moment of consumption, and at the moment of production: time, truth, and power.

Time

The topic of climate change is suffused with the concept of time. Even the term 'climate change' (cf. the older term 'greenhouse effect') directly references time: what was climate before; how has it changed; what is climate like at present; and what does it mean for the future? This review has shown how visuals are a key communicative tool for visualizing climates past and present; and increasingly, for stimulating imaginations of climate futures.

The lack of propositional syntax in visual imagery means portraying the concept of time is necessarily reliant on loose, imprecise, and unsystematic cues. It relies on the consumer of the visual text consuming these visual cues using the same schema as the visual text producer. In some cases, these visual cues appear to be so widespread as to be almost universal within a culture, such as the use of sequential shots within a televisual documentary to portray the passing of time. Similarly, climate visuals may rely on a composite of sequential images in order to portray time, such as the paired images of glacier retreat promoted by NGO Greenpeace.[34] There are also interesting questions around the use of images to portray past impacts of climate change, if the intention is to promote future engagement with the issue. Doyle suggests that the Greenpeace images of glacier retreat provoke feelings of nostalgia and regret.[34] If Greenpeace's aim is to promote engagement with climate change, evidence suggests that these sorts of images make people feel climate change is an important issue, but they also decrease feelings of self-efficacy.[54,55]

Truth

This review has referred to visual texts in order to emphasize that visuals are always read—consumed through our own social subjectivities and experiences. Whether an image is more (a scientific figure) or less (a photograph of a polar bear) stylized, decisions have still been made about which aspects of reality to make more or less salient within an image. Hence, studies examining the use of visuals explicitly recognize that images do not portray an 'objective reality'[17] but are instead normative statements portraying a particular way of seeing the world.[14,15]

Despite this, visual images (and especially photographs) are often seen as 'speaking the truth'.[4] This review has explored how visuals have been used to portray 'truth' (and the controversy this may cause) across several types of visual corpora, including scientific imagery,[39,40] NGO visuals,[32,34] and televisual documentaries.[30] Often, these visuals attempt to persuade consumers of the 'proof' of climate change through visuals, or invite them to 'bear witness' to a changing climate.[32] As Doyle states, this is problematic in that while these visual may attempt to encourage consumers to feel shock and a sense of loss at witnessing climate impacts, they

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also render climate change as a past event, rather than an issue for the present or future.

Related to the concept of 'truth', is how to portray uncertainty within climate visual imagery. Scientists continue to struggle with how to adequately represent uncertainty in easily understandable yet scientifically valid ways,[39] and 3D visualization participatory processes also need to explicitly deal with the representation of uncertainty. But how do other climate visuals deal with the representation of uncertainty?

Power

Inherent in any discussion of communication is the concept of power: who produces texts; for whom; why, and when? The repetition and normalization of particular types of visual imagery (or image absence) manifests power for some voices (and not others). Thus, the use of particular visual imagery helps to promote particular ways of conceptualizing climate change, while marginalizing others. Images form part of the 'cultural politics of climate change'—the 'dynamic and contested spaces where various 'actors' battle to shape public understanding and engagement [. . .] where formal climate science, policy, and politics operating at multiple scales permeate the spaces of the 'everyday'.[73:3]

Questioning power relations and imagery is particularly pertinent at the moment of production. This review focused on two areas of research that seek to understand how visuals are (re)produced, and to actively co-produce new types of climate visual imagery. But research at the moment of the visual text has shown how powerful interests (including in advertising,[3] and in news media[27]) shape visual discourses of climate change in particular ways. Understanding visual discourses then, and how they are shaped and mediated by powerful interests at each moment in the communications cycle, is a research area of some importance for visual scholars.

FUTURE DIRECTIONS

This article has synthesized an emerging literature of the visualization of climate change. It shows how climate visualization is a nascent research area, with many exciting and novel new projects exploring climate imagery in its many forms. This review has exposed several areas in need of more detailed theoretical and empirical investigation. Three broad areas are outlined below:

First, we suggest that visual images can help to enable people to imagine futures under climate change. This may occur at the moment of consumption and production. For example, the review has shown how powerful interests help shape our everyday mediated experiences of climate change, through the display of particular visual discourses of climate change in newspapers and on television. But could other types of visual imagery gain prominence? How might this happen, and would it provoke different forms of engagement? Visual researchers could investigate the site of production of visual images in both public and private spheres to shed light on this area.

Second, the review has synthesized a diverse corpora of visual image types. But several types of visuals are either missing entirely, or worthy of more in-depth exploration. For example, at the moment of the visual text, cartoons are a specific visual device that can both reflect and shape the cultural politics of climate change.[74,75] Research could usefully explore visuals in online-only fora, such as in blogs, or Youtube videos. Additionally, there is very little research exploring that most intense visual experience, television. Emerging research is starting to explore the moment of image consumption, especially for images which are participant (co)-created; from household thermal imagery[76] to photos produced by research participants.[72] At all moments in the visual communication cycle, research has focused on Western, English-speaking nations. Therefore, significant opportunities exist for researchers to investigate climate visuals in different corpora.

Third, the diversity of methodologies employed to explore the visual representation of climate change is worthy of comment. Studies reviewed here have used content analysis, discourse analysis, semiology, surveys, Q-method, social semiotics, and photo-elicitation. Methods which have been successfully used in other areas of visual research, but have not yet been applied to climate visual research, include ethnography and compositional interpretation see.[22] Ethnography, in particular, would seem to be a useful methodology to employ at both the moment of consumption and production. Some studies use multiple methods in order to examine visual image production, visual text, or consumption. Several studies at the moment of the image explicitly triangulate data from multiple methods: usually, a quantitative content analysis, with qualitative methods to explore the cultural and political contexts in which visual discourses are situated.[24,27] Visual researchers should explicitly state when multiple methods are used, especially when a combination of methods cause epistemological tensions. The wide range of methodologies employed by the studies examined here demonstrates how the investigation of climate communication through

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visual imagery is a multidisciplinary, and often interdisciplinary, research area. Also, several of the research methods used are innovative and novel. A suggestion for good practice in this area, then, is for a clear description of the methodologies employed when investigating visual communications (including, as applicable, the sharing of analytic tools such as codebooks), as methodological information in visual studies is often implied rather than explicitly described.[27,77] Such methodological details should be written in such a way that they are accessible to interdisciplinary audiences.

This review has demonstrated how images are helping to shape the production and (re)making of meanings about climate change.[78] It has shown how the dominance of certain images (or types of images) over others shapes the cultural and political discourse of climate change in important ways. While images have always been used to illustrate, visualize and inspire engagement, a focus on the work of images in shaping the political and cultural discourse of climate change has, until recently, been scarce. This review has synthesized emerging literature from the multidisciplinary field of visual climate change communication. We hope the review, and the suggested research directions, spur further research interest in this nascent field.

ACKNOWLEDGMENTS

The first author is funded through an Economic and Social Research Council fellowship (ES/K001175/1).

REFERENCES

1. Anderson A. Media, politics and climate change: towards a new research agenda Sociology. *Compass* 2009, 3:166–182.
2. Moser S. Communicating climate change: history, challenges, process and future directions. *WIREs Clim Change* 2010, 1:31–53.
3. Hansen A, Machin D. Visually branding the environment: climate change as a marketing opportunity. *Discourse Stud* 2008, 10:777–794.
4. Joffe H. The power of visual material: persuasion, emotion and identification. *Diogenes* 2008, 55:84–93.
5. Smith N, Joffe H. Climate change news in the British press: the role of the visual. *J Risk Res* 2009, 12:647–663.
6. Slovic P, Finucane ML, Peters E, MacGregor DG. The affect heuristic. In: Gilovich T, Griffin D, Kahneman D, eds. *The Psychology of Intuitive Judgment*. New York: Cambridge University Press; 2002, 397–420.
7. Slovic P, MacGregor DG, Peters E. *Imagery, Affect, and Decision-Making*. Eugene, OR: Decision Research; 1998.
8. Szalay LN, Deese J. *Subjective Meaning and Culture: An Assessment Through Word Associations*. Hillsdale, NJ: Lawrence Erlbaum Associates; 1978.
9. Leiserowitz T. American risk perceptions: is climate change dangerous? *Risk Anal* 2005, 25:1433–1442.
10. Leiserowitz T. Climate change risk perception and policy preferences: the role of affect, imagery and values. *Clim Change* 2006, 77:45–72.
11. Smith N, Leiserowitz A. The rise of global warming scepticism: exploring affective image associations in the United States over time. *Risk Anal* 2012, 32:1021–1032.
12. Lorenzoni I, Leiserowitz A, Doria MD et al. Cross-national comparisons of image associations with global warming and climate change among laypeople in the United States of America and Great Britain. *Journal of Risk Research* 2006, 9:265–281.
13. Graber DA. Seeing is remembering: how visuals contribute to learning from television news. *J Commun* 1990, 40:134–155.
14. Popp RK, Mendelson AL. 'X'-ing out enemies: time magazine, visual discourse, and the war in Iraq. *Journalism* 2010, 11:203–221.
15. Messaris P, Abraham L. The role of images in framing news stories. In: Reese SD, Gandy OHJ, Grant AE, eds. *Framing Public Life*. Mahwah, NJ: Taylor & Francis; 2001, 215–226.
16. Grabe ME, Bucy EP. *Image Bite Politics: News and the Visual Framing of Elections*. Oxford University Press; 2009.
17. Urry J. The tourist gaze "revisited". *Am Behav Sci* 1992, 36:172–186.
18. Cosgrove D. Contested global visions: one-world, whole-Earth and the Apollo space photographs. *Ann Assoc Am Geogr* 1994, 84:270–294.
19. Hall S. Encoding/decoding. In: Hall S, Hobson D, Lowe A, Willis P, eds. *Culture, Media, Language*. London: Hutchinson; 1980, 128–138.
20. Corner J. Textuality, communication and media power. In: Howard D, Walton P, eds. *Language, Image, Media*. London: Blackwell; 1983, 266–281.

 © 2013 John Wiley & Sons, Ltd.

21. Carvalho A, Burgess J. Cultural circuits of climate change in UK broadsheet newspapers, 1985–2003. *Risk Anal* 2005, 25:1457–1469.
22. Rose G. *Visual Methodologies: An Introduction to Researching with Visual Materials*. London: Sage; 2012.
23. Manzo K. Beyond polar bears: re-envisioning climate change. *Meteorol Appl* 2010, 17:196–208.
24. DiFrancesco DA, Young N. Seeing climate change: the visual construction of global warming in Canadian print media. *Cult Geogr* 2010, 18:517–536.
25. Achong K, Dodds R. Anthropogenic climate change coverage in two Canadian newspapers, the Toronto Star and the Globe and Mail, from 1988–2007. *Environ Sci Policy* 2012, 15:48–59.
26. Hespanha SR. *Thematic and affective content in textual and visual communication about climate change: historical overview of mass media sources and empirical investigation of emotional responses*. PhD thesis, Geography, University of California, Santa Barbara; 2011.
27. O'Neill S. Image matters: climate change imagery in US, UK and Australian newspapers. *Geoforum* 2013, 49:10–19.
28. Emmerich R. *The Day After Tomorrow*. USA: 20th Century Fox; 2004.
29. Guggenheim D. *An Inconvenient Truth*. USA: Paramount Classics; 2006.
30. Mellor F. The politics of accuracy in judging global warming films. *Environ Commun* 2009, 3:134–150.
31. Lester L, Cottle S. Visualizing climate change: television news and ecological citizenship. *Int J Commun* 2009, 3:920–936.
32. Doyle J. Seeing the climate? The problematic status of visual evidence in climate change campaigning. In: Dobrin S, Money S, eds. *Ecossee: Images, Rhetoric and Nature*. New York: State University of New York Press; 2009, 279–297.
33. Manzo K. Imaging vulnerability: the iconography of climate change. *Area* 2009, 42:96–107.
34. Doyle J. Picturing the clima(c)tic: greenpeace and the representational politics of climate change communication. *Sci Cult* 2007, 16:129–150.
35. Doyle J. *Mediating Climate Change*. Farnham: Ashgate; 2011.
36. Gordon R, Carrigan M, Hastings G. A framework for sustainable marketing. *Market Theory* 2011, 11:143–163.
37. Svoboda M. Advertising Climate Change: A Study of Green Ads, 2005–2010. Yale forum on climate change and the media; 2011.
38. Linder SH. Cashing-in on risk claims: on the for-profit inversion of signifiers for "global warming". *Social Semiotics* 2006, 16:103–132.
39. Schneider B. Image politics: picturing uncertainty. In: Gramelsberger G, Feichter J, eds. *Climate Change and Policy*. Berlin: Springer-Verlag; 2011, 191–209.
40. Schneider B. Climate model simulation visualisation from a visual studies perspective. *WIREs Clim Change* 2012, 3:185–193.
41. Regaldo A. Global warring: in climate debate, the 'Hockey Stick' leads to a face-off. *Wall Street Journal* 2005. Available at: http://online.wsj.com/article/0,,SB110834031507653590,00.html. (Accessed September 23, 2013).
42. Appell D. Behind the hockey stick. *Sci Am* 2005, 292:34–35.
43. Hamblyn R. The whistleblower and the canary: rhetorical constructions of climate change. *J Hist Geogr* 2009, 35:223–236.
44. Mahony M and Hulme M. The colour of risk: an exploration of the IPCC's "Burning Embers" diagram. *Spontaneous Generations* 2012;6(1913-0465).
45. Anderson K, Bows A. A new paradigm for climate change. *Nat Clim Change* 2012, 2:639–640.
46. Yusoff K, Gabrys J. Climate change and the imagination. *WIREs Clim Change* 2011, 2:516–534.
47. Cameron F, Hodge B, Salazar JF. Representing climate change in museum space and places. *WIREs Clim Change* 2013, 4:9–21.
48. TippingPoint. TippingPoint: introduction to project database. Available at: http://www.tippingpoint.org.uk/projects/. 2012. (Accessed September 23, 2013).
49. Giannachi G. Representing, performing and mitigating climate change in contemporary art practice. *Leonardo* 2012, 45:124–131.
50. Buckland D. Climate is culture. *Nat Clim Change* 2012, 2:137–140.
51. Dunaway F. Seeing global warming: contemporary art and the fate of the planet. *Environ Hist* 2009, 14:9–31.
52. Gamson WA, Modigliani A. Media discourse and public-opinion on nuclear power—a Constructionist approach. *Am J Sociol* 1989, 95:1–37.
53. Domke D, Perlmutter D, Spratt M. The prime of our times? An examination of the 'power' of visual images. *Journalism* 2002, 3:131–159.
54. O'Neill SJ, Nicholson-Cole S. Fear won't do it': promoting positive engagement with climate change through visual and iconic representations. *Sci Commun* 2009, 30:355–379.
55. O'Neill SJ, Boykoff M, Niemeyer S, Day S. On the use of imagery for climate change engagement. *Glob Environ Chang* 2013, 23:413–421.
56. Lowe T, Brown K, Dessai S, de Franca DM, Haynes K, Vincent K. Does tomorrow ever come? Disaster narrative and public perceptions of climate change. *Public Underst Sci* 2006, 16:435–457.

 © 2013 John Wiley & Sons, Ltd.

57. Hannah D. Art and climate change references. In: Black BC, Hassenzahl DM, Stephens JC, Weisel G, eds. *Climate Change: An Encyclopedia of Science and History*. Santa Barbara: ABC-CLIO, LLC; 2012, 90–96.
58. Miles M. Representing nature: art and climate change. *Cult Geogr* 2010, 17:19–35.
59. Graves R, Madoc-Jones D. Postcards From the Future. Museum of London; 2010.
60. Bishop I, Lange E. *Visualization in Landscape and Environmental Planning: Technology and Applications*. London, New York: Taylor & Francis; 2005.
61. Sheppard S. *Visualizing Climate Change*. Abingdon: Earthscan, Routledge; 2012.
62. Dockerty T, Lovett A, Sünnenberg G, Appleton K, Parry M. Visualising the potential impacts of climate change on rural landscapes computers. *Environ Urban Syst* 2005, 29:297–320.
63. Jude S, Jones AP, Andrews JE, Bateman IJ. Visualisation for participatory coastal zone management: a case study of the Norfolk coast, England. *J Coast Res* 2006, 22:1527–1538.
64. Sheppard S. Landscape visualisation and climate change: the potential for influencing perceptions and behaviour. *Environ Sci Policy* 2005, 8:637–654.
65. Sheppard SRJ, Shaw A, Flanders D, Burch S, Wiek A, Carmichael J, Robinson J, Cohen S. Future visioning of local climate change: a framework for community engagement and planning with scenarios and visualisation. *Futures* 2011, 43:400–412.
66. Cohen SJ, Sheppard S, Shaw A, Flanders D, Burch S, Taylor B, Hutchinson D, Cannon A, Hamilton S, Burton B, et al. Downscaling and visioning of mountain snow packs and other climate change implications in North Vancouver, British Columbia. *Mitig Adapt Strat Glob Chang* 2012, 17:25–49.
67. Burch S, Sheppard SRJ, Shaw A, Flanders D. Planning for climate change in a flood-prone community: municipal barriers to policy action and the use of visualizations as decision-support tools. *J Flood Risk Manage* 2010, 3:126–139.
68. Gustafson K, Al-Sumait F. *Photo Conversations About Climate: Engaging Teachers and Policymakers Through Photography and Narrative*. Department of Communication: University of Washington; 2009.
69. Wang C. PhotoVoice: concept, methodology, and use for participatory needs assessment. *Health Educat Behav* 1997, 3:369–387.
70. Lardeau M, Healey G, Ford J . The use of PhotoVoice to document and characterize the food security of users of community food programs in Iqaluit, Nunavut. *Rural Remote Health* 2011, 11:1690.
71. Devine-Wright H, Devine-Wright P. Social representations of electricity network technologies: Exploring processes of anchoring and objectification through the use of visual research methods. *Brit J Soc Psychol* 2009, 48:357–373.
72. Baldwin C, Chandler L. At the water's edge': community voices on climate change. *Local Environ Int J Just Sustain* 2010, 15:637–649.
73. Boykoff MT. *Who Speaks for the Climate? Making Sense of Media Reporting on Climate Change*. Cambridge, UK: Cambridge University Press; 2011.
74. Manzo K. Earthworks: the geopolitical visions of climate change cartoons. *Polit Geogr* 2012, 31:481–494.
75. Rudiak-Gould P. Climate change and anthropology: the importance of reception studies. *Anthropol Today* 2011, 27:9–12.
76. Goodhew J, Goodhew S, Auburn T, De Wilde P, Pahl S. A preliminary investigation of the potential for thermographic images to influence householders' understanding of home energy consumption. *25th ARCOM Conference*; 2009.
77. Christmann GB. The power of photographs of buildings in the Dresden urban discourse: towards a visual discourse analysis. *Qual Soc Res* 2008, 9:11.
78. Seppänen J, Väliverronen E. Visualising biodiversity: the role of photographs in environmental discourse. *Sci Cult* 2003, 12:59–85.

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