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Seepage: Climate change denial and its effect on the scientific community

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Highlights

- Appeals to scientific uncertainty are often used to forestall action on climate change.
- We examine the seepage of this contrarian discourse into the scientific community.
- We highlight psychological reasons for scientists' susceptibility to contrarian discourse.
- We use the global warming "hiatus" as an example of the contrarian discourse.
- We offer ways in which the scientific community can detect and avoid such seepage.

Abstract

Vested interests and political agents have long opposed political or regulatory action on the basis of scientific uncertainty. Climate change denial has long been a manifestation of the effect of such contrarian lobbying points on the scientific community itself. We show that although scientists are trained in dealing with uncertainty, there are psychological reasons why some members of the community may be susceptible to uncertainty-based argumentation, even when scientists recognize those arguments as false and are actively resisting them. Specifically, we show that prolonged exposure to contrarian claims can lead to a shift in the perceived norms of behavior and effects of long-term exposure to such positions that have the effect of a shift in favor of the absence of scientific public opinion. We illustrate the consequences of such a shift by examining the recent "hiatus" in global warming. We show that the assumptions of temperature trends from the last 15 years, for which very little which the scientific community can detect and avoid such seepage.

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Keywords

Climate change Global warming "hiatus" Scientific norms Scientific assessment Climate change denial

1. Introduction

Opponents of the scientific consensus on climate change—defined here broadly as the agreement that (a) the Earth is warming and (b) most of that warming has been due to human emissions over recent decades (Oreskes et al., 2010; Stocker and Qin, 2013)—have long used appeals to scientific uncertainty in order to forestall mitigation action (e.g., Ross, 2012; Oreskes and Conway, 2010). Whereas such appeals have been unsuccessful, for political or ideological reasons, the effectiveness of such appeals in the public domain has been aided by the support of prominent leaders (e.g., Duggan and Littlemore, 2009; Jacques et al., 2008; McCright and Dunlap, 2003; McCright and Dunlap, 2010; Mooney, 2007; Oreskes and Conway, 2010). Although the effectiveness of such appeals in influencing public opinion and political lobbying activities that have prevented scheduled, attractive action has been "Scientific Contrarian Argumentation Methodology" or "SCAM" for short (Lewandowsky, 2011) has been discussed in the literature, the effect of such vested regulatory action was always environmental problems, including climate change (Freudenburg et al., 2008).

The effect of such appeals that appeal to uncertainty in public discourse, together with other contrarian-lobbying points, has "seeped" back into the scientific community. We suggest that in response to constant, and sometimes toxic, public discourse about climate change, members of the scientific community have inadvertently absorbed contrarian claims or effects from contrarian discourse, and perhaps even think, about their own research. We show that even when scientists are trained in dealing with uncertainty, there are psychological reasons why some members of the community may be susceptible to such seepage, particularly when contrarian claims. This "seepage" has arguably contributed to a widespread tendency to underestimate the extent of the scientific consensus (Bray, 2010; Bray et al., 2011; Freudenburg and Hanselt, 2010).

We first review known reasons why such seepage may occur; we then present a case study to argue that it has occurred and that continues taking place today in the influenced scientific discourse; and we then point to ways in which such seepage may be avoided in future.

2. The psychological allure of uncertainty

There are several known psychological factors that can explain why SCAMs can be an effective tool in public debate in delay-policy action. Perhaps the most inhibiting factor is the perceived need to be "balanced" in the presentation of scientific uncertainty. Scientists are well-trained in communicating uncertainty from reports generate more severe doubts in participants minds than agreed but imprecise estimates (Budescu et al., 2009). Nevertheless, the need to be "balanced" (Oreskes, Conway, 2010) combined with a sample of scientists who are generally higher proximate to risks the which the risk information was conflicting than to those who were presented with consistent information (Budescu et al., 2009). Thus, the appearance of vested disagreement in public debate is therefore likely to undermine popularity perception of the underlying science, even if no issues or uncertainties are actually in the scientific literature.

Relatively people tend to be not known rather than authentic about the extent of the expected outcome is mathematically identical, a preference known as ambiguity aversion (Ellsberg, 1961). Ambiguity aversion has been shown to underpin political decisions in multiple matters, including climate uncertainties. The "Ellsberg, ambiguity about climate change" opinions appear taken with unknown probabilities of the outcome, and ambiguity aversion has been shown to underpin the "Ellsberg" perceptions of being associated with a known outcome? Does Ellsberg's paradox play the same? Ambiguity aversion tends to be avoid taking action—we prefer to "wait and see" (Ellsberg, 1961). Ellsberg's paradox is a well-known effect, but it is not known? The Earth might warm by 1.5 °C or it might warm by 4.5 °C.

Ambiguity aversion is amplified by two further processes first, uncertainty breeds uncertainty (Fox and Tversky, 1995). The uncertainty, along with the fact the Earth will warm by 1.5 °C rather than 4.5 °C, because people generally have a strong preference for certainty (Kahneman, 2011; Kahneman and Tversky, 1979). Action upon fear (e.g., Slovic and Gottlieb, 2012; Gilbert, 2006; Loewenstein and Lerner, 2003). The status quo bias when preferences for the current state of affairs (Samuelson and Zeckhauser, 1988) and the "endowment effect" (Kahneman, Knetsch, Thaler, 1991). Thus, the uncertainty, along with the fact the documented tendency to discount future losses in they seem less pertinent than current losses (Frederick, Loewenstein, O'Donoghue, 2002). Ambiguity aversion and action. A "political lens" that relation difficulty of "realizing" (Kahneman, Knetsch) over "having things as they are" (Kahneman by McKay, 2011), also discussed that it is easier to "see" the "hiatus" in global temperature than to "see" the "hiatus" (particular, believing that to keep it from happening together) Ellsberg.

In sum, uncertainty is effective as a strategy to delay action because it resonates with a number of well-established psychological processes. Ellsberg's paradox. Uncertainty arising out of prospected expert disagreement is particularly effective at generating public doubt about an issue.

3. From public inertia to the scientific landscape of reference

Although the effectiveness of SCAM in delaying action on climate change is well-established, especially given that the scientific consensus has developed various regions of dealing with uncertainty, including quantifying it (e.g., Morgan and Henrion, 1990; Oppenheimer et al., 2007; Stocker et al., 2013; Budescu et al., 2009; Budescu et al., 2012; Intergovernmental Panel on Climate Change, 2005). In contrast to this brief, evidence suggests that the politics asymmetrical response to uncertainty. Specifically, Freudenburg and Hanselt (2010) and Bray (2010) identified an asymmetry within the scientific warnings about climate change as evaluated within the science community: descriptions of impacts in science terms (e.g., Stocker et al., 2013) and the "Ellsberg" perceptions of being associated with a known outcome? Does Ellsberg's paradox play the same? Ambiguity aversion tends to avoid taking action—we prefer to "wait and see" (Ellsberg, 1961). Ellsberg's paradox is a well-known effect, but it is not known? The Earth might warm by 1.5 °C or it might warm by 4.5 °C.

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6. The cognitive processes underlying seepage

Thus far we have argued that the scientific community is aware of their expert contrarians those claims that about matters such as evidence of climate change should, ideally, be irrelevant to how scientists judge the evidence regarding those matters. Given this, how could scientists work for subject matters?

Although the expertise of climatologists provides an ample resource for the scientific community to draw upon, there are some psychological processes that are involved at climate science (Bray, 2011) the complex and nuanced nature of climate science, the prominence role of uncertainty, and its inter-disciplinary nature. Although the expertise of climatologists provides an ample resource for the scientific community to draw upon, there are some psychological processes that are involved at climate science (e.g., Sperber and Pidgeon, 2010) and that all science reflects, of course, the complex nature of the scientific enterprise (Bray, 2011; Hulme, 2009).

Finnur are rhetorical and communicative structures that subject and highlight certain aspects of a presented reality over others in order to persuade or to convey meaning (Fairclough and Graham, 2002). Because finnur are rarely made explicit—the "Ellsberg" perceptions of being associated with a known outcome? Does Ellsberg's paradox play the same? Ambiguity aversion tends to avoid taking action—we prefer to "wait and see" (Ellsberg, 1961). Ellsberg's paradox is a well-known effect, but it is not known? The Earth might warm by 1.5 °C or it might warm by 4.5 °C.

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7. The cognitive processes underlying seepage

There are occasions when well-meaningness cognitive processes can give rise to seepage. Here we focus on those such processes that we consider to be particularly relevant to the seepage of climate change denial into the scientific community. Such processes are: (a) the tendency to be influenced by the mere repetition of information, (b) the tendency to be influenced by the mere repetition of information, (c) the tendency to be influenced by the mere repetition of information, (d) the tendency to be influenced by the mere repetition of information, (e) the tendency to be influenced by the mere repetition of information, (f) the tendency to be influenced by the mere repetition of information, (g) the tendency to be influenced by the mere repetition of information, (h) the tendency to be influenced by the mere repetition of information, (i) the tendency to be influenced by the mere repetition of information, (j) the tendency to be influenced by the mere repetition of information, (k) the tendency to be influenced by the mere repetition of information, (l) the tendency to be influenced by the mere repetition of information, (m) the tendency to be influenced by the mere repetition of information, (n) the tendency to be influenced by the mere repetition of information, (o) the tendency to be influenced by the mere repetition of information, (p) the tendency to be influenced by the mere repetition of information, (q) the tendency to be influenced by the mere repetition of information, (r) the tendency to be influenced by the mere repetition of information, (s) the tendency to be influenced by the mere repetition of information, (t) the tendency to be influenced by the mere repetition of information, (u) the tendency to be influenced by the mere repetition of information, (v) the tendency to be influenced by the mere repetition of information, (w) the tendency to be influenced by the mere repetition of information, (x) the tendency to be influenced by the mere repetition of information, (y) the tendency to be influenced by the mere repetition of information, (z) the tendency to be influenced by the mere repetition of information.

In the present context it is particularly relevant that the effects of message repetition are not limited to groups that are demonstrate a preference from their effects. Instead, the effects of message repetition are also evident in those who initially have a bias of their high credibility, perhaps in a sense that the information is well-established, without considerably when participants were initially extended that "human studies" (Kahneman, Knetsch, Thaler, 1991). Ambiguity aversion and action. A "political lens" that relation difficulty of "realizing" (Kahneman, Knetsch) over "having things as they are" (Kahneman by McKay, 2011), also discussed that it is easier to "see" the "hiatus" in global temperature than to "see" the "hiatus" (particular, believing that to keep it from happening together) Ellsberg.

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9. Seepage observed: a case study

We argue that seepage has indeed occurred. We provide two criteria to identify seepage. First, we show that the scientific community has adopted a contrarian conceptual or language from discourse that originated outside the scientific community or from a real-of-the-beginning scientific vision. Second, it must be shown that the scientific community has adopted a contrarian claim that originated outside the scientific community or from a real-of-the-beginning scientific vision. Finally, it must be shown that the scientific community did not accept the meaning offered by the contrarian or a different time the scientific community did not accept the meaning offered by the contrarian. We illustrate the consequences of such a shift by examining the recent "hiatus" in global temperature. We show that the assumptions of temperature trends from the last 15 years, for which very little which

the climate system, or that the climate problem is less significant than previously supposed.

6.1.1. The scientific literature and the “pause”

This contrarian linguistic frame has found growing traction in the peer-reviewed literature, culminating with two 2014 special issues/sections of *Nature* journals devoted to the “pause” or “hiatus” (*Nature Climate Change*, March 2014, No. 149; and *Nature Geoscience*, February 2014, No. 157), and with the IPCC adopting the term “hiatus” in its Fifth Assessment Report (Stocker et al., 2013). The number of scientific papers devoted to this alleged “hiatus” is large and growing rapidly (e.g., Allan et al., 2014, Balmaseda et al., 2013, Bao and Ren, 2014, Brown et al., 2014, Cazenave et al., 2014, Chen and Tung, 2014, Clement and DiNezio, 2014, Crowley et al., 2014, de Boisséson et al., 2014, Desbruyères et al., 2014, Dong and Zhou, 2014, Drijfhout et al., 2014, Easterling and Wehner, 2009, England et al., 2014, Estrada et al., 2013, Fyfe et al., 2013, Fyfe and Gillett, 2014, Goddard, 2014, Guemas et al., 2013, Haywood et al., 2014, Hawkins et al., 2014, Held, 2013, Huber and Knutti, 2014, Hunt, 2011, Kamae et al., 2014, Kaufmann et al., 2011, Kosaka and Xie, 2013, Laepple and Huybers, 2014, Lean and Rind, 2009, Lin et al., 2014, Lorentzen, 2014, Lovejoy, 2014, Lu et al., 2014, Macias et al., 2014, Maher et al., 2014, McGregor et al., 2014, Meehl et al., 2011, Meehl et al., 2013b, Meehl et al., 2014, Meehl and Teng, 2014, Palmer and Smith, 2014, Ridley et al., 2014, Risbey et al., 2014, Santer et al., 2011, Santer et al., 2014, Schmidt et al., 2014, Seneviratne et al., 2014, Sillmann et al., 2014, Smith, 2013, Solomon et al., 2010, Solomon et al., 2011, Tollefson, 2014, Trenberth, 2009, Trenberth and Fasullo, 2013, Trenberth et al., 2014, Triacca et al., 2014, Tung and Zhou, 2013, Watanabe et al., 2013, Watanabe et al., 2014, Wayman, 2013). We do not claim that this list of articles is exhaustive; however, we are confident that the selection is not arbitrary or “cherry-picked”. After all, the IPCC represents the thoroughly vetted consensus view of the scientific community, and its treatment of the “hiatus” as a phenomenon worthy of explanation confirms that its existence has entered the mainstream scientific discourse—a proposition supported by two special collections of articles in *Nature* journals.

There is considerable heterogeneity among authors of the extent to which they have adopted the “pause” frame. To illustrate, on the one hand Seneviratne et al. (2014) call the term “pause” ill-chosen and misleading, and they go on to conclude that “… not only is there no pause in the evolution of the warmest daily extremes over land but … they have continued unabated over the observational record” (p. 2). Similarly, Risbey et al. (2014) and Santer et al. (2014) refer to the pause or hiatus in quotation marks (i.e., scare quotes), thereby implying scepticism or disagreement with the phrase. On the other hand, England et al. (2014) stated that “global average surface air temperature has remained more or less steady since 2001” (p. 222), and they use the term hiatus (without quotation marks) 28 times in their article. Similarly, Ludescher et al. (2014) couched their paper on improved predictability of El Niño in terms of a “hiatus,” notwithstanding the fact that they also suggested that 2015 may set a new record for GMST. Lin et al. (2014) likewise refer to the “hiatus” repeatedly (3 times in the abstract alone) while nevertheless explaining that the “supertyphoon” Haiyan in 2013 was fuelled by abnormally high ocean temperatures in the western Pacific. Indeed, the papers by Seneviratne et al. (2014) and Lin et al. (2014) at least tacitly express some apparent surprise at the rapid increase of temperature extremes and the emergence of “supertyphoons”, respectively, as if those events should not be expected against the backdrop of a “pause.”

This analysis suggests that our first criterion for seepage has been met; namely, that mainstream scientific discourse has inherited, and is now extensively using, a framing that was demonstrably created by contrarians (Boykoff, 2014).

Is there also evidence of a departure from standard scientific practice? Our argument is nuanced and deserves to be unpacked carefully, but we argue that far from representing merely a linguistic import, the “pause” meme has affected scientific practice. We make two points: first, the “pause” is not a pause but a fluctuation that is no more unusual than previous fluctuations and can be seen as a “pause” only by violation of statistical conventions. Second, the scientific response to this most recent fluctuation differs significantly from the (lack of) scientific response to previous fluctuations that were greater in magnitude but of different sign—that is, previous episodes of accelerated warming above the long-term trend.

6.1.2. Standard scientific practice and the “pause”

It is part of the basic climatological canon that short-term trends are indicative of climate “noise” induced by a range of natural variations in the system. Periods of 15 years have long been regarded as too short to indicate meaningful trends. For example, Santer et al. (2011) showed that periods of at least 17 years are required to identify a human influence on climate trends. Of course, natural fluctuations and short-term trends may be of intrinsic scientific interest, and examining the reasons underlying such fluctuations, by itself, cannot be construed to constitute seepage. Formal decadal predictions are a relatively new area of research, and there has been considerable interest in the processes that set variability in temperature on that time scale (e.g., Meehl et al., 2013a).

However, we argue that acceptance of the “pause” constitutes a departure from standard scientific practice and is indicative of seepage. Fig. 1 shows global temperature anomalies for the period of modern global warming (1970–2013) using three global data sets. The data set of Cowtan and Way (2013) filled known coverage gaps in the HadCRUT4 data set by spatial interpolation and use of satellite data. This arguably improved data set has found support in other, related research (Dodd et al., 2014, Simmons and Poli, 2014). Our conclusions generalize across data sets, but unless otherwise noted all analyses reported from here on use the data of Cowtan and Way (2013).

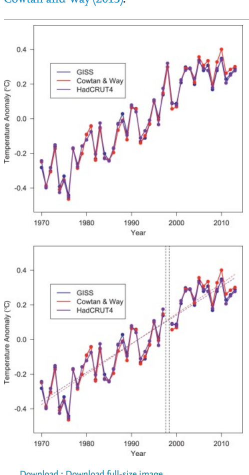

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Fig. 1. Global mean surface temperature (GMST) anomalies from three data sets. GISS, NASA Gisstemp; HadCRUT4, UK Met Office; Cowtan & Way, Cowtan and Way (2013). To align the three data sets, which use slightly different climatological baselines, all anomalies here are computed for the period considered to encompass modern global warming (1970–2013); see (Foster and Rahmstorf, 2011). The top panel shows the complete record from 1970 to 2013 inclusive; the bottom panel omits observations for 1998 (indicated by vertical dashed lines) and adds best-fitting regression lines estimated from the entire time series (1970–2013), *including* 1998.

Claims about a “pause” typically invoke a period commencing in 1998; the top panel of the figure shows that that year saw particularly high temperatures owing to an extreme El Niño event. When this single outlying year is omitted (as illustrated in the bottom panel), the purported pause in warming is no longer apparent. Statistically, what one observes is a decrease in the rate of warming—a slowdown, if you will—but this slowdown is at most modest: during the last 15 years (1999–2013) the linear trend is .13 °C/decade, compared to the trend for the overall period (1970–2013) which is .18 °C/decade. It is only when 1998 is arbitrarily used as the starting point to define the “pause” that the recent rate of global warming has been appreciably lower (.10 °C/decade) than the long-term trend. The top panel in Fig. 2 shows this reduced trend (in red) against the 95% confidence envelope of the long-term trend.

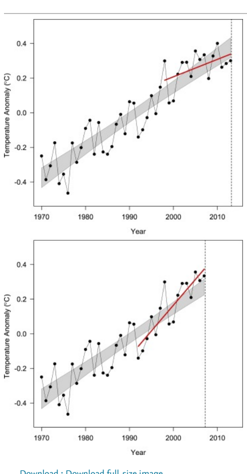

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Fig. 2. Global mean surface temperature (GMST) anomalies for the data from Cowtan and Way (2013). Both panels show the data (filled plotting symbols) and the 95% confidence envelope for the linear trend estimate based on the entire period of modern global warming (1970–2013). The top panel additionally shows the trend line for the 16 years from 1998 to 2013, and the bottom panel shows the trend for the 16 years from 1992 to 2007. The bottom panel shows data only to 2007, the year that is considered to be the “present” for this demonstration. See text for details. (For interpretation of the references to colour in the text, the reader is referred to the web version of this article.)

Thus, arguments about a “hiatus” or “pause” can only be sustained by ignoring the fact that the most recent trend is statistically nearly identical to that of other decades unless a single particular year is used as a starting point—in other words, only by cherry-picking. The use of a single “cherry-picked” outlying year to establish the presence of a “pause”—without *a priori* definition of what time period is necessary and sufficient to observe a “pause”—does not conform to conventional statistical practice and is testament to the degree to which the climate mainstream has embraced the “pause” meme for extra-scientific reasons.

To illustrate, Smith (2013) suggested that “it is now clear that the rate of warming has slowed substantially over the past 15 years or so (Fig. 1) and the observations are very much at the lower end of model simulations” (p. 618). Notably, the figure that accompanies the above statement shows that present temperatures are well within the 95% envelope of model projections, and that the most recent excursion of the data outside that envelope occurred around 1945, when temperatures were *higher* than expected by the models. The phrase “very much at the lower end of model simulations” is thus not readily reconciled with the data to which it refers.

Likewise, the IPCC AR5 report devotes considerable space and analysis to the “hiatus,” defined as the reduced GMST trend during 1998–2012. (The IPCC does not explain why 1998 is used as a starting point and seemingly takes it for granted, notwithstanding its clear outlying status.) The German government criticized the usage of the term “hiatus” and provided the following comment (identified as being of “high priority”) on the IPCC's relevant Summary for Policy Makers: “In addition, the underlying report and the TS label the recent reduction in surface warming as ‘hiatus’. The web site http://thesaurus.com gives as definition of this expression ‘pause, interruption’, http://www.merriam-webster.com gives ‘1a: a break in or as if in a material object, 2a: an interruption in time or continuity; break; especially: a period when something (as a programme or activity) is suspended or interrupted.’ All these definitions do not appropriately describe the recent temperature evolution as there is not a pause or interruption, but a decrease in the warming trend, and the first decade of this century has been the warmest since preindustrial times, see Figure SPM1. (a), lower figure. Hence, the expression ‘hiatus’ is strongly misleading and should not be used throughout the report” (http://www.climatechange2013.org/images/report/WGIAR5_FGD_FinalDraftSPMComments.pdf). The German delegation's suggestion was not adopted by the chapter authors. In summary, we suggest that there is sufficient evidence to consider the current discussion of a “pause” to reflect seepage: scientists have at least tacitly changed their interpretation of the data such that what once was considered to be variability has now become a “pause” or a “hiatus.” Although the control experiment can never be conducted, we suggest that in the absence of concerted contrarian attempts to highlight the “pause”—which commenced at least as early as 2006, merely 8 years after the outlying El Niño event of 1998 (Carter, 2006)—the scientific community would not have given short-term variability the undue attention it has now received, used misleading language to describe it, and confused a change in the rate of warming with a cessation in warming.

Our conclusion does not imply that research aimed at addressing the causes underlying short-term fluctuations in the warming trend is invalid or unnecessary. On the contrary, it is a legitimate and fruitful area of research, and we are certain it was not done because climate scientists intended to accept a contrarian frame—rather, if any values other than scientific curiosity drove their research, it was more likely to have been a desire to rebut contrarian talking points than a willingness to accept them. Whether that research constitutes seepage depends on whether it ignores, adopts, or rejects the framing of those fluctuations as a “hiatus” in climate change. Research that ignores or rejects that framing could not be seen to be subject to the cognitive processes underlying seepage and is not seepage. On the other hand, research that explains fluctuations by uncritically adopting the language of “pauses” and a “hiatus” likely fits the definition of seepage.

6.2. The seepage that did *not* occur: “Global warming has accelerated”

To place the flurry of research activity arising from the most recent fluctuation in global warming into a broader context, it is informative to consider previous fluctuations from the long-term trend. The bottom panel of Fig. 2 shows the trend for the 16 years leading up to 2007: this short-term trend (.30 °C/decade) departs from the long-term trend (.18 °C/decade for 1970–2013) by a considerably larger margin than the negative deviation experienced during the last 16 years (1998–2013; .10 °C/decade).

For statistical confirmation, we computed all possible 15-year trends for the period 1970–2013 (i.e., 1970–1984, 1971–1985, etc.) and converted the short-term trends of interest into *z*-scores. The *z* of the most recent period (i.e., the “pause”) relative to all others is −.89, −1.52, and −1.36, respectively, for Cowtan and Way (2013), HadCRUT4, and GISS. By contrast, the 15-year periods of most rapid warming have *z*-scores of 2.22, 1.87, and 2.09, respectively. In other words, across all data sets, the recent change in the rate of warming constitutes a notably *smaller* deviation from the overall trend than were previous periods of accelerated warming.

It follows that if an observer had applied the same logic to the data in 2006 or 2007 that gave rise to the “pause” in 2013—namely, drawing conclusions based on the preceding 15 or 16 years—then the literature in the years after 2007 should have been replete with articles seeking to reconcile the accelerated warming with climate models and basic climatological parameters. To our knowledge, this did not occur. We are not aware of two special issues of *Nature* journals that were devoted to the spectre of “out-of-control catastrophic warming” based on the 15 (or 16) years leading up to 2007. Likewise, the positive fluctuation from the long-term trend leading up to 2007 was not used to re-assess (transient) climate sensitivity, in contrast to endeavours that have used the current departure from the long-term trend for that purpose (e.g., Lewis, 2013, Lewis and Curry, 2014, Otto et al., 2013, Stott et al., 2013).

No contrarians drew attention to the anomalously large positive temperature trend, because there are no significant contrarian groups misrepresenting the science from the side of exaggeration. This asymmetry of response—a strong response to a contrarian exploitation of a period of slower-than-average rate of increase in temperature but no attention to a period of faster-than-average rate—supports our interpretation of the impacts of contrarian pressure on the impartiality of scientific work.

6.3. The full circle of seepage

In summary, it is apparent that the scientific community has in the past resisted the allure of larger short-term fluctuations that fell above the long-term trend, whereas it recently embraced a more modest excursion below the long-term trend as something special that required explanation. Moreover, in so doing, the community —including the IPCC—adopted the phraseology of a “pause” or “hiatus” with its heavily laden linguistic implications.

The danger of accepting such misleading terminology becomes particularly clear when scientists attempt to interpret the implications of research findings for policy action. A conspicuous example has been offered by Victor and Kennel (2014), who argued recently in *Nature* that the world should “ditch the 2 °C warming goal,” and focus instead on a set of more diverse measures of climate change and its impacts. Their reasoning rests in large part on the alleged “pause.” For example, Victor and Kennel (2014) state that there is a “troubling pause,” that “average global surface temperature [have] stalled since 1998”, and that “the planet's average temperature has barely risen in the past 16 years.” To address these presumed problems Victor and Kennel (2014) offer the radical policy prescription of abandoning a widely accepted and almost universally understood policy.

Whether or not their proposal has merit for other reasons remains to be seen; what is important here is that their prescription has taken the path of seepage full circle: from contrarian meme to an erosion of scientific practice to a recommendation to abandon a long-standing policy goal that, in the view of at least some scientists, was itself set for political reasons and was more lenient than the science would suggest (e.g., Hansen et al., 2013).

6.4. Expert cognition and the “pause”

We listed several psychological factors at the outset that may render scientists vulnerable to constant contrarian opposition. We then suggested that scientists departed from long-established practice in their field while responding to the “pause” in global warming. At first glance, this claim may seem adventurous: how can a community of experts with decades of relevant expertise, who successfully resisted rewriting of the canon when global temperature rises exceeded the long-term trend in the past, cast aside long-standing practice when seeking to explain a “pause”?

Upon closer inspection, however, our claim may not appear quite so adventurous: for example, Kelemen et al. (2013) showed that even “… physical scientists from top-ranked American universities” (p. 1074) displayed increased acceptance of unwarranted teleological explanations—e.g., that leaves on plants exist in order to provide shade, as purported by Aristotle—when put under time pressure. Teleological explanations for inanimate natural phenomena are conventionally rejected by contemporary scientists, based on their quasi-religious tacit appeal to design and animism. The fact that scientists fail to reject such explanations when put under cognitive pressure demonstrates the capacity of scientists to be influenced by relatively subtle stressors. Although time pressure differs considerably from the social pressures that confront climate scientists, the results of Kelemen et al. (2013) should at least alert us to the possibility that scientific reasoning may be altered by exogenous pressures.

Turning to the specifics of the “pause”, there is a relevant body of evidence in cognitive science which shows that people's knowledge is “partitioned” into modules that appear to be independent of each other and that are accessed on the basis of contextual cues (e.g., Kalish et al., 2004, Lewandowsky et al., 2002, Lewandowsky et al., 2006, Sewell and Lewandowsky, 2011, Yang and Lewandowsky, 2003, Yang and Lewandowsky, 2004). Because access to knowledge is specific to the context in which it is queried, people may respond in one context by completely ignoring knowledge they demonstrably possess in a different context (Yang and Lewandowsky, 2004). This context-specificity can arise even though the context cue is normatively irrelevant (i.e., it does not stand in any predictive relationship with the correct outcome), and it may lead to surprisingly contradictory responses to problems that, normatively, require the same response. Lewandowsky and Kirsner (2000) showed that this context specificity, and propensity for contradiction, even holds among experts.

It follows that there is nothing cognitively surprising about a situation in which climate scientists may teach their students in the classroom that 15-year trends are of insufficient duration to be climatologically relevant, while the same experts simultaneously conduct research that uses a 15-year “pause” to redefine basic climatological parameters (cf. Otto et al., 2013). All it may take is the creation of a pervasive linguistic and social context by contrarians, and scientists may feel bound to respond to challenges within that context—even if outside the context, their responses would be recognized to be at odds with prevailing practice. There is direct evidence that people's choices are determined by which of a person's multiple social identities is made salient at the time of a decision (LeBoeuf et al., 2010), and people's expressed preferences may be in conflict between contexts.

7. Construing uncertainty

Seepage can only occur when there is perceived uncertainty. If the public is certain that the earth is round, the flat-earth society can say whatever they like without making any impact on public opinion. In the case of climate change, however, the public continues to find it difficult to resist the allure of uncertainty, and political arguments continue to rely on Scientific Certainty Argumentation Methods (SCAMs). Given that uncertainty is an inevitable part of any scientific endeavour, and given that the particularly large uncertainties associated with climate change provide ample opportunity for seepage to occur and perpetuate SCAMs, how should scientists respond?

The tacit logic underlying SCAMs is that scientific uncertainty about climate science implies uncertainty about whether something should be done in response to it. This connection between scientific uncertainty and policy uncertainty is intuitively powerful and often taken for granted in public discourse. It is, however, incorrect. We have shown earlier (Lewandowsky et al., 2014a, Lewandowsky et al., 2014b) that if scientific uncertainty about the evolution of the climate system is greater than thought, this virtually always implies that the potential adverse consequences are also greater. For example, the statistical properties of extreme values mandate that increasing uncertainty about the extent of future sea level rise requires increasingly greater protective measures if the risk of inundation is to be kept constant (Hunter, 2012). It follows that any appeal to scientific uncertainty should compel a stronger, rather than weaker, concern about unabated warming than in the absence of uncertainty (Lewandowsky et al., 2014a, Lewandowsky et al., 2014b).

This actual implication of scientific uncertainty—namely, that greater scientific uncertainty implies greater *certainty* about the need for a policy response—is counterintuitive but undermines the reasoning of SCAMs. We therefore suggest that scientific uncertainty presents an opportunity for scientists to reframe SCAMs in a scientifically more appropriate manner. As noted by Jasanoff (2007), “the great mystery of modernity is that we think of certainty as an attainable state” (p. 33). Certainty may not be attainable, but uncertainty provides a certain impetus for action, and that recognition may be an important element in imbuing the scientific community with resilience to SCAMs and, by implication, seepage.

8. Conclusion

The conflation of public and professional debate is characteristic of scientific controversies in which non-experts have become engaged in scientific debates for political, social, or other reasons. This conflation is an indicator of the failure of scientists to maintain a clear demarcation between intra-scientific and extra-scientific considerations, a failure of what sociologist Thomas Gieryn (1983) has described as “boundary work”—the successful articulation and protection of the boundaries of the scientific domain. Many recent “scientific” controversies in which the scientific facts are disputed not by fellow experts, but by lay people, may be understood as a failure of boundary work.

Boundary work failures reflect the inability of scientists to persuade the lay public of the correctness of scientific conclusions—such as the safety of vaccinations or the age of the Earth—but they do not generally reveal evidence of scientists altering their own views of the matter in response to non-expert resistance. Historian Milena Wazeck (2013) has described how “lay experts”—men with some kind or degree of scientific training but generally not in physics—together with a few disgruntled physicists in the early 20th century challenged the theory of relativity, managing to maintain an on-going public debate long after the theory was broadly accepted by experts. Their opposition was rooted in ontological considerations, as they feared the implications of relativity for the role of the human observer in science, and/or because the theory marginalized them in the scientific world. Mainstream physicists may have been bothered by popular rejection and misconception, but they did not let it influence the course of their research. Similarly, AIDS researchers have explicitly sought to delegitimize denial and have undertaken strong efforts to defend the boundary between science and pseudoscientific challenges (e.g., Nattrass, 2011).

In climate science, we see a similar phenomenon of non-experts challenging an established body of evidence that has converged on the conclusion that global warming is unequivocal and in all likelihood due to human industrial and agricultural activity. But in this case we see scientists not only responding to these contrarian claims, but publishing a significant number of papers in peer-reviewed journals to try to explain them. In effect, scientists came to doubt their own conclusions, and felt compelled to do more work to further strengthen them, even if this meant discarding previously accepted standards of statistical practice. This, we suggest, is evidence of seepage: that non-epistemological considerations have seeped into—and thereby altered—scientific research and debate. Confidence, like prematurity and credibility, are value judgments, but it seems reasonable to conclude that the pressures of climate contrarians has contributed, at least to some degree, to undermining the confidence of the scientific community in their own theory, data, and models, all of which permit—and indeed expect—changes in the rate of warming over any arbitrarily chosen period.

Scientists have a unique and crucial role in public policy: to communicate clearly and accurately what we know about technical issues relevant to social and political decision-making. Ideally, this means neither overstating nor understating the evidence for any particular claim. While scientists cannot be expected to achieve a perfect match between what we know and what we communicate, we can do more to ensure that we do not inadvertently allow contrarian, skeptical, and denialist claims to seep into our thinking, leading us to overstate uncertainty, under-communicate knowledge, or add credence to erroneous claims by spending undue amounts of time responding to them, much less “explaining” phenomena that do not even exist.

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Appendix A. Responding to seepage

A.1. Stereotype threat

Research has identified various intervention strategies to reduce or eliminate the effects of stereotype threat.

Deemphasizing threatened group identity. Performance can be enhanced by blurring boundaries between groups (e.g., if women list the similarities between men and women before taking a maths test, their performance disadvantage under stereotype threat is reduced or eliminated; Rosenthal and Crisp, 2006). An analogue might be for climate scientists to consider the fact that they use the same scientific method as any other scientist—and that scientists are by and large the most trusted segment of society.

Self-affirmation. Self-affirmation involves people to think about aspects of themselves that they value or believe are important aspects of their esteem, usually by recalling a situation in which they felt good about themselves because they relied on their core values. There is evidence that self-affirmation eliminates or reduces the performance detriment that usually results from stereotype threat (Martens et al., 2006). Self-affirmation can have surprisingly lasting consequences: in one study, writing about their most important values twice at the beginning of a 15-week college course in physics reduced the gender gap considerably and elevated the modal grade of women from C to B (Miyake et al., 2010). In the scientific arena, affirmation can again invoke the fact that scientists enjoy considerable trust in the population at large.

Awareness of stereotype threat. Finally, mere awareness of the effects of stereotype threat may serve to eliminate its effects on performance. Johns et al. (2005) showed that when women are put under stereotype threat, their performance is unimpaired if the threat manipulation is accompanied by an explanation that any anxiety they may experience “could be the result of these negative stereotypes that are widely known in society and have nothing to do with your actual ability” (p. 176).

A.2. Pluralistic ignorance

When people are informed about the actual prevalence of behaviours, they no longer conform to the behaviour that they had (mistakenly) perceived to be the majority's behaviour (Schroeder and Prentice, 1998). So it is crucial for scientists to know what their colleagues are thinking (e.g., http://results.visionprize.com/).

A.3. Third-person effect

Attempts to eliminate the third-person effect (TPE) have often been unsuccessful. A recent exception is the work by Tal-Or and Tsfati (2007), who showed that the TPE is at least partially “substitutable” by other self-preserving mechanisms.

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