



The tipping point trend in climate change communication

Chris Russell^{a,*}, Zoe Nyssa^b

^a Carleton University, School of Journalism & Communication, 305 St. Patrick's Bldg., 1125 Colonel By Dr., Ottawa, ON, Canada K1S 5B6

^b University of Chicago, The Committee on Conceptual and Historical Studies of Science Social Sciences Building, Rm. 205, 1126 East 59th Street Chicago, IL, 60637, USA

ARTICLE INFO

Article history:

Received 27 July 2008

Received in revised form 3 April 2009

Accepted 22 April 2009

Keywords:

Alarmism

Climate change communication

Dangerous anthropogenic interference

Metaphor

News media

Threshold

Tipping point

ABSTRACT

This article documents the use of tipping points in climate change discourse to discuss their significance. We review the relevant literature, and discuss the popular emergence of tipping points before their adoption in climate change discourse. We describe the tipping point trend in mainstream US and UK print news media and in the primary scientific literature on climate change by replicating the methodologies of Oreskes [Oreskes, N., 2004. The scientific consensus on climate change. *Nature* 306, 1686] and Boykoff and Boykoff [Boykoff, M.T., Boykoff, J.M., 2004. Balance as bias: global warming and the US prestige press. *Global Environmental Change* 14, 125–136]. We then discuss the significance of climate change tipping points and their popular use in terms of generative metaphor.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

On 6 December 2005, in a presentation to the American Geophysical Union (AGU), James Hansen stated that, “we are on the precipice of climate system tipping points beyond which there is no redemption” (Hansen, 2005, p. 8). Hansen’s warning helped initiate a tipping point trend in climate change communication that was quickly reflected in public debate. These warnings were front page news by January 2006, with *The Washington Post* reporting that, “[t]his ‘tipping point’ scenario has begun to consume many prominent researchers in the United States and abroad. . .” (Eilperin, 2006, p. A01). Tipping point warnings are now evident not only in prestige media and popular discourse, but in the primary science and U.S. congressional testimony as well. Only 2 years after Hansen’s initial tipping point warning, the AGU dedicated a half-day session to exploring the relevance and scope of tipping points to climate systems. Kerr (2008), covering the session for *Science*, concluded that use of the notion had become acceptable: “Tipping points, once considered too alarmist for proper scientific circles, have entered the climate change mainstream” (p. 153).

The rapid mainstreaming of tipping point warnings of climate change danger raises several questions. Do tipping points represent an important shift in climate change discourse or, as the editors of *Nature* suggest, is this simply old wine in new

bottles? Do tipping points induce unwarranted anxiety and perhaps fatalism (Nature, 2006; Hulme, 2006), or, on the other hand, do they help correct for the “false sense of security” produced by smooth projections of change, which can lull society into inactivity (Lenton et al., 2008, p. 1792; cf. Lenton and Schellnhuber, 2007; Risbey, 2008)? Should we draw any conclusions from the fact that popular discourse on tipping points precedes use of the concept in peer-reviewed climate change science? Does the divergence of tipping point warnings from the terminology found in the Intergovernmental Panel on Climate Change 4th Assessment Report (IPCC AR4) require explanation?

This article documents the use of tipping points in climate change discourse and discusses their significance in light of these questions. First, we review the relevant literature on climate change communication and revisit Schön’s (1979) distinction between concepts, re-description, and generative metaphors to theorize how new perspectives on climate change are developed. Second, we trace the mainstream emergence of tipping points through the work of Malcolm Gladwell to clarify its popular associations. Third, we describe the tipping point trend in the primary scientific literature on climate change, and in mainstream U.S. and U.K. print news media. Fourth, we examine trends that emerge in scientific and media discourse.

2. Climate change communication: the research literature

Research into climate change communication has broadened significantly in recent years and now deals substantively with interdisciplinary scientific communication, the scientist/

* Corresponding author. Tel.: +1 612 239 6284.

E-mail addresses: chris.russill@gmail.com (C. Russell), znyssa@uchicago.edu (Z. Nyssa).

policy maker interface, international diplomacy, as well as media coverage and public understanding. Researchers concerned with public understanding have long recognized that news media are important sources of scientific information among non-scientists. Nisbet and Myers (2007) comprehensive summary of the results of 20 years of public opinion surveying found “strong connections between patterns in media attention to global warming and shifts in poll trends” (p. 445). Research investigating the connection between scientific knowledge, media, and public understanding of climate change frequently suggests a “gap” between scientific and media representations of anthropogenic climate change. The idea is that a communication failure between journalists and scientists results in divergent representations of the issue, and that the difference or ‘gap’ in depictions of climate change prevents the public from learning about its relevance to society. Two studies are frequent points of reference for establishing this conclusion. Oreskes (2004) canvassed the statements of major professional scientific organizations and analyzed a random sample of the abstracts of the research literature from 1993 to 2003 to argue there was scientific consensus regarding the fact of anthropogenic climate change. Boykoff and Boykoff (2004) conducted a content analysis of US prestige newspapers to determine how well news represented this claim. Other researchers have used cross-national media comparisons to illuminate the greater divergence of US media from other national media on this point (Dispensa and Brulle, 2003), or focused on specific instances of political economic manipulation (McCright and Dunlap, 2000, 2003; Antilla, 2005; Lahsen, 2005; Jacques et al., 2008).

A second research tradition dealing with climate change communication prioritizes the relationship of communication to motivation and social change. These researchers argue that lacking correct information is not the main barrier to action. Instead, it is important to ask how climate change problems are made relevant to specific audiences in different contexts (cf. Moser and Dilling, 2007) and to acknowledge the importance of culture (Hulme, 2008; cf. Pettenger, 2007). A frequent concern is the way problem formulations generate or dampen opportunities for social change. For example, Skodvin’s (2000) focus on “problem diagnosis” illuminates social interactions where facts and values intermingle in the co-constitution of problem statements and solution paths: “scholarly attention has been redirected from the processes whereby scientific knowledge is communicated to policymakers towards the processes [whereby] scientific knowledge is integrated with policy concerns in comprehensive problem definitions that form interpretative frameworks whereby problems are made negotiable. . .” (Skodvin, 2000, p. 18).

Problem diagnoses are often expressed in the language of marketability or framing. Ungar’s (2007) concepts of “issue culture” and “bridging metaphors,” for example, are discussed in terms of selling climate change. People will attend to climate change insofar as it fits or fails to fit conceptions of a “hot crisis,” a frame of understanding that accelerated action on stratospheric ozone depletion (Ungar, 1998). Similarly, Williams (2000) argues that climate change must be treated in terms of “packageable solutions” to compete for media attention and to avoid skeptical counter-claims. If the problem is not reconfigured to suit conventional forms of action, or if it is not “‘packaged’ in a way that makes the situation a matter of common sense and at the same time resolves our orientation to the problem in terms of action,” then media will lose interest and coverage will decline (Williams, 2000, p. 66).

The degree to which climate change communication must accommodate to preexisting institutional conditions is an open question and recommendations to embrace media conventions often seem to demand acquiescence to the rules of the game. Schneider (1988) calls this situation the “double ethical bind,”

where a concern for scientific accuracy must be balanced by attention to media effectiveness (p. 114). The bind has prompted concerns that the bending of problem formulations to accommodate media conventions disadvantages indigenous voices and more expansive ecological perspectives that embrace cultural dimensions of climate change (Smith, 2007; Hulme, 2008).

In this second research tradition, a key issue is the lack of commensurability between problem statements and proposed solutions (Williams, 2000; Ereaut and Segnit, 2006; Moser and Dilling, 2007; Risbey, 2008). Those emphasizing the extent of the problem are often charged with forwarding “fear appeals” or even “climate porn,” which suggests a perverse pleasure is gained by circulating catastrophic visions of the future (Ereaut and Segnit, 2006). Others defend alarmist portrayals on the grounds that modern institutions are inadequate for addressing the challenge, and that commitments to existing institutions render climate change incapable of solution. In each case, problem diagnoses are criticized for presuming an unworkable set of solutions.

Risbey (2008) distinguishes alarmist from alarming perspectives and he suggests that a “new discourse is emerging which underscores the scope of the problem and the scope and feasibility of solutions. This discourse differentiates itself from existing discourses which view the magnitudes of the problem or of solutions as prohibitive” (p. 26). From this viewpoint, differences in problem formulation are not attributed to distortion, inaccuracy, or evaluated in terms of the positivist problem solving ideologies critiqued by Smith (2007) and Hulme (2008). Instead, problems are evaluated for their consistency with scientific understanding. It is in recognition of the malleability of problem setting processes and as part of an effort to introduce greater urgency into the diagnosis of climate-related threats that tipping point warnings have emerged.

One difficulty in assessing the appropriateness of tipping point warnings is the frequent slippage from physical to biological to social referents, a potential conflation introduced by Gladwell’s (2000) interpretation of epidemiological perspectives. Is the notion appropriate as a description of the way physical components of the climate system change, or as a means of understanding social behavior, or both? Is it intended as a scientific concept, or as a metaphor? In discussing tipping points in climate change communication, it is helpful to revisit Donald Schön’s work on problem setting in social policy and to distinguish between concepts, re-description, and generative metaphor.

Schön sought to understand how new perspectives on policy problems were developed from the adoption of generative metaphors. Schön (1979) believed that policy disputes often resulted from the use of “conflicting frames, generated by different and conflicting metaphors” (p. 139). He hoped greater clarity on the role of generative metaphor would help explain cognitive innovations, and serve as a critical tool for clarifying conflicts based in competing metaphors. For Schön, generative metaphor takes place when a familiar description is displaced by “a different, already-named process,” which then serves as an alternative description able to illuminate and re-prioritize different aspects of a complex situation (p. 141). “What makes the process one of metaphor making, rather than simply of redescribing, is that the new putative description already belongs to what is initially perceived as a different, albeit familiar thing. . .” (p. 141).

A generative metaphor has a lifecycle. There will be an initial and unjustified use of the metaphor, then the formulation of an analogy able to restructure perception of an existing situation, and only then the potential development of a concept or general model (pp. 142–143). The initial application of the metaphor will look like a silly mistake, and it often is. On such occasions, the effort to rethink a situation is unlikely to proceed beyond the initial experiments with the metaphor. Hansen, for instance, spoke of a

slippery slope, a Faustian bargain, and a climate change time bomb, before settling on tipping points (Russill, 2008). In some instances, a useful generative metaphor might be abandoned prematurely, since it fails to fit the expected criteria for accepting a concept or model. Moreover, successful generative metaphors rarely bear the traces of the earliest efforts to apply them. For example, the metaphor of the great ocean conveyor belt no longer prompts much pause or reflection. Its first use was almost whimsical, as the example of a fun-house ride was used to explain nutrient distribution in the sea, but the conveyor belt was used subsequently to guide the development of a model to explain the global nature of ocean circulation (Brüning and Lohmann, 1999).

Not all metaphors are generative, and metaphors can be generative in different ways. Brüning and Lohmann (1999) distinguish how a “deepening metaphor” and an “extension metaphor” can aid the development of a model (p. 382). A deepening metaphor simplifies a complex situation by emphasizing special or unacknowledged features, which might make a complicated pattern more understandable (p. 396). It is quite possible that this was the initial intention of Hansen’s (2005) tipping point warning of climate change. An extension metaphor is more complex than the prevailing description or representation of a phenomenon, at least in its focus on unclear or poorly understood features (p. 392). The work of Hansen et al. (2008) and Lenton et al. (2008) on tipping elements and tipping points represent this kind of development. Generative metaphors may illuminate previously ignored aspects of a situation; more likely, however, a generative metaphor alters perception by re-weighting select aspects of a situation.

The difficulties in explaining complex phenomena are obvious enough, and we often get more than we bargain for in using metaphor. In 2002, Carl Wunsch found seven different inconsistent definitions of “thermohaline circulation,” a proliferation that was perhaps partly the result of an overextended analogy (p. 1179). The situation with respect to tipping points is made especially complex by the potential conflation of two kinds of tipping: the tipping over of a glass, a familiar physical example, and the tipping of disease transmission into an epidemic, the description Gladwell (2000) mapped onto our understanding of communication and society.

3. The popular emergence of tipping points

Discussions of tipping points in climate science often point directly to the popular influence of Malcolm Gladwell. In her review of the appropriateness of tipping points in climate science, science writer Gabrielle Walker (2006) observed that “[t]he idea is spreading like contagion” in climate change discourse (p. 802). Walker rightly noted that Gladwell “was comparing the way aspects of life suddenly shift from obscurity to ubiquity to effects normally studied in epidemiology. Gladwell’s tipping points were manifestations of the catchiness of behaviours and ideas” (p. 802). Similarly, the editors of *Nature* (2006) associate the term with contagion and encourage its application to the social dimensions of the climate change:

It is possible to make people change their minds and behaviours, and for those changes to spread like a contagion. ‘Look at the world around you,’ Gladwell argues. ‘It may seem like an immovable, implacable place. It is not. With the slightest push – in just the right place – it can be tipped.’ (*Nature*, p. 785)

Gladwell is also accorded popular priority in the most exhaustive scientific consideration of the value of tipping point terminology. Lenton et al. (2008) view tipping points as “a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system,” and they cite Gladwell’s idea

that “little things can make a big difference” as a precursor (p. 1786). With respect to social change, Moser and Dilling’s (2007) benchmark collection on climate change communication includes several references to tipping points, from various authors, including their summary chapter. Moser and Dilling (2007) propose an “S-curve” for conceptualizing social change that is distinguished by stages of predevelopment, take-off, break-through, and stabilization (pp. 492–493). Tipping points are located within this framework for understanding the diffusion of innovations and defined as “moments in time where a normally stable or only gradually changing phenomena suddenly takes a radical turn” (Moser and Dilling, 2007, p. 492). Gladwell is mentioned directly.

In *The Tipping Point*, Gladwell (2000) adopted an epidemiological perspective to discuss how beliefs and behavior change. The tipping point is “that one dramatic moment in an epidemic when everything can change all at once. . .” (p. 9). It is “sudden change,” not “steady progression” or “proportionality” that characterizes shifts in social behavior and beliefs (pp. 12–13). Most significantly, such change is epidemic and contagious in nature. There are thresholds of extreme sensitivity where the slightest perturbation can result in vastly different social trends. According to Gladwell, cultural prejudice blocks this realization. We fail to think in terms of thresholds and sensitivity to rapid change. Social policies presume linear notions of social change; stable and mechanistic perspectives on cause and effect guide our thinking about social problems. But if “social problems behave like infectious agents” (Gladwell, 1996, paragraph 5), and if behavior is potentially contagious “in the same way that an infectious disease is contagious” (paragraph 15), then social policy must be reconceived.

Gladwell was interested initially in efforts to reduce crime in New York City, and he believes the “broken windows” application of the tipping point perspective succeeded: attention to seemingly tangential dimensions of the context for crime (the removing of graffiti, the policing of subway turnstills, the fixing of broken windows) altered the way situations were perceived, and this perception induced a new pattern of social behavior. Gladwell (2000) believes the example can be generalized. Shifts in the perception of social problems can proliferate rapidly and drive new patterns of behavior. These perceptual shifts result from small alterations in a given context, and the resulting change self-sustains once a given threshold is crossed. The key is to view society in terms of viral transmission: “Ideas and products and messages and behaviors spread just like viruses do” (p. 7). In this respect, Gladwell’s book evokes themes of chaos, complexity, and catastrophe theory, while remaining firmly committed to the notions of epidemic and contagion.

Gladwell (2000) looks at epidemics in terms of contagious people, infectious agents, and environmental context, and he discusses how communication is a primary vehicle of social change. Contagiousness is “a function of the messenger,” part of an effort to find the right person to carry a message (p. 234). Messengers should be influential connectors (socially connected people), mavens (people offering new information or perspectives) or salespeople (people able to overcome opposition through persuasion). Framing or “stickiness,” is “a property of the message” (p. 234) and Gladwell discusses the importance of repetition, narrative, and other ways of influencing perception through the structuring of information. Finally, Gladwell discusses the importance of context and he develops a number of rules for helping people alter the popular perception of familiar situations. The result is that communication assumes much more weight as a vehicle for social change. For example, when James Hansen told Iowa state officials that their refusal to site a new coal plant would send a message and tip public sentiment against coal fired energy,

he assumed this theory. Materially, the implications of one less coal plant are inconsequential to ameliorating global climate change; in terms of tipping points, however, Hansen believes a small change can make a huge difference. “Iowa, and this specific case, can be a tipping point, leading in a new direction” (Hansen, 2007c, p. 5).

4. Methods: documenting and interpreting the tipping point trend

In order to determine and contextualize the significance of the tipping point trend, we attempted to replicate and expand the methods of those studies that have become standard points of reference, particularly Oreskes’s (2004) survey of the scientific literature and Boykoff and Boykoff (2004) and Boykoff’s (2007) analyses of the prestige news media. Oreskes (2004) searched the ISI Web of Science index between 1993 and 2003 for science articles published that contained the term “global climate change” in the title, abstract or author-supplied keywords. Her search returned 928 articles. We attempted to replicate this result by searching the Scientific Citation Index (SCI) of the ISI Web of Knowledge (accessed through the University of Minnesota subscription, February 2008, using “global climate change,” for the period 1993–2003, and limiting document types to articles). The search resulted in 929 articles. No article made reference to tipping points.

We then searched for the period 2003–2007 and returned 607 articles. None of these articles made reference to tipping points; one article used the terminology of “turning point”. We expanded this search to science articles published between 1975 and 2007 that contained the phrases “climate”, “global warming”, “global cooling” or “climate change” as well as “tipping point”, “turning point”, and “tip* point” (using wildcard character *). Articles that included the phrases “tipping point” or its variants and one of the other climate-related search terms were then hand sorted for relevancy. The results for each of these searches were broken out by annual publication total in order to see trends over time.

Boykoff and Boykoff (2004) conducted a survey of climate change reports in the American and British prestige press from 1988 to 2002; Boykoff (2007) extended this survey from 2003 to 2006. The authors took 1988 as the starting point for several reasons, including that in this year NASA scientist James Hansen (later a primary source of tipping point discourse) argued before the U.S. Congress that climate change was anthropogenic and required action. As mention of tipping points in the news media do not appear before the 1990s, we retained the 1988 start date but extended the search to include articles published through 2007. Boykoff and Boykoff defined the prestige press based on several factors, considering published circulation audits but also geography and influence when compiling their publication set. In their 2004 study, this was comprised of the New York Times, the Los Angeles Times, the Washington Post and the Wall Street Journal. Boykoff (2007) expanded this to include the preceding four papers plus USA Today and, in the UK, the Independent (and Independent on Sunday), The Times (and The Sunday Times), and the Guardian (and Observer). For purposes of consistency, our study included this later corpus but was later expanded to include the national dailies of Canada (The Globe and Mail and National Post), and of Australia (The Australian) in order to further establish national trends in climate change discourse.

Boykoff and Boykoff searched their sample set using the key phrases ‘climate change’ and ‘global warming’ via the Lexis Nexis and ProQuest/ABI Inform databases. We used these search terms as well as those used for the ISI Web of Science search described above. The US Congressional Record was also searched for key words “climate”, “tipping point” and “turning point” for all

available searchable Congresses (#101–110, spanning the years 1989–2007) using the Library of Congress THOMAS archive. Because the Record comprises a smaller corpus and the key word search is more limited in function, search terms were left as broad as possible in order to capture any possible relevant mentions. Results were hand sorted for those instances of tipping points in relation to climate change. The search was limited to articles, and it excluded book reviews and articles from wire services (i.e., there are no duplications in these totals).

The analysis of this sample employs a qualitative orientation similar to Risbey’s (2008) work on different representations of climate change problems. Risbey (2008) emphasized the “element of judgment” involved in climate change communication and sought to contrast popular understandings with features of climate science at the conceptual level (p. 27). Similarly, we attempt to locate trends in the uses of tipping points, to illuminate important features of the context of usage, and to articulate the grounds for preferring or rejecting use of tipping points in climate change discourse.

5. Results: general

Fewer stories about climate change appear in the US prestige media than in the prestige media of Australia, Canada and the United Kingdom, though the total mentions of climate change in the US Congressional Record exceeded mentions in the prestige media of all four countries until 2000 (see Fig. 1), particularly in the lead up to the Kyoto Protocol. The idea of climate tipping points only gained traction in the media after Hansen’s warnings in 2005 and the trend has not yet appeared to peak in the media (see Fig. 2). Mentions of climate-related tipping points appear more frequently in the UK press compared to the US; this is perhaps an artifact of the more frequent reporting on climate change in the UK. In the US Congressional Record, mentions of climate-related tipping points appeared three times in 2006, several months after Hansen’s warning, and seven times the following congressional year. “Tipping point” in general has become a more common trope among US legislators, particularly when referencing war in Afghanistan and Iraq.

Reference to tipping points in climate change is an interesting but not robust trend in climate change communication. The first climate-related tipping point appeared in the US media in 2003 and in the UK media in 2002. Through 2007, there were 222 articles with tipping point references to climate change in the UK and 108 articles in the US. In 2003 general usage of the term took off in the

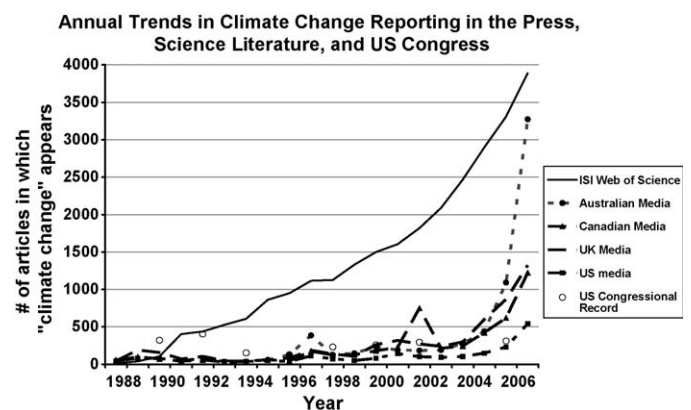


Fig. 1. Annual trends in climate change reporting. Year-to-year totals of articles in which the phrase “climate change” appears at least once (totals were not hand-sorted). ISI Web of Science database used for assessing annual trends in the scientific literature. Totals reported for national media are median figures. U.S. Congressional Record searched via Library of Congress THOMAS archive.

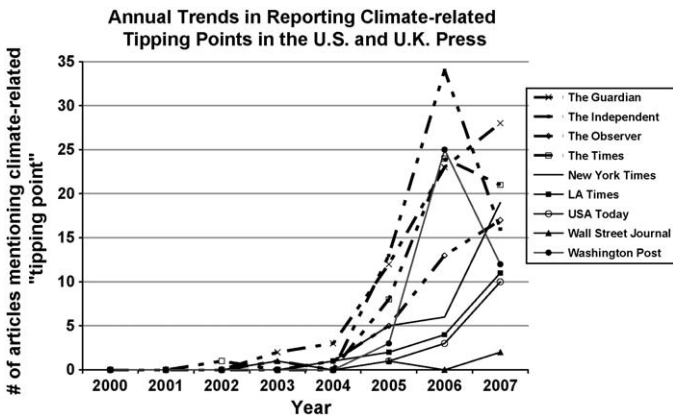


Fig. 2. Annual trends in reporting climate change-related tipping points. The full text of each paper was searched for instances of the phrase “tipping point” and “climate change” or “global warming” from 1988 to 2007 and then hand-sorted for relevance (years 1988–2001 had no instances of climate change-related tipping points in the press and are excluded from this figure). Searches included all articles and opinion pieces but excluded book reviews and letters to the editor. L.A. Times and Wall Street Journal searched via ProQuest database; The Guardian, The Independent and The Independent on Sunday, The Times and Sunday Times, New York Times, Washington Post and USA Today searched via the Lexis Nexis database; The Observer searched via the Factiva database.

press; 1408 of 1664 mentions in the US media (85%) occurred from 2003 onward, in the UK, 1211 of 1379 (88%) from 2003 onward. Climate change tipping points represent 16.1% of all tipping point mentions in the UK press, and 6.5% of such mentions in the US press. It should be considered in interpreting this data that the recent emergence of climate change tipping points in mainstream print media has coincided with a general increase in climate change related news stories.

It is interesting that tipping point warnings in popular discourse precede their use as a scientific concept in the published literature. It is also clear that scientific sources, if not scientific publications, are a frequent source of tipping points in media discourse. James Hansen and John Schellnhuber, in particular, introduced climate change tipping points into popular discussion before publishing scientific papers that employ the concept.

6. Results: scientific literature

Three research papers constitute the main publications and perhaps the entire primary research literature on climate change tipping points before 2007. Each paper is concerned with melting Arctic sea ice in climate model simulations, a subsequent point of public debate in the wake of the 2007 IPCC AR4. It appears the concept of climate change tipping points is introduced into the research literature by Lindsay and Zhang (2005) in their *Journal of Climate* article, “The Thinning of Arctic Sea Ice, 1988–2003: Have We Passed a Tipping Point?” The criterion they introduce for determining the crossing of a tipping point is system change initiated by an external forcing that is not required to sustain the new pattern of change: “The large changes that began in 1989 suggest that the system had reached a tipping point, a state of the system for which temporary changes in the external forcing (dynamics) created a large internal response that is no longer directly dependent on the external forcing and is not easily reversed” (p. 4881). Rapidity or abruptness of change is noted as a feature of Arctic sea ice, but not treated as definitive of tipping point crossing. Irreversibility is emphasized as likely, but not considered definitive. The non-linearity of the system change is not emphasized or remarked upon, and the notions of threshold and sensitivity are absent. No previous reference to climate change tipping points is noted and the novelty of this conceptual

application is not mentioned; however, the more familiar notion of turning point is used as a synonym for tipping point. Positive feedback is emphasized repeatedly. Issues of urgency or implications for policy change are not addressed or implied.

Winton’s (2006) paper is also titled with a question, “Does the Arctic sea ice have a tipping point?” Winton does not reference Lindsay and Zhang (2005), though there is similar concern with determining whether modeling simulations permit the attribution of tipping points to the climate system. Winton’s paper emphasizes positive feedback, non-linearity, and tests a hypothesis with clear policy implications: the degree to which climate model simulations used in the IPCC AR4 evince rapid change with potential for non-linear impacts on climate change. Concern regarding the exclusion of non-linear scenarios from IPCC assessment reports dates to as early as 2001 (Mastrandrea and Schneider, 2001). Oddly, Winton’s paper does not use the concept of “tipping point,” except in the title, and the paper never answers the question asked in the title in direct fashion. Winton does stress the quality of shifted equilibrium and the paper begins with the analogy of a slowly tipped glass that moves from an upright position to “a new stable equilibrium on its side” (p. 1).

Holland et al. (2006) underscore the rapid nature of Arctic sea ice changes and raise the question of how to assess whether a tipping point has been reached. They cite Lindsay and Zhang’s (2005) characterization, “strong positive feedbacks accelerate ice retreat and result in an era of thinner, less extensive ice cover in the Arctic,” though Holland et al. remain non-committal on the question of crossing a tipping point, citing a “patchy observational record” and the “considerable natural variability in the Arctic.” Holland et al. (2006), like Winton (2006), are examining the potential for abrupt transitions in climate model simulations used in the IPCC AR4 (2007). They are also concerned with the threat posed by abrupt change and cite Winton’s (2006) findings in their conclusion, which associates more frequent rapid change with higher greenhouse gas emissions scenarios. One might suggest there is an expanded conception of tipping points in Holland et al. (2006). Whereas Lindsay and Zhang (2005) applied the simple criterion of internal system response as newly dominant in accounting for change, Holland et al. introduce accelerated change that results from positive feedbacks as a feature of tipping point crossing.

7. Results: scientific literature: debate on tipping point usage

The scientific community’s informal assessments of the tipping point concept express a clear concern with increasing media attention to climate change tipping points. It is surprising that these assessments rarely focus on the primary scientific literature. In the most prominent example, Walker (2006) investigated the applicability of climate change tipping points in light of rapidly expanding media coverage and suggested the notion had “caught on in academic papers and political debates as well as headlines” (p. 802). Published as a “News Feature” for *Nature*, Walker defined tipping points in terms of internally driven system change that previously required external forcing and that had the potential for irreversibility. Tipping points are made of “self-sustaining feedback” (p. 804). The definition is similar to that used in Lindsay and Zhang’s (2005) work, and Walker interviews a number of prominent scientists on the topic. However, Walker’s conclusion lets the initial question go unanswered, and she shifts from a consideration of tipping points in climate systems to the matter of tipping points in human behavior.

An editorial from the editors of *Nature* (2006) also fails to comment on the extent of tipping point applications in the climate change research literature, while recommending its use for the understanding of social phenomena. The effect is to confuse the

trend by failing to determine if tipping point usage is primarily media or policy driven. Such objections are anticipated, at least in part, when commentators observe that the idea behind tipping points is not new; the editors of *Nature*, for example, suggest it is old wine in new bottles. Similarly, Gavin Schmidt (2006), a colleague of James Hansen at NASA, made this point in his explication of Hansen's meaning for the popular climate blog, *Real Climate*. However, if new terminology is now preferred, then why? What, if anything, is signaled by the fact that popular usage of climate change tipping points appears to precede and motivate more formal and scientific uses? These questions go unasked, although the conversation is suggestive of generative metaphor. The idea is not novel, but the contemporary application of the tipping point description is intended to produce new perspectives on a social policy problem by displacing conventional understandings of the situation.

8. Results: scientific literature: re-description and generative metaphor

Another interesting feature of the relationship between primary research and public discourse on climate change tipping points is the citation and re-description of scientific work in support of the notion when the referenced work does not explicitly mention tipping points. Hoegh-Guldberg et al. (2007), for example, present research suggesting climate change is “driving reefs toward the tipping point for functional collapse” (p. 1737). They use the term to indicate a rapid shift to a stable state that is probably irreversible. Once again, this is consistent with Lindsay and Zhang's (2005) initial meaning. However, Hoegh-Guldberg et al. (2007) cite Mumby et al. (2007) in support of their idea of an ecosystem tipping point, even though the referenced article does not use tipping terminology. It is hardly a question of distortion. Mumby et al. (2007) are clearly concerned with critical thresholds that once passed will result in irreversible change (also, P.J. Mumby is second author of the Hoegh-Guldberg et al. (2007) article). Yet, it is not made clear why the threshold concept is re-described as a tipping point by Hoegh-Guldberg et al. (2007).

The most illuminating example of re-description is James Hansen's recent work. Although Hansen began issuing tipping point forewarnings of danger in 2005, it is only in 2007 that tipping points find a place in his own research. In a paper discussing the divergence of his views from the IPCC AR4, Hansen (2007a) re-describes two of his previous publications in this manner: “Positive climate feedbacks and global warming already ‘in the pipeline’ due to climate system inertia together yield the possibility of climate ‘tipping points’ (Hansen et al., 2007a) . . .” (p. 5). In one of these referenced papers, Hansen et al. (2007b), “Climate Change and Trace Gases,” he does not use tipping point terminology, although the concept of “albedo flips” is suggestive of popular uses.

In the other referenced paper, Hansen et al. (2007a), “Dangerous human-made interference with climate: a GISS modelE study,” the terminology of tipping points is used though the matter is more complex. The paper in question was submitted in 2006, published for comment, revised in March 2007 in response to the comments of two anonymous referees, and accepted and published in its current form, 7 May 2007, with a NASA press release issued 30 May 2007. In this research, Hansen et al. (2007a) cite Lindsay and Zhang's (2005) use of tipping points (Hansen et al., 2007a, p. 2296), and conclude that the idea of a crossed tipping point for Arctic sea ice is not yet warranted. Later in the paper, Hansen et al. (2007a) also weigh in on Lovelock's (2006) contention of a crossed tipping point. In both cases, unavailability is a defining criterion for making the determination (p. 2306).

Three points are of interest: First, in terms of the content of the published paper, Hansen et al. (2007a) use more strict criteria than

Lindsay and Zhang (2005) and Lovelock (2006) for making a determination regarding the crossing of tipping points. It is a synonym for threshold in Lovelock's (2006) book. It is internally driven system change as a result of an external forcing that is no longer required to sustain change that defines tipping point crossing for Lindsay and Zhang (2005); unavailability or irreversibility were not required in this last case.

Second, Referee #1 for Hansen et al. (2007a) queries the appropriateness of tipping point usage in the manuscript. In response, Hansen justifies its inclusion in three ways: (a) by referencing to its prior use in Lindsay and Zhang (2005), (b) by stating its consistency with the conclusions offered in the paper, and (c) by emphasizing its efficacy for communicating with the public and policymakers about climate change dangers. Hansen claims of Lindsay and Zhang (2005) that “the phrase is used extensively (even in the paper's title),” although Lindsay and Zhang (2005) use the concept only three times in the body of their paper, which is the same number of uses as the published version of Hansen et al. (2007a). More importantly, Hansen elaborates his use of the tipping point concept in a manner extending the definition in Lindsay and Zhang.

“Tipping point”, although objectionable to some scientists, conveys aspects of climate change that have been an impediment to public appreciation of the urgency of addressing human-caused global warming. It is a valid concept: as climate forcing and global warming increase, a point can be reached beyond which part of the climate system changes substantially with only small additional forcing. Examples include loss of Arctic sea ice and ice sheet disintegration. The practical importance of these intervals of high sensitivity, paradoxically, is amplified by climate system inertia, especially the inertia of oceans and ice sheets. One effect of inertia, in the real-world case with continually increasing climate forcing, is that the system is out of equilibrium. The extent of disequilibrium (measured, e.g., by the planetary energy imbalance) may be enough, as an interval of high sensitivity is reached, to carry the system through a change (loss of all Arctic sea ice or disintegration of an ice sheet) with little or no additional forcing.

This helpful clarification does not make it into the published paper or appear until Hansen et al. (2008). Tipping points are a focus of the NASA (2007) press release for the paper. It emphasizes “critical tipping points,” and suggests that, “Tipping points can occur during climate change when the climate reaches a state such that strong amplifying feedbacks are activated by only moderate additional warming” (NASA, 2007, paragraph 3). The press release encourages the impression that the research is centrally concerned with tipping points, and at least one news story focused on this aspect primarily.

Third, the emphasis on the efficacy of tipping points for communicating with the public and policymakers about climate change dangers illustrates the role of generative metaphor. The presentation of tipping points varies across Lindsay and Zhang (2005), Hansen et al. (2007b), the reply of Hansen et al. (2007b) to the reviewer's comments, the NASA press release, and in subsequent press coverage. Each of these references is more or less consistent, and if taken as an instance of generative metaphor, it would represent the process of mapping a familiar description to a new domain. If viewed as an instance of re-description, or as simply “new wine in old bottles,” these slippages are disturbing since the description is imprecise. When viewed as an instance of generative metaphor, these slippages are to be expected as part of an effort to solve a policy problem by re-structuring public perception in a new and substantive way. As Ogunseitani (2003)

observes, generative metaphors are illuminated during efforts to “make the normative leap from findings of fact to policy recommendations” (p. 102), and Schön emphasizes how the initial efforts will be inexpert and imprecise. In Hansen's case, it is clear that tipping points express anxiety regarding the possibility that climate change may soon generate problems that are incapable of solution.

9. Results: media

Most news articles used tipping points only once and it is rare for the terminology to receive explicit definition. The term appeared multiple times in less than 15% of news stories. Very few stories used the term in the headline, and most news stories did not point to the novelty of the concept, or to the shift in policy debate its usage would seem to imply (Eilperin, 2006; Vergano and O'Driscoll, 2007). Such concerns might have been signaled implicitly by the common use of “scare quotes” in using the term. On occasion an adjective is used, such as “perceptual,” “legal,” or “consensual” tipping points.

In instances where tipping points receive explicit definition, the definition is often alarmist: “Among climatologists who study the Amazon, the buzz words these days are “tipping point” – the moment at which damage to the environment is so severe and widespread that it pushes the ecosystem into an irreversible cycle of self-destruction” (Rohter, 2007, p. A3). Most references to tipping points are of this sort. The term is mentioned and followed by speculation on the possible consequences of crossing tipping points, usually without indication of whether the possibility is plausible, probable, or quite likely. As Hulme's (2006) criticism of tipping point terminology implied, the connection of tipping points to worst-case disaster or crisis scenarios is evident.

A good example is Vergano and O'Driscoll's (2007, April 4) article, “Is Earth near its ‘tipping points’? Scientists: there may be no return from climate change,” which reports the release of the WG II IPCC AR4. The article begins, “Earth is spinning toward many points of no return from the damage of global warming, after which disease, desolation and famine are inevitable. . .”. Though a typical example of how tipping points are used, this article is distinguished by a discussion of whether the use of worst-case scenarios in policy and public discourse is appropriate. Tipping points were not mentioned in the IPCC AR4 or in accompanying material from the organization. Several other news stories emphasized the idea of a discrete threshold or “point of no return” for climate change danger.

Some stories reference skeptical climate change discourse, but in only two significant instances is anthropogenic climate change questioned directly. When debate is used as an organizing frame for the article, it is a question of adaptation vs. precautionary responses, or the degree of anthropogenic contribution. Most articles emphasize amplified urgency, rather than balance. Climate scientists are frequent sources of quotation, as are politicians and environmental advocates. Al Gore and Tony Blair appear with some frequency. Among experts, James Hansen, James Lovelock, and Mike Hulme appear most often. Mark Serreze is a frequent voice in *The Independent*.

The referent for tipping point usage was distinguished as physical, social, biological/special, and indiscriminate. Only the *Washington Post* featured more social referents than physical referents with intended meaning. The *Wall Street Journal* and *New York Times* featured roughly equal physical and social uses. The *LA Times* and *USA Today* used physical references slightly more frequently. The U.K. papers used physical references most frequently, with the *UK Times* at 61% and *The Independent* at 71% of all referents being physical.

Physical and social referents for climate change tipping points draw on similar notions of non-linear and abrupt change, but the

connotations of catastrophe, danger and uncontrollability are prominent when physical systems are the referent. Several references insist on these associations and the urgency they should entail. The most frequent expression of urgency is emphasis on the irreversibility of events or irreparability of expected damages; loss of control is sometimes mentioned in such contexts and appears to be an implicit understanding. Physical tipping points are often considered a point of no return. When tipping points are applied to social referents, these dimensions are almost always absent. Whereas tipping point proponents believe the vulnerability of climatic systems is masked by misplaced beliefs in their resilience, the vulnerability of social systems to change is encouraged as a promising insight. The resilience or lack of change in public opinion and social systems is the danger in these cases.

It is typical of physical references to mention sea ice or glaciers. Social tipping points most frequently deal with business, technology adoption, or public opinion. News in *The Independent* has featured discussion on whether physical tipping points have already been passed. The most interesting case involves the paper commissioning its own analysis showing that a tipping point – for CO₂ equivlency understood in terms of heat absorbing properties – had already been crossed (McCarthy, 2006). Otherwise, it is extremely rare for news articles to suggest physical tipping points have already been passed, particularly in the United States. *The Los Angeles Times* quotes a Scripps' scientist saying, “People talk about tipping points. We have gone past it. There is nothing we can do to stop it. The only question is how big a hit we are going to take” (Hotz and Cline, 2006, A1). This perspective does make evident an interesting feature of tipping point discourse. While typically perceived as an alarmist or alarming discourse used to advance a precautionary policy, once passed, tipping points would appear to entail a policy of adaptation.

10. Discussion

The most prominent uses of tipping point terminology in climate change communication draw attention to the threats represented by abrupt transitions, non-linearity, threshold crossing, positive feedbacks, and potential irreversibility, often in connection to anthropogenic GHG forcing. These uses are shaped by concerns with the policy-relevance and the public communication of climate science. For example, Winton (2006) and Holland et al. (2006) searched modeling simulations used in the IPCC AR4 for evidence of rapid, non-linear change in Arctic sea ice and returned interesting though equivocal results. Their research clearly anticipates debate over how to express the urgency associated with threats of abrupt change in 2007 IPCC AR. The 2007 IPCC AR4 did not utilize tipping point terminology or suggest new urgency regarding abrupt climate change.

The desire to increase public urgency is driving the mainstreaming of tipping points in climate change communication, not the reporting of peer-reviewed research. Hansen warned about climate change tipping points well before publishing on the concept, as did John Schellnhuber. These warnings drew the attention of their national governments, which in turn amplified concerns in media and public discourse. By 2006, tipping point forewarnings were associated with prominent scientists and public figures in mainstream media coverage. The tipping point trend was recognized as novel and perhaps even overestimated in its frequency. The earliest uses were clearly metaphorical. Only the most rudimentary forms of explication and measurement existed for climate change tipping points. In discussions of the physical components of the climate system, most media uses of the terminology prognosticate a tipping point (they speak of passing them in the future) and suggest a set of undesirable consequences that might occur as a result (though often without a measure of

plausibility or probability attached). It is clear that the broad application of tipping points to climate change is intended to imply that the climate system is much more sensitive to changes than commonly thought, and it introduces the idea of a discrete threshold (a “point”) for defining danger. The main anxiety is that climate change could soon generate problems that are incapable of solution.

The lack of tipping point forewarnings in the 2007 IPCC AR4 is open to several interpretations. In Hulme’s (2006) view, the difference between scientists issuing tipping point forewarnings and the 2007 IPCC AR4 resulted from a distortion of scientific knowledge, one motivated by use of a “discourse of catastrophe” to communicate worst-case scenarios. Tipping points warnings of abrupt climate change were new forms of an overly alarmist climate discourse. Hansen et al. (2007a) accounts for the divergence of his views from the IPCC AR4 in terms of “scientific reticence,” a concept intended to illustrate the misuse of scientific skepticism in contentious policy situations. Hansen et al. (2008) have also begun to better elaborate the tipping point concept in the primary literature. The same is true for Lenton et al. (2008), who explicitly diverge from the IPCC AR4 in favor of greater urgency on the basis of an elaborated scientific terminology for “tipping” phenomena. Though their respective points of emphasis differ – Hansen stresses inertia in the climate system and Lenton and co-workers emphasize bifurcation – both uses of tipping point represent an effort to transform the long-term processes of climate change into threshold oriented warnings on the assumption that these better suit human perceptions of danger.

It is likely that melting sea ice will become an increasingly contentious topic of debate in climate change discussions. It remains the most frequent example of tipping points in media coverage, and insofar as tipping points remain a subject of dispute, the debate will likely focus on the proper interpretation of sea-ice changes.

Climate change communication among the scientific community, policymakers, and mainstream media is characterized by a highly complex set of interactions, and it is difficult to draw firm conclusions based on our limited methodology. It is important not to be misled regarding the impact of public debate on scientific conceptualization by interpreting influence simply in terms of the priority of publication dates. Moreover, the degree to which public dispute over tipping points and the appropriate urgency for warnings was preceded and mediated by informal professional discussions is difficult to gauge. Lenton et al. (2008), for example, was based in an expert elicitation exercise that drew on the collective judgments of many participants.

11. Conclusion

The use of tipping points originates in a desire to reshape how the public views dangerous climate change. Hansen’s (2005) initial use of tipping point emerged in opposition to the burning embers diagram of the IPCC AR3, a representation that was criticized as fuzzy and incapable of motivating action. The depiction had no clear thresholds and the possibility of large-scale discontinuities was simply one reason for concern among many. Tipping points, on the other hand, suggest moments or intervals of high sensitivity to abrupt and irreversible changes, and they are intended to aid in the identification of discrete thresholds for danger. Media coverage emphasizes these points in a sensational and alarming way. As Hansen (2007b) argued, the rationale for tipping points is the belief that their use “conveys aspects of climate change that have been an impediment to public appreciation of the urgency of addressing human-caused global warming”. Lenton et al. (2008) quite consciously develop their vocabulary on behalf of a proposal for a global warning system.

The initial decision to use tipping points is based primarily in assumptions regarding communicative effect. If tipping points are considered in terms of generative metaphor, this intention is more apparent. Proponents of tipping points believe that public opinion does not express suitable urgency, and that the lack of urgency results from the “false sense of security” produced by smooth projections of change (Lenton et al., 2008, p. 1792). Critics of tipping points argue that increased public urgency is not warranted, or that it may not have the desired effect (leading instead to fatalism or cynicism). Some of the disagreement over tipping points is based in a difference of opinion regarding the ability to determine a discrete threshold for danger. Tipping points draw attention to intervals of sensitivity to rapid, non-linear change, but the determination of a tipping point is entangled with assumptions regarding the capacity of humans to respond to danger. Tipping points express anxiety over the possibility that climate change could pose problems incapable of human solution, or a loss of control. Insofar as social behavior is the primary referent for tipping points, Gladwell’s assumptions regarding human communication are usually accepted without discussion.

There is a greater need to acknowledge the metaphorical character of tipping point warnings of climate change danger, as scientists and others strive to reshape climate change as a social policy problem. This does not preclude the development of concepts and models. As part of this process, it may prove helpful to better distinguish tipping points, in the sense of change coming from the internal dynamics of a system rather than an external force, from thresholds (a shift from one identifiable regime to another at an identifiable point without entailing rapid change), feedbacks (a forcing that that is rapidly cumulative over cycles but which remains the same), and other concepts implied in the explanation of climatic systems.

Finally, the tendency to slip between or conflate physical and social references in tipping point discourse should be assessed more critically. There are numerous examples of this problem and it is perhaps encouraged by the conclusion of Lenton et al. (2008) in favor of “a rigorous study of tipping elements in human socio-economic systems” (p. 1792). In such instances, it is clear that the use of tipping point frameworks imply not only a policy orientation, but also an understanding of how human communication guides social behavior. The appropriateness of tipping points should be debated and assessed in terms that make these assumptions explicit.

Acknowledgements

The authors would like to acknowledge the generous insights and criticism shared by Jeremy Packer. The article also benefited from the perceptive questions of Bill Kinsella, Carolyn Miller, two anonymous referees, the editors of this journal, and conversations with Chad Lavin. Finally, we would like to acknowledge the research assistance of Kristen Hines, and research support from the University of Minnesota, Twin Cities.

References

- Antilla, L., 2005. Climate of skepticism: US newspaper coverage of the science of climate change. *Global Environmental Change* 15, 338–352.
- Boykoff, M.T., Boykoff, J.M., 2004. Balance as bias: global warming and the US prestige press. *Global Environmental Change* 14, 125–136.
- Boykoff, M.T., 2007. Flogging a dead norm? Newspaper coverage of anthropogenic climate change in the United States and United Kingdom from 2003–2006. *Area* 39, 470–481.
- Brüning, R., Lohmann, G., 1999. Charles S. Peirce on creative metaphor: study of the conveyor belt metaphor in oceanography. *Foundations of Science* 4, 389–403.
- Dispensa, J.M., Brulle, R.J., 2003. Media’s social construction of environmental issues: focus on global warming—a comparative study. *International Journal of Sociology and Social Policy* 23, 74–105.

- Eilperin, J., 2006. Debate on climate shifts to issue of irreparable change: some experts on global warming foresee 'Tipping Point' when it is too late to act. *The Washington Post*, January 29, A01.
- Ereaut, G., Segnit, N., 2006. Warm Words: How are we Telling the Climate Story and can we Tell it Better? Institute for Public Policy Research, London.
- Gladwell, M., 1996. The tipping point. *The New Yorker*, June 3 (http://www.gladwell.com/1996/1996_06_03_a_tipping.htm).
- Gladwell, M., 2000. *The Tipping Point: How Little Things can Make a Big Difference*. Back Bay Books, Boston, MA.
- Hansen, J., 2005. Is there still time to avoid "dangerous anthropogenic interference" with global climate? A tribute to Charles David Keeling. *American Geophysical Union*, San Francisco, December 6 (<http://www.columbia.edu/~jeh1/>).
- Hansen, J., et al., 2007a. Dangerous human-made interference with climate: a GISS model E study. *Atmospheric Chemistry & Physics* 7, 2287–2312.
- Hansen, J., et al., 2007b. Climate change and trace gases. *Philosophical Transactions of the Royal Society* 365, 1925–1954.
- Hansen, J., 2007a. Scientific reticence and sea level rise. *Environmental Research Letters* 2, 1–6.
- Hansen, J., 2007b. Reply to two referees' comments, March 27 (<http://www.cosis.net/members/journals/df/article.php?paper=acpd-6-12549>).
- Hansen, J., 2007c. Iowa coal case. Testimony submitted to the Iowa Utilities Board, November 5 (http://www.columbia.edu/~jeh1/2007/IowaCoal_20071105.pdf).
- Hansen, J., et al., 2008. Target atmosphere CO₂: where should humanity aim? *The Open Atmospheric Science Journal* 2, 217–231.
- Hoegh-Guldberg, et al., 2007. Coral reefs under rapid climate change and ocean acidification. *Science* 318, 1737–1742.
- Holland, M.M., Bitz, C.M., Trembley, B., 2006. Future abrupt reductions in the summer Arctic sea ice. *Geophysical Research Letters* 33, L23503.
- Hotz, R.L., Cline, E., 2006. Hot? Yes. Global Warming? Maybe; causes of the current heat wave are complex. *Los Angeles Times*, July 26, A1.
- Hulme, M., 2006. Chaotic world of climate truth. *BBC News*, November 4 (<http://news.bbc.co.uk/1/hi/sci/tech/6115644.stm>).
- Hulme, M., 2008. Geographical work at the boundaries of climate change. *Transactions of the Institute of British Geographers* 33, 5–11.
- Jacques, P.J., Dunlap, R.E., Freeman, M., 2008. The organization of denial: conservative think tanks and environmental skepticism. *Environmental Politics* 17, 349–385.
- Kerr, R.A., 2008. Climate tipping points come in from the cold. *Science* 319, 153.
- Lahsen, M., 2005. Technology, democracy, and U.S. climate politics: the need for demarcations. *Science, Technology and Human Values* 30, 137–169.
- Lenton, T.M., Schellnhuber, H.J., 2007. Tipping the scales. *Nature Reports*, November 22 (<http://www.nature.com/climate/2007/0712/pdf/climate.2007.65.pdf>).
- Lenton, T.M., et al., 2008. Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences* 105, 1786–1793.
- Lindsay, R.W., Zhang, J., 2005. The thinning of Arctic sea ice, 1988–2003: have we passed a tipping point? *Journal of Climate* 18, 4879–4894.
- Lovelock, J., 2006. *The Revenge of Gaia*. Basic Books, New York.
- Mastrandrea, M.D., Schneider, S.H., 2001. Integrated assessment of abrupt climatic changes. *Climatic Policy* 1, 433–449.
- McCarthy, M., 2006. Greenhouse gases are already past threshold that spells disaster; climate change: the tipping point. *The Independent*, February 11, 2.
- McCright, A.M., Dunlap, R.E., 2000. Challenging global warming as a social problem: an analysis of the conservative movement's counter-claims. *Social Problems* 47, 499–522.
- McCright, A.M., Dunlap, R.E., 2003. Defeating Kyoto: the conservative movement's impact on U.S. climate change policy. *Social Problems* 50, 348–373.
- Moser, S.C., Dilling, L., 2007. Toward the social tipping point: creating a climate for change. In: *Creating a Climate for Change: Communicating Climate Change & Facilitating Social Change*, Cambridge University Press, New York, pp. 491–516.
- Mumby, P.J., Hastings, A., Edwards, H.J., 2007. Thresholds and the resilience of Caribbean coral reefs. *Nature* 450, 98–101.
- NASA, 2007. Press release: research finds that earth's climate is approaching 'dangerous' point. May 30 (<http://www.giss.nasa.gov/research/news/20070530/>).
- Nature, 2006. Editor's summary. *Nature* 441, 785.
- Nisbet, M.C., Myers, T., 2007. Twenty years of public opinion about global warming. *Public Opinion Quarterly* 71, 444–470.
- Ogunseitan, O.A., 2003. Framing environmental change in Africa: cross-scale institutional constraints on progressing from rhetoric to action against vulnerability. *Global Environmental Change* 13, 101–111.
- Oreskes, N., 2004. The scientific consensus on climate change. *Nature* 306, 1686.
- Pettenger, M.E., 2007. *The social construction of climate change*, Ashgate, Burlington, VT.
- Risbey, J.B., 2008. The new climate discourse: alarmist or alarming? *Global Environmental Change* 18, 26–37.
- Rohter, L., 2007. Brazil, alarmed, reconsiders policy on climate change. *New York Times*, July 31, A3.
- Russill, C., 2008. Tipping point forewarnings of climate change communication: some implications of an emerging trend. *Environmental Communication* 2, 133–153.
- Schmidt, G., 2006. Runaway tipping points of no return. *Real Climate Blog*, July 5 (http://www.realclimate.org/index.php/archives/2006/07/runaway-tipping-points-of-no-return/langswitch_lang/sk).
- Schneider, S.H., 1988. The greenhouse effect and the U.S. summer of 1988: cause and effect or a media event: an editorial. *Climatic Change* 13, 113–115.
- Schön, D.A., 1979. *Generative metaphor: a perspective on problem-setting in social policy*. In: *Metaphor and Thought*, Cambridge University Press, Cambridge, pp. 254–284.
- Skodvin, T., 2000. *Structure and Agent in the Scientific Diplomacy of Climate Change*. Kluwer Academic Publishers, Dordrecht, Netherlands.
- Smith, H.A., 2007. Disrupting the global discourse of climate change: the case of indigenous voices. In: *The Social Construction of Climate Change*, Ashgate, Burlington, VT, pp. 197–215.
- Ungar, S., 1998. Bringing the issue back in: comparing the marketability of the ozone hole and global warming. *Social Problems* 45, 510–527.
- Ungar, S., 2007. Public scares: changing the issue culture. In: *Creating a Climate for Change: Communicating Climate Change & Facilitating Social Change*, Cambridge University Press, New York, pp. 81–88.
- Vergano, D., O'Driscoll, P., 2007. Is Earth near its 'tipping points'? Scientists: there may be no return from climate change. *USA Today*, April 4, 1D.
- Walker, G., 2006. The tipping point of the iceberg. *Nature* 441, 802–805.
- Williams, J., 2000. The phenomenology of global warming: the role of proposed solutions as competitive factors in public arenas of discourse. *Human Ecology Review* 7, 63–72.
- Winton, M., 2006. Does the Arctic sea ice have a tipping point? *Geophysical Research Letters* 33, L23504.
- Wunsch, C., 2002. What is thermohaline circulation? *Science* 238, 1179–1181.