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The "Pause" in Global Warming: Turning a Routine Fluctuation into a Problem for Science

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ABSTRACT

There has been much recent published research about a putative "pause" or "hiatus" in global warming. We show that there are frequent fluctuations in the rate of warming around a longer-term warming trend, and that there is no evidence that identifies the recent period as unique or particularly unusual. In confirmation, we show that the notion of a "pause" in warming is considered to be misleading in a blind expert test. Nonetheless, the most recent fluctuation about the longer-term trend has been regarded by many as an explanatory challenge that climate science must resolve. This departs from long-standing practice, insofar as scientists have long recognized that the climate fluctuates, that linear increases in CO_2 do not produce linear trends in global warming, and that 15-year (or shorter) periods are not diagnostic of long-term trends. We suggest that the repetition of the "warming has paused" message by contrarians was adopted by the scientific community in its problem-solving and answer-seeking role and has led to undue focus on, and mislabeling of, a recent fluctuation. We present an alternative framing that could have avoided inadvertently reinforcing a misleading claim.

Capsule: Contrarian discourse about a "pause" in global warming has found traction in climate science even though there is little evidence for anything but a fluctuation in the warming rate similar to earlier deviations from a longer-term trend.

Many indicators confirm that the Earth continues to warm from greenhouse gases (Abraham et al. 2013; Balmaseda et al. 2013; Durack et al. 2014). Notwithstanding, climate contrarians have been claiming for nearly a decade that global warming has "stopped" (Carter 2006). Boykoff (2014) showed how, over time, those repeated contrarian claims entered the discourse in the media and among policy makers and politicians. In consequence, climate change has frequently been framed around the presumed fact that global warming—measured by global mean surface temperature (GMST)—has "stalled", " stopped", "paused", or entered a "hiatus." Evidence for the widespread adoption of this frame is provided by a *Google Trends* analysis (conducted on 21 October 2014), which reveals that the search term "global warming stopped" has been used nearly continuously since February 2008, with distinct spikes ahead of the climate meetings in Copenhagen (December 2009) and Doha (November 2012).

This frame has also found explicit uptake in the peer-reviewed literature, with two special issues of *Nature* journals devoted to the "pause" or "hiatus" in early 2014, and a total of more than 40 articles having appeared in print on the "pause" by 2014. Moreover, the Intergovernmental Panel on Climate Change (IPCC), which reflects the scientific consensus on climate change, adopted the term "hiatus" in its Fifth Assessment Report, and even gave it a definition "as the reduction in GMST trend during 1998–2012 as compared to the trend during 1951–2012" (Stocker et al. 2013, Box TS.3).

Is there a meaningful "pause" or "hiatus" in global warming? If not, what has caused the scientific community to devote such intense activity to analyzing something that does not exist? This article presents evidence that there has been no meaningful "pause" in global warming and offers an account of why this notion has become so widespread in the scientific community.

There has been ongoing analysis and commentary arguing against the existence of a statistically-meaningful "pause" for several years (e.g., Foster and Rahmstorf 2011). Two analyses of the

GMST time series have failed to find any statistical evidence for a slowdown (Foster and Abraham 2015), or a distinct change point in the rate of warming (Cahill et al. 2015). There have also been questions about biases in some data sets used to identify a potential pause (Cowtan and Way 2014; Karl et al. 2015). Most recently, a bias-corrected release of NOAA's National Centers for Environmental Information (NCEI) data set (Karl et al. 2015), assessed the rate of warming during the "hiatus" period identified by the IPCC (1998–2012) to differ little from the longer-term trend considered by the IPCC for comparison (1951–2012). Although those bias corrections were unavailable at the time when the "pause" gained entry into the literature, we show below that our conclusions do not depend on those corrections.

Accordingly, there are other indications of long-standing disquiet with the presumed "pause". For example, the IPCC's use of the term hiatus (without scare quotes) came under critical scrutiny during review of the Fifth Assessment Report. In a high-priority comment on the Summary for Policy Makers, the German government noted that the term "hiatus" was strongly misleading and recommended against its use.[1] Although the German delegation's suggestion was not adopted, it points to a fundamental problem surrounding the "pause": what exactly is meant by a "pause" or "hiatus"?

[1]The full comment reads as follows: "…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 program 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`).

1. What is a "pause"?

By definition, a "pause" involves the interruption or suspension of a process. The presence of a "pause" or "hiatus" in global warming would thus mean what contrarians say it means (e.g., Carter 2006); namely, that warming had stopped, at least for a time. Determining whether warming has stopped is non-trivial because greenhouse-driven global warming is expressed on multi-decadal and longer timescales (i.e., 30 years and longer), whereas on shorter time scales (10 to 20 years) the rate of warming speeds up and slows down relative to the longer-term average trend (Houghton et al. 1995; Risbey 2015). At one point or another, there may therefore be periods of limited duration during which surface temperatures do not increase significantly.

In this article, we consider the period since 1970 to provide a representation of the "longer-term" rate of greenhouse warming that is characteristic of the modern period. The choice of period marking the longer-term trend is necessarily somewhat arbitrary. The year 1970 has been statistically identified as an approximate marker of an upsurge in the rate of global warming on multi-decadal time scales (Cahill et al. 2015). This longer-term trend (1970–2014) has been estimated at $0.17K$/decade (Cowtan and Way 2014; Karl et al. 2015) or $0.16K$/decade (NASA GISTEMP; Hansen et al. 2010, and the U.K. Met Office's HadCRUT4; Morice et al. 2012).

By contrast, we refer to decadal scale (10-20 years) variations in the rate of warming about a longer-term trend as *fluctuations*. Here we focus on 15-year trends to reflect the duration of the presumed "hiatus" employed by the IPCC (Stocker et al. 2013, Box TS.3). Those fluctuations may be driven by internal variability (ocean circulation and its coupling to the atmosphere), or they may involve variations in external forcings of the climate system (such as solar irradiance and aerosol concentrations), or both. These fluctuations are "routine" in the sense that they occur commonly and are caused by different combinations of the same set of processes.

A given fluctuation is defined by a start year and an end year, and its magnitude is highly dependent on the choice of start and end years. For example, the decadal rate of warming during the 15 years centered around 2005 was $0.11K$; for the 15 years centered on 1999 it was $0.31K$—a nearly threefold difference resulting from a shift of the temporal window by 6 years (data from Cowtan and Way 2014). Fluctuations can therefore display warming rates that are greater than or less than the greenhouse-driven longer-term trend. There may also be short-term periods of cooling embedded within a longer-term warming trend (Easterling and Wehner 2009).

Any claims of a "pause" or "hiatus" in the recent rate of warming must therefore be assessed against the overall pattern of fluctuations in the temperature record. A claim to find a "pause" or "hiatus" is a different claim than a "fluctuation" and implies that the fluctuation is extraordinary in a particular way: The meaning of the terms "pause" and "hiatus" implies that the normal fluctuations in warming rate have been surpassed such that warming has stopped. We next show that no such stoppage has occurred.

2. Global warming continues: The statistical evidence

Detailed analyses of temperature trends have been reported previously (Easterling and Wehner 2009; Santer et al. 2011; Karl et al. 2015). Here we generalize and update those results. The top panel of Figure 1 shows all possible 15-year trends in GMST for the period 1970–2014 (i.e., 1970–1984, 1971–1985, and so on; $N = 31$) for four different data sets. It is clear that the short-term trend sometimes falls above the longer-term trend (indicated by the gray band) and sometimes below it. It is also clear that warming has continued throughout the 45 years as none of the trends are zero (dashed horizontal line).

The linear trend in GMST (established by Ordinary Least Squares on annual global means) is statistically significant for the last 15-year period (ending in 2014) for three of the four available

data sets: GISS (trend $b = 0.08K$/decade; test statistic $t = 2.20$; level of significance $p < .05$), the data set of Cowtan & Way ($b = 0.10K$/decade; $t = 2.41$; $p < .05$), and the most recent NOAA data set by Karl et al. ($b = .11K$/decade, $t = 3.25$, $p < .007$). Only HadCRUT4, which does not cover parts of the Arctic where warming is known to be most rapid, fails to yield a significant trend for this 15-year period ($b = .07K$/decade, $t = 1.70$, $p > .10$). When a further year is included in the analysis, HadCRUT4, too, yields a significant trend ($b = .09K$/decade, $t = 2.48$, $p < 0.03$).

Although the most recent 15-year trend is significant for most data sets, there have been 6 occasions since 1970 when a 15-year trend would have failed to reach significance (using GISS); namely, in the years 1986, 1993, 1994, 1995, 2011, and 2012. At all those times, the preceding 15 years failed to show significant warming. At all those times, the inclusion of further years renders the trend significant. The claim that global warming uniquely "stopped" during any recent 15-year period is therefore not sustainable. Conversely, any argument about a "pause", "hiatus", or "stoppage" could have been made with equal justification (or lack thereof) repeatedly during the past 45 years.

Nor does the most recent fluctuation constitute a uniquely large deviation from the longer-term trend. This is shown in the bottom panel of Figure 1 which plots the same 15-year trends but converted into absolute z-scores. The advantage of z-scores is that they re-express each data point as a deviation from the overall mean of a sample in units of standard deviation, thereby providing an indication of the extremity of observations. To compute z-scores, the mean of all possible trends was first subtracted from each individual trend, and each such difference was in turn divided by the standard deviation of all trends. To permit a comparison of decelerating ($z < 0$) and accelerating ($z > 0$) fluctuations, the z-scores were converted to absolute values for plotting. For clarity, z-scores that were originally negative are plotted in blue in Figure 1, and those that were originally positive are shown in red.

For a "pause" to be distinctive, it must deviate below the longer-term trend more than previous periods deviated *above* the longer-term trend—otherwise, it can be considered just a fluctuation like others observed in the past. The bottom panel of Figure 1 shows that this criterion for distinctiveness is not met: For all data sets bar HadCRUT4, the "pause" is less anomalous than the accelerated period of warming that took place during the 15 years spanning 1999 (i.e., 1992–2006). That is, the absolute magnitudes of the z-scores associated with the recent deceleration (whichever recent year is picked as the point on which the "pause" is centered) are consistently smaller—sometimes by a considerable margin—than those for the 1999 acceleration. Only for HadCRUT4, and only for the 15-year period centered on 2005, are the z-scores for the "pause" and the maximum warming virtually indistinguishable (1.86 vs. -1.90).

Taken together, the statistical evidence presented here and elsewhere (Cahill et al. 2015; Foster and Abraham 2015) shows that the "pause" period is comparable in statistical terms with other recent fluctuations. Any exceedance of the z-score of the pause period compared to other fluctuations, if it exists, is marginal and depends on the details of which data set is used and precisely what time window is used to assess the "pause". The "pause" is not unusual or extraordinary relative to other fluctuations and it does not stand out in any meaningful statistical sense.

Note that these conclusions are not dependent on the choice of baselines to represent longer-term greenhouse warming. For example, a longer baseline such as the IPCC's 1951–2012 period yields a lower longer-term trend, thus rendering any fluctuations with slower rates of warming even less unusual. Our conclusions are also qualitatively unaffected by modeling of autocorrelations and by the choice of window size for the short-term trend.

We next show that experts fail to detect evidence for a pause in a blind test.

3. Global warming continues: The blind expert test

The forecasting of time series data is central not only to climatology, but also to economics, finance, and allied disciplines. Forecasting techniques have therefore attracted considerable research attention, and the last 25 years have seen a striking re-evaluation of the role of human judgment in forecasting. Whereas human judgment used to be given little if any credence in forecasting, today it is "...recognised as an indispensable component of forecasting" (Lawrence et al. 2006, p. 493).

People are known to be able to learn smooth functions with considerable precision (DeLosh et al. 1997; Lewandowsky et al. 2002). People are also able to extract information from noisy data presented in graphical form (Lewandowsky and Spence 1989). In forecasting studies, participants across a broad range of expertise are now generally thought to perform well (Harvey and Bolger 1996; Harvey et al. 1997; Du and Budescu 2007), and domain experts outperform statistical models in some circumstances (Forrest et al. 2005), although this is becoming increasingly less common in weather forecasting (Baars and Mass 2005).

Here, we are interested in human forecasting not because people's predictions might constitute a viable alternative to the projections of climate models, but because forecasting judgments reveal people's perceptions of the trend in a data set. People's extrapolations of visually-presented temperature data can therefore reveal whether people believe that global warming has "stopped."

To assess the claim that global warming has stopped, Lewandowsky (2011) presented naïve participants with a graph of the historical temperature record, which either identified the data as global temperatures or as a fictitious share price. Figure 2 shows the results of Lewandowsky (2011) for the condition in which the data were identified as global temperatures. Respondents clearly did

not perceive a pause or hiatus in the GMST data,[2] as revealed by the fact that their extrapolations (large squared plotting symbols) had a statistically significant positive slope. Extrapolations did not differ notably from a condition (not shown in the figure) in which the stimulus data were presented as fictitious share prices. In the eyes of naïve observers, therefore, global warming has not stopped but is set to continue. People's extrapolations were, however, conservative, falling consistently below the linear extrapolation of the long-term trend. The tendency to underestimate a long-term trend is a well-established phenomenon in judgmental forecasting known as trend damping (Harvey and Bolger 1996). It merits further exploration because it raises the possibility that people are overly-sensitive to any slowing in warming.

This possibility was explored in a blind test involving professional economists, who were asked specifically to comment on the presence of a pause or hiatus in GMST. The sample of economists ($N = 25$) was tested online and was recruited by a survey firm, Qualtrics.com. All experts held at least a Master's degree or a PhD in economics or an allied discipline, with all but 4 experts reporting 5 or more years of professional experience. Participants were shown the GMST data through 2010, but presented as "world agricultural output" (see Figure 3). The graph was accompanied by the following statement that experts had to evaluate in light of the plotted data: "A prominent Australian critic of conventional economics, Mr. X., publicly stated in 2006, that 'There IS a problem with the growth in world agricultural output—it stopped in 1998.' A few months ago, Mr. X. reiterated that '…there's no trend, 2010 is not significantly more productive in any way than 1998.' " This statement is an exact translation, into the economic terms of world agricultural output, of a series of public statements about the putative "pause" or "stoppage" of global warming (Carter 2006, 2011).

[2]It must be noted that at the time of the study, the time series ended in 2009. However, at that time the idea of a "pause" had already been established in contrarian discourse.

The experts responded to 6 test items, which are shown in Table 1.[3] The table also shows the responses of the experts on a 6-point scale that ranged from "Strongly disagree" (1) to "Strongly agree" (6). Any mean response above 3.5 therefore represents agreement, and any mean response below 3.5 disagreement, respectively, with the test item (there was no "neutral" response category). It is clear that the experts disagreed with the invocation of a pause: Experts rejected the idea that the data confirm the statement and instead find that the data contradict the statement. The experts also found the statement to be misleading and ill-informed. The experts were divided on whether or not the statement is fraudulent, although nearly 2/3 of them endorsed that possibility as well. The experts were also divided on whether the statement might be compatible with the data in a "narrow sense".

These results from our experiment are consistent with an earlier informal study conducted by the Associated Press with a small sample of statisticians who were blind to the data source (Borenstein 2009). Those experts, too, saw no evidence for a decline in the temperature trend and instead decried the cherry-picking of observations on which that claim was based.

In summary, in two blind tests, experts and novice observers alike consider the evidence of continued global warming to be clear. By contrast, statements endorsing the pause were identified by experts in forecasting and time series analysis to be misleading and at odds with the data.

4. Where did the "pause" come from?

Our preceding analyses show that the entrenchment of the "pause" concept in the literature is incommensurate with the lack of evidence supporting it, and that it does not pass a blind expert

[3]The experiment involved additional statements by contrarians, pertaining to other climate variables, such as glaciers and Arctic ice, that are not relevant to the present article and are not reported here.

test. Despite that, large segments of the climate science community, including the IPCC (Stocker et al. 2013, Box TS.3), have adopted the notion of a "pause" or "hiatus" in global warming.

This is not to say that interpretations of the "pause" are entirely uniform. A few articles addressing the "pause" question its existence. For example, Seneviratne et al. (2014) call the term misleading and 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. 163). Risbey et al. (2014) show that recent fluctuations are not unusual and do not constitute meaningful evidence against climate model projections. Santer et al. (2014) refer to the pause or hiatus in quotation marks (i.e., scare quotes), thereby implying skepticism or disagreement with the phrase. However, the majority of the more than 40 articles on the "pause" that we know of start from the premise that the pause is meaningful, and present it as a significant development requiring explanation. Moreover, some researchers (albeit a minority) have taken the "pause" to imply that the climate system may be less sensitive to greenhouse gas emissions than previously thought (Lewis 2013; Otto et al. 2013; Curry 2014; Lewis and Curry 2014). But any use of the term—except in a clearly refutatory context—is problematic because it reinforces, both in scientific and public debate, the belief that there has been a statistically meaningful cessation of warming when there has not.

How did this occur?

We have shown in detail elsewhere (Lewandowsky et al. 2015) that there are several psychological and cognitive reasons why climate scientists may have been susceptible to the meme of a pause that demonstrably originated in contrarian discourse on the internet and in the media (Boykoff 2014). Here, we suggest that a contrarian meme can find entry into the scientific community simply by exploiting scientists' commitment to explanation and to responding to intellectual challenges. Scientists generally strive to emphasize factual information and de-emphasize

value judgements. Indeed, "disinterestedness" has long been identified as one of the core norms of science (Merton 1942).

In a world in which contrarian claims in the media and other public arenas are over-represented (Boykoff and Boykoff 2004; Elsasser and Dunlap 2013; Boykoff 2013), scientists may feel the need to respond to these claims. This may occur informally, as when friends, neighbors, or family members ask questions about contrarian claims they encountered online, or formally, when journalists, editors, or policy makers seek answers to contrarian talking points. If these encounters involve loaded questions, such as "What about the 'pause' in warming?", then climate scientists may inadvertently accept the biasing terms in which those questions are framed.

Frames are rhetorical and communicative structures that select and highlight certain aspects of a perceived reality over others (Dirikx and Gelders 2010). Because frames are rarely made explicit—for example, few people know that the use of the term "climate change" rather than "global warming" was advocated by Republican strategist Frank Luntz (Mooney 2005; Lakoff 2010)—frames can shape in a hidden manner the way in which people discuss an issue (de Boer et al. 2010). Would voters be more likely to support a price on carbon if it were framed as an "additional tax burden", "insurance premium for your grandchildren's well-being", or "putting a fair price on the true cost of oil and gas?" Even simple choices of wording, such as "tax" vs. "offset" can have large effects on people's endorsement of policy options (Hardisty et al. 2010).

Simply by being exposed to the pause meme for over a decade, and by explaining short-term fluctuations from a longer-term trend in the terms posed to them, scientists have accepted a contrarian frame, and this acceptance may in turn have subtly changed scientists' way of thinking (Lewandowsky et al. 2015).

To illustrate, we provide citations from some recent articles on the "pause" in Table 2. None of those articles questioned the fundamental fact that the Earth is warming from greenhouse gas

emissions, and some authors even underscored the likelihood of future warming, for example by suggesting that the "...present hiatus will be short-lived" with "rapid warming set to resume" once the present decadal variation comes to an end (England et al. 2014, p. 225). Nonetheless, the majority of articles accepted the framing of a "pause" and sought to explain its cause. Furthermore, the citations in Table 2—typically from the opening paragraph of an article—show that authors often framed the article by juxtaposing the continuing increase of atmospheric CO_2 levels with the presumed lack of warming on a decadal scale as though this presented a notable scientific problem at odds with expectations from greenhouse theory.

The statements in Table 2—and similar but often tacit implications of many other articles—are at variance with long-established knowledge that multi-decadal natural variations in climate are superimposed on a longer term CO_2 warming trend. These variations demonstrate that whereas CO_2 may increase year after year, surface temperature need not. More than 20 years ago, the IPCC's Second Assessment Report pointed to the importance of decadal and longer time-scale variability (Houghton et al. 1995, pp. 329–330), as did a U.S. National Research Council report (Martinson 1995). The IPCC summary for policymakers in the 1995 report cautioned that future decadal scale changes would include considerable natural variability despite the longer-term warming.

If this knowledge had been foremost on scientists' minds, rather than the contrarian "pause" meme, the framing of many recent research articles arguably would have been different. Instead of opening an article with "Despite ongoing increases in atmospheric greenhouse gases, the Earth's global average surface air temperature has remained more or less steady since 2001", we suggest that scientists might have adopted a more appropriate framing such as "It has long been known that the longer-term greenhouse warming trend is punctuated with decadal and longer fluctuations. In this article we show that the most recent fluctuation during which warming fell below the longer-term trend was due to ...."

5. The merits of research on the "pause"

The body of work on fluctuations in warming rate has clearly contributed to our understanding of decadal variations in climate. For example, studies have shown that the negative radiative forcing from stratospheric loadings of volcanic aerosol has increased in recent years, and is larger than previously thought (Solomon et al. 2011; Neely et al. 2013; Ridley et al. 2014; Santer et al. 2014). Research has also highlighted processes whereby the ocean can vary the rate at which heat is taken up from the surface (Kosaka and Xie 2013; England et al. 2014).

Research on decadal fluctuations has also highlighted differences in expectations between climate projections that tend to average out decadal variations and the actual transient response of the climate system (Schneider and Thompson 1981) that includes such variation. Research has shown that differences in expectation between averages of projections and the actual transient response are related to model-versus-observed differences in the phasing of internal variability (Meehl and Teng 2014; Risbey et al. 2014), systematic errors in some of the external forcings used in CMIP5 simulations (Fyfe et al. 2013; Schmidt et al. 2014), incomplete coverage and quality of observations (Karl et al. 2015), and use of incommensurate measures between models and observations (Cowtan et al. 2015).

In addition, the statistical properties of many different examples of decelerating fluctuations are very similar in observations and in models (Risbey et al. 2014; England et al. 2015; Marotzke and Forster 2015). Other research has highlighted that there will be similar fluctuations (in both directions; faster as well as slower warming) in the future, a point about which policy makers perhaps need to be reminded (Easterling and Wehner 2009; Hawkins et al. 2014; England et al. 2015).

Research on the "pause" has thus ultimately reaffirmed the overall reliability of climate models for projecting temperature trends. However, by accepting the framing of a recent fluctuation as a "pause" or "hiatus", that research has, ironically and unwittingly, entrenched the notion of a "pause" (with all the connotations of that term) in the literature as well as in the public's mind.

6. Putting the pause to future "pauses"

To avoid mis-framing in the future does not mean that scientists should necessarily avoid an issue simply because it has gathered public prominence or is being used by contrarians. Scientists have previously responded to contrarian memes with success, for example by showing that appeals to the sun or galactic cosmic rays fail to explain global warming (Benestad 2013; Sloan and Wolfendale 2013). Concerning the recent fluctuation, we have shown that its framing as a "pause" or "hiatus" that constitutes a problem for greenhouse warming is incorrect, because it is not meaningfully different from other fluctuations in warming rate. If the fluctuation were instead framed as an instance of decadal variation, then scientists can put the pause to misleading contrarian claims that global warming has stopped.

It bears remembering that the point of contrarian memes is to "keep the controversy alive" (Oreskes and Conway 2010). Accepting contrarian linguistic frames helps maintain the fiction that the science is still too uncertain to form a reliable basis for public policy. Moreover, it should be noted that the remaining uncertainties often provide a greater, rather than lesser, impetus for mitigation (Lewandowsky et al. 2014b,a).

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Table 1. Test items and responses given by expert economists to contrarian statements endorsing the "pause" that were evaluated in light of the data.

Test item	Agreement[a]	Mean[b]	t[c]	p[d]
The data confirm the claim made by Mr. X	.36	2.84	-2.72	$< .02$
The data contradict the claim made by Mr. X	.68	4.12	2.58	$< .02$
The claim made about the data by Mr. X is misleading	.76	4.28	3.67	$< .002$
The claim made about the data by Mr. X is ill-informed	.76	4.04	2.38	$< .03$
If incompetence is ruled out, the claim made about the data by Mr. X is fraudulent	.64	3.84	1.49	n.s.
The statement by Mr. X is compatible with the data in a narrow sense, but the data do not support the implication of his statement, which is that world agricultural output is no longer growing	.52	3.60	0.34	n.s.

[a] Proportion of experts out of 25 who agreed (rating > 3) with the test item.
[b] Mean response on the 6-point scale. Any value > 3.5 represents agreement.
[c] Single-sample t-statistic ($df = 24$) comparing the mean response to the null hypothesis that the mean is equal to 3.5 (neutrality on the 6-point scale).
[d] p-value of the t-test in the previous column.

Table 2. Representative quotations from peer-reviewed articles that frame the "pause" or "hiatus" as a problem for climate science

Quotation	Source
"Reconstructions of global mean surface temperature [Hansen et al., 2010; Morice et al., 2012] show rising values after the 1960s but a slowing of the warming in the 2000s, even though atmospheric greenhouse gas concentrations continued to increase. This hiatus in warming may have been exaggerated by sampling errors [Cowtan and Way, 2014], but a significant slowdown is evident."	(Drijfhout et al. 2014, p. 7868).
"Despite ongoing increases in atmospheric greenhouse gases, the Earth's global average surface air temperature has remained more or less steady since 2001."	(England et al. 2014, p. 222).
"The warming of the climate system is unequivocal as evidenced by an increase in global temperatures by 0.8°C over the past century. However, the attribution of the observed warming to human activities remains less clear, particularly because of the apparent slow-down in warming since the late 1990s."	(Estrada et al. 2013, p. 1050).
"Despite a sustained production of anthropogenic greenhouse gases, the Earth's mean near-surface temperature paused its rise during the 2000–2010 period."	(Guemas et al. 2013, p. 649).
"Given the widely noted increase in the warming effects of rising greenhouse gas concentrations, it has been unclear why global surface temperatures did not rise between 1998 and 2008."	(Kaufmann et al. 2011, p. 11790).
"Despite the continued increase in atmospheric greenhouse gas concentrations, the annual-mean global temperature has not risen in the twenty-first century, challenging the prevailing view that anthropogenic forcing causes climate warming."	(Kosaka and Xie 2013, p. 403).
"Despite continued growth in atmospheric levels of greenhouse gases, global mean surface and tropospheric temperatures have shown slower warming since 1998 than previously."	(Santer et al. 2014, p. 185).
"Despite increasing radiative forcing, the observed globally averaged annual mean surface temperature (Tmean) has only increased very slowly since the late 1990s (e.g., IPCC AR5 2013)."	(Sillmann et al. 2014, p. 1).

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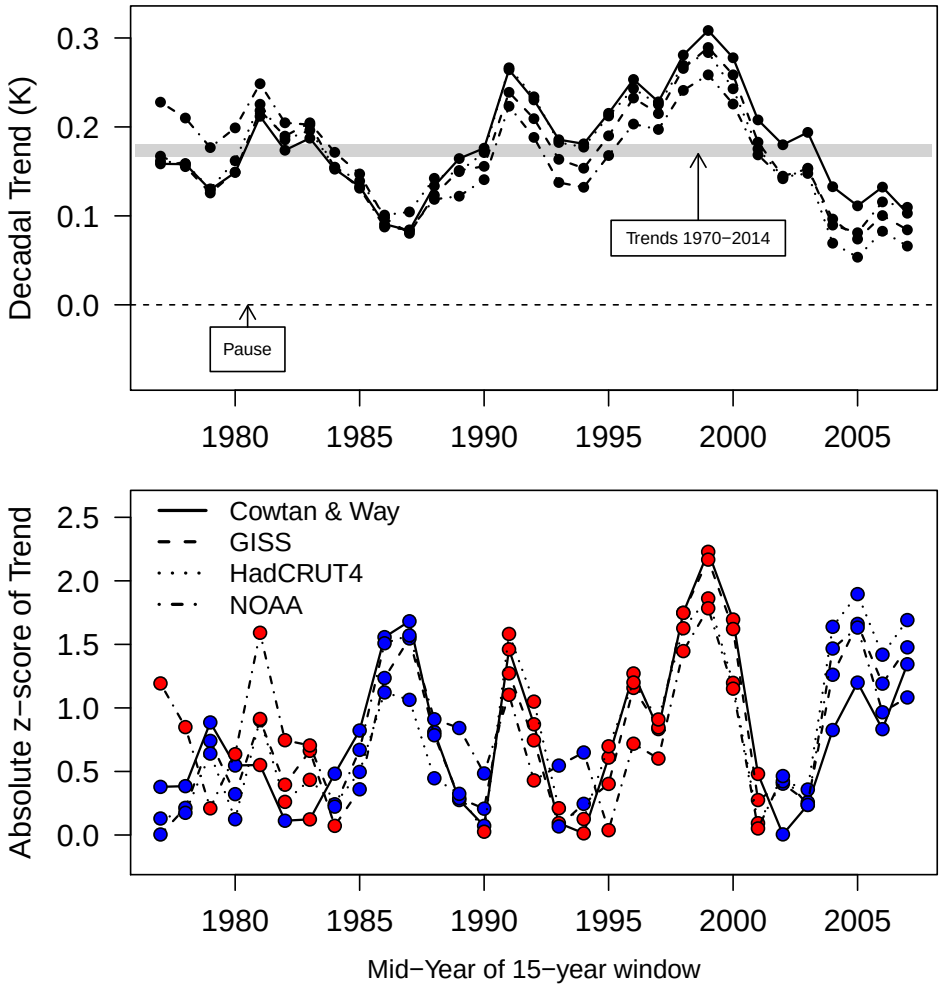

Figure 1. Summary of all possible 15-year trends in global mean surface temperature (GMST) between 1970 and 2014 inclusive. The top panel shows the trend (K/decade) for the 15-year window centered on the plotted year for four data sets: NASA's GISS (Hansen et al. 2010, downloaded 17 Jan 2015), the UK Met Office's HadCRUT4 (Morice et al. 2012, downloaded 2 Feb 2015), the coverage-bias corrected version of HadCRUT4 reported by (Cowtan and Way 2014, downloaded 2 Feb 2015), and the latest NOAA data set (Karl et al. 2015, downloaded 12 Aug 2015). The GISS data set is based on sea surface temperature data ERSSTv3b. The decadal temperature increase is greater than zero (dashed horizontal line) in all data sets at all times. The gray horizontal band represents the average of the trends between 1970 and 2014 across the 4 data sets. The longer-term trend is represented as a band to capture some of the uncertainty from data set to data set, but also to indicate that this is an inherently imprecise quantity because it varies with the exact period that is chosen to represent a longer-term trend. The bottom panel shows the same data, but 15-years trends are converted into absolute z-scores, by expressing each observed trend as the absolute difference in standard-deviation units from the mean of all trends since 1970. Originally positive z-scores (representing greater than average warming) are plotted in red, and originally negative z-scores are shown in blue.

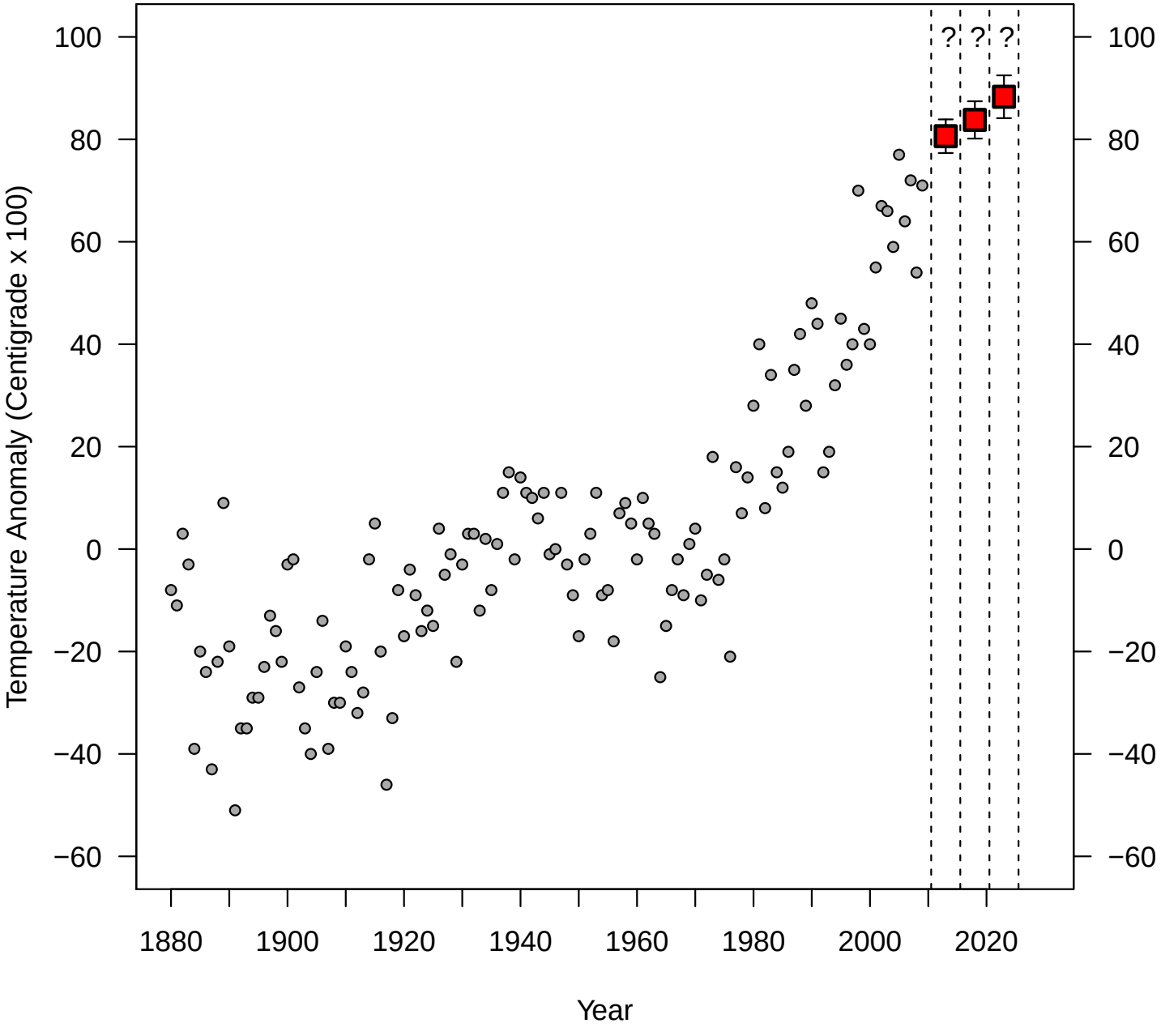

Figure 2. Stimuli and data from an experiment by Lewandowsky (2011). Grey circles show actual global mean land-surface air temperature anomalies from 1880 to 2009. Extrapolations of the trend by the respondents are represented by large red squares. When the graph was presented as a stimulus, the 3 "?"s at the top identified the 3 columns in which participants marked their predictions. Temperature data are GISS Surface Temperature Analysis (GISTEMP; Hansen et al. 2010). NASA Goddard Institute for Space Studies. Dataset accessed 2010-02-04 at `http://data.giss.nasa.gov/gistemp/`

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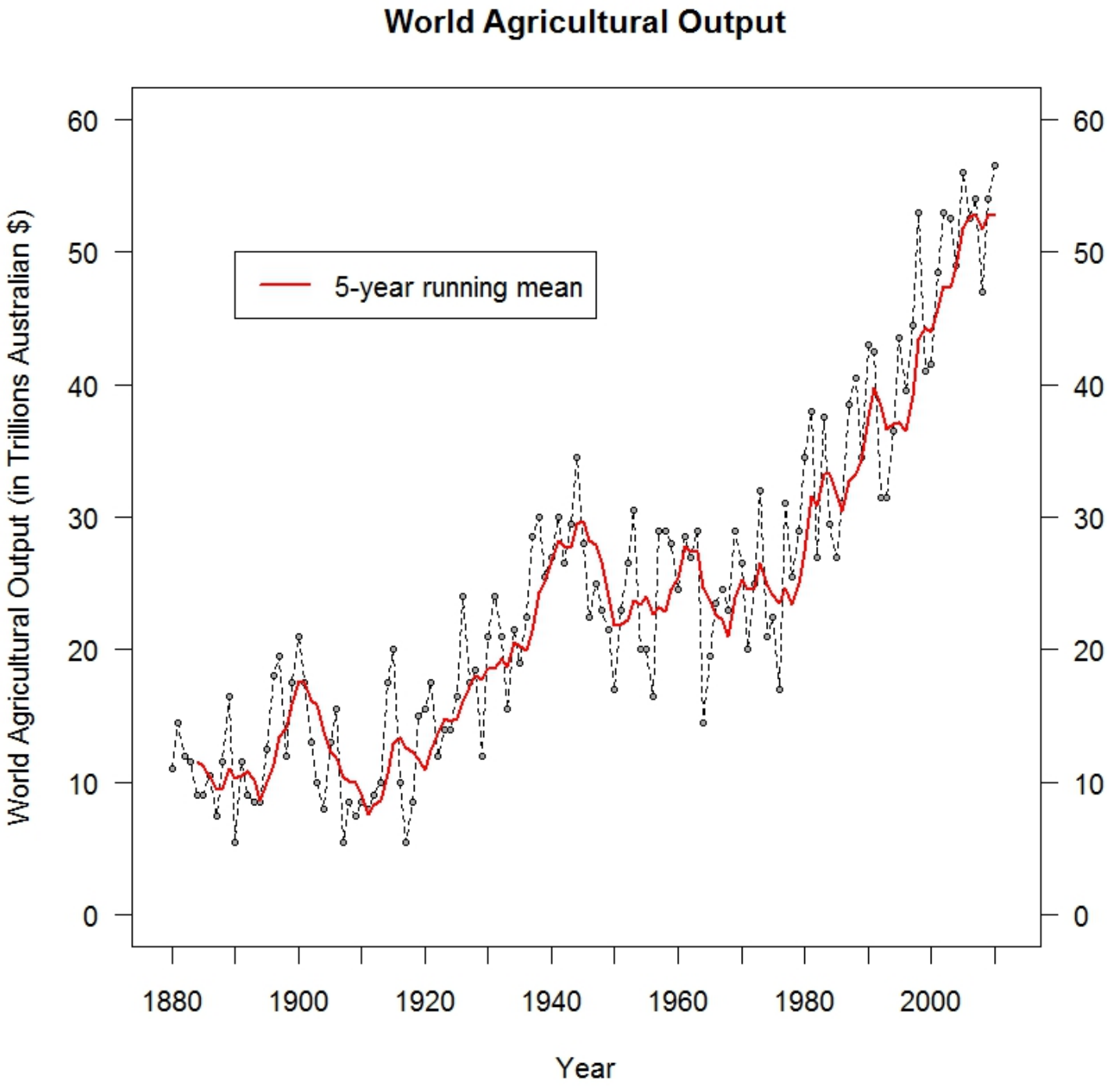

Figure 3. Stimulus data shown to expert economists in a blind test of contrarian statements invoking the "pause". See text for details. Data are actually global land-sea surface temperature anomalies, GISS Surface Temperature Analysis (GISTEMP; Hansen et al. 2010). NASA Goddard Institute for Space Studies. Dataset accessed 2011-03-03 at `http://data.giss.nasa.gov/gistemp/`.