Does it matter if the consensus on anthropogenic global warming is 97% or 99.99%?

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Abstract

Cook et al. (2013) reported a 97% scientific consensus on anthropogenic global warming (AGW), based on a study of 11,944 abstracts in peer-reviewed science journals from 1991-2011. This estimate was corroborated by a complementary survey of the authors of the papers. Powell (2016) claims that the Cook et al. methodology was flawed and that the true consensus is virtually unanimous at 99.99%. Powell's method underestimates the level of disagreement because it relies on finding explicit rejection statements in the abstracts of published papers as well as the assumption that abstracts without a stated position endorse the consensus. However, the Cook et al. results show that rejecting authors also published abstracts expressing no position, and survey responses revealed that papers may express disagreement with AGW despite the absence of a rejection statement in the abstract. Cook et al.'s 97% result takes these cases into account. Furthermore, contrary to Powell's claims, we show quantitatively that the Cook et al. method is valid for the now universally accepted theory of plate tectonics. The ~3% of scientists who either dispute or are undecided about AGW do not present a coherent case against the theory and their arguments have invariably been rebutted. Nevertheless, because of the politicization of the issue, dissenters are accorded undue attention in the media and in public debate (Boykoff, 2013). Surveys reveal a large gap between the public perception of the degree of scientific consensus on AGW and reality. We argue that it is the size of this gap, rather than the small difference between 97% and 99.99%, that matters in communicating the true state of scientific opinion to the public.

Introduction

Scientists are usually unconcerned with the quantification of consensus within their own fields. They know which questions are largely settled and where the interesting and disputed research frontiers lie. The public and non-specialists, however, are typically unable to assess competing claims by evaluating the scientific literature and must instead rely on heuristics, such as preponderant expert opinion, as guides to form conclusions about technical matters outside their expertise.

Measuring the level of scientific consensus on anthropogenic global warming (AGW) has become important because the public discourse has been distorted by opponents of emission-mitigation policies. These critics of climate action have inflated the number and prominence of the few scientists who doubt the mainstream scientific understanding, synthesized by the Intergovernmental Panel on Climate Change (Oreskes & Conway, 2011). It is in this politicized context that studies of the level of expert consensus have become the focus of contrarian dispute, often more so than the physical science itself.

In an article published in the *Bulletin of Science, Technology & Society* in 2016, James Powell argued that the widely-accepted 97% consensus figure on AGW is too low and that expert agreement is closer to a "virtually unanimous" 99.99%. It should be noted that Cook et al. (2013) (hereafter "C13") examined abstracts from 1991-2011, whereas Powell's study covered the period 2013-2014.

Powell makes the following four main arguments:

- Consensus studies by Doran & Zimmerman (2009), the Pew Research Center (2015) and Anderegg et al. (2010) fail to reveal a near-unanimous consensus on AGW "…because of some combination of small sample size, reliance on fallible opinion, and inclusion of nonexperts…"
- The C13 study of 11,944 articles in the peer-reviewed literature from 1991-2011 failed to adequately measure the consensus because it ignored the abstracts and papers that did not express an opinion on AGW.
- Applying the C13 methodology to a universally accepted theory like plate tectonics would yield misleading or absurd results.

- If it were true that 3% of scientists rejected or were uncertain about AGW, then the case for action to prevent global warming would be weakened, since, by comparison with now-settled scientific questions like continental drift and the origin of lunar craters, the existence of dissenters might suggest that AGW theory was about to be overthrown.

The first argument is perhaps best answered by Cook et al. (2016) (hereafter "C16"), a meta-study of consensus surveys since 1991, co-authored by many of the researchers of the original surveys. It concluded that the expert consensus on AGW correlates with climate expertise and the level of consensus found depends on the methodology and specific questions asked. Among climatologists actively publishing climate research in the peer-reviewed literature, 90-100% endorse the view that humans have been responsible for the increase in global surface temperatures since the mid-twentieth century, with results clustered around 97%.

The remaining three arguments will be discussed in detail below.

The method of Cook et al. (2013)

Powell (2016) writes:

> Fortunately, in contrast to most areas of human affairs, in science we do not have to rely on opinion: We have the peer reviewed, evidence-based scientific literature, authored by experts. To assess the state of a science, it is to that literature that we must turn.
>
> …the Cook et al. method is about articles and their subject and language, not about whether their authors accept AGW and thus not about the true consensus.

A single definition of "true consensus" does not exist. Literature surveys and opinion polls independently assess the level of consensus, but each method measures a slightly different aspect of expert knowledge. Therefore, a reliable assessment of consensus is best made using multiple lines of evidence that point to the same general conclusion (C16).

Powell's main criticism of C13 is that 66.4% of the abstracts examined were rated as "no position" and excluded from the consensus calculation. To count as an endorsement, C13 required that the abstract text refer to modern global warming or climate change and state, either implicitly or explicitly, that humans are the main cause. It is true that many authors of those "no position" abstracts may hold views that endorse AGW, but if the texts of their abstracts did not provide evidence for this, no guess was made about their opinions. The "no position" abstracts were therefore not used to calculate the consensus percentage.

In addition to third-party abstract ratings, C13 invited authors to rate their own papers. Of all papers that were self-rated, 1.8% rejected the consensus. Thus, regardless of assumptions about no-position papers, according to the authors of the peer-reviewed climate articles, a maximum of 98.2% of papers endorse the consensus – contrary to Powell's claim of a near-unanimous 99.98% consensus based on a count of abstracts and 99.99%, based on authors.

Powell assumes that making no statement is equivalent to endorsement, yet evidence from C13 contradicts this: for example, Spencer et al. (2007) was rated as rejection, but five other papers by the same lead author were rated as "no position". It is illogical to assume, as Powell does, that those papers represent endorsements. This counter-example shows that "no position" is not synonymous with endorsement. Indeed, that assumption results in a circular argument: assuming near-unanimous agreement to conclude that there is near-unanimous agreement.

Although the "no position" abstracts were not used in the calculation of the consensus, they were not overlooked. C13 showed that the percentage of such abstracts rose from approximately 50% in the mid 1990s to over 60% by 2000 (C13, Figure 1 (b)). Such an increase is to be expected as the central premise becomes accepted (Oreskes, 2007; Shwed and Bearman, 2010). Counter-intuitive though it may seem, a strengthening consensus is associated with a rising proportion of "no position" abstracts or papers. Nevertheless, in the case of AGW, the self-ratings reported in C13 and the presence of "no position" papers by authors of "rejection" papers show that it is incorrect to assume that "no-position" equals endorsement.

Measuring the consensus on plate tectonics

We agree with Powell that plate tectonics provides a good analog for examining the applicability of consensus estimation techniques. We concur also that papers in the recent peer-reviewed literature that reject the theory of plate tectonics are extremely rare. Also, we accept Powell's finding that explicit endorsement statements in the recent geological literature are likely to be uncommon. The scientific controversy on plate tectonics was essentially over by the late 1970s.

However, Powell is incorrect to assert that using the C13 methodology to measure the consensus on plate tectonics would result in the absurd case of "dividing zero by zero". An important feature of the C13 method was not just to investigate *explicit* endorsements or rejections, but also to identify *implicit* endorsements. Powell examined several cases of consensus science and wrote:

> In each of the examples above [plate tectonics, evolution, meteorite impacts on the moon], there were no direct endorsements and no rejections. Would the Cook et al. (2013) method still work? No. To calculate their 97.1%, Cook et al. divided the number of endorsements by the total of endorsements plus rejections. But for these examples, that would leave us dividing zero by zero. If the method does not work in general, why should it work in the case of AGW?

We tested how a modified version of C13 would work regarding the consensus on plate tectonics by rating 265 abstracts in the twelve issues of the journal *Geology* from 2015 and 66 abstracts from the six 2015 issues of the *Journal of the Geological Society*. Both journals are prominent and established peer-reviewed publications that cover the gamut of geological science. According to SCImago (2007), *Geology* and the *Journal of the Geological Society* are ranked, #1 and #3 among non-specialized geology journals, and they have H-indices of 154 and 87 respectively.

Our criterion for identifying implicit endorsement of plate tectonics was the uncritical mention of certain key elements of the theory, for example: *sea-floor spreading*; *continental drift; subduction; transform faulting*; *mountain building by means of continental collision*; and/or mention of global-scale paleogeographic features, for example, *Pangea*; *Tethys Ocean*. We also

looked for examples of explicit endorsement and for any kind of rejection of the theory of plate tectonics, but found none.

Of the 265 *Geology* abstracts, 65 (24.5%) were rated as "implicit endorsements" and 200 (75.5%) were judged to be "no position". The *Journal of the Geological Society* yielded 30 (45.5%) "implicit endorsement" and 36 (54.5%) "no position" ratings. Using the C13 methodology for calculating consensus (i.e., the number of endorsements divided by the sum of endorsements and rejections) yields 100%. This survey should not be taken as a definitive assessment of the plate-tectonic consensus; it covered only a small sample of the recent literature and is intended to be exploratory. Further description on the methodology can be found in the Appendix. Details of individual ratings can be viewed online at http://sks.to/S17-PT-ratings.

Even though the theory of plate tectonics forms the fundamental framework of modern geology, more than half of these samples did not mention any key features of the theory at all and were therefore rated "no position". This is partly because many researchers focus on subjects (e.g., mineralogy, geomorphology, glaciology, sedimentology) in which plate-tectonic processes do not usually need to be mentioned. Certainly, in neither the case of AGW nor that of plate tectonics do the large proportions of "no position" abstracts indicate that there is any widespread uncertainty among scientists. For example, Legates et al. (2013) claimed that the results of C13 showed "just 0.3 % endorsement of the standard definition of consensus: that most warming since 1950 is anthropogenic." because only 41 (according to their count) of the 11,944 abstracts that were examined explicitly endorse that statement. If we were to apply the same reasoning to abstracts in the modern geological literature—lacking as they are in explicit endorsement statements of plate tectonics—it would lead to the absurd conclusion that there is no consensus, rather than it being extremely close to 100%.

It is only if one adopts a consensus methodology that relies solely on explicit rejections or endorsements of plate tectonics—as Powell has done—that a survey of the recent literature might yield no examples of rejection or endorsement.

Does a 97% consensus imply a significant level of doubt?

Powell quotes Senator Ted Cruz's speculation about the pre-Copernican consensus on heliocentrism to imply that the existence of a 3% minority of disagreement on AGW might allow a claim to be made that climate science is similarly vulnerable to overturning. A parallel argument would hold that since continental drift was once a minority view among geologists, its ultimate acceptance vindicates other minority views, such as disagreement about AGW. Do these examples of minority views ultimately becoming mainstream apply to the case of AGW?

As Powell noted, pre-Copernican astronomical models and methods were not scientific. Moreover, resistance to the heliocentric model arose from established religion, not science. As for continental drift, prior to the 1950s, both sides of the debate were largely speculating when it came to global tectonic processes, especially regarding the age and origin of the ocean crust. The controversy was resolved as new geophysical information became available (e.g., Runcorn, 1965; Isacks et al., 1968; Hess, 1962; Vine & Matthews, 1963; summarized in Powell, 2015).

In North America, opposition to the theory of continental drift was rooted as much in cultural assumptions about the scientific method as it was in dispassionate weighing of the evidence. The theory-first proposals of some European geologists like Alfred Wegener conflicted with the inductive, multiple-working-hypotheses method preferred by American geologists who, as a result, considered the drift theory to be unscientific. However methodological objections disappeared as the evidence for continental drift, and the consilience and explanatory power of the plate tectonics theoretical framework became evident (Oreskes, 1999).

The scientific understanding of the greenhouse effect and the influence of human emissions emerged more gradually. The pioneering work of John Tyndall in the mid-nineteenth century, the contributions of Svante Arrhenius around the turn of the twentieth century and Guy Callendar in the 1930s notwithstanding, the significance of human emissions in enhancing the greenhouse effect was not widely accepted until the second half of the twentieth century (Plass, 1956). As new evidence emerged and better models were developed, the consensus among climate experts on AGW quickly expanded (Weart, 2008). By the early 1990s, the AGW consensus was robust and well established (Oreskes, 2004a; Shwed & Bearman, 2010; C13).

Although there are parallels between the growth of knowledge in climate science and plate tectonics, of the two theories, only AGW has obvious implications for public policy, especially regarding the need to reduce greenhouse-gas emissions to stabilize the climate (Oreskes, 2004b). These policy implications have motivated some corporations, industry lobby groups, conservative think tanks and individuals to challenge the scientific consensus on AGW, with some dissenters manufacturing doubt to create the impression of widespread controversy within the expert community (Oreskes & Conway, 2011). The few AGW contrarians who are qualified scientists do not have a coherent model that could replace the mainstream view, but instead have proposed scattered, mutually-incompatible hypotheses that have been repeatedly refuted by subsequent scientific analysis (e.g., Abraham et al., 2014; Benestad et al., 2015; Lewandowsky et al., 2016). Very rare dissenting scientific opinions can be found on plate tectonics (e.g., Scalera, 2003, Ollier, 2006), but, in contrast to the situation in AGW, these views receive little attention in the media and none from politicians.

Doubt about mainstream climate science that involves attacks on individual scientists or the entire field has an epistemically detrimental effect, impeding knowledge production (Biddle & Leuschner, 2016). We propose that this negative influence is best confronted not by insisting that objections do not exist, but by exposing the dissenting science as incoherent, false and motivated by politics (van der Linden, 2017; Cook et al., 2017, in revision).

Discussion

Out of 11,944 abstracts published from 1991-2011, C13 found just 26 examples of explicit rejection (i.e., categories 6 and 7). These categories were defined, respectively, as: “Explicitly minimizes or rejects that humans are causing global warming” and “Explicitly states that humans are causing less than half of global warming”. Using Powell’s methodology of calculating consensus using only explicit rejections of AGW, the C13 results would produce a consensus of 99.78%. In his study, Powell found 5 rejections out of a sample of 24,210 abstracts published in 2013 and 2014, and calculated a similar consensus value of 99.98%. (Powell also calculated a higher consensus percentage, based on author count, of 99.99%.) Plainly, the main difference between C13 and Powell is not in how abstracts are rated, but in the treatment of the “no position” abstracts and in C13’s inclusion of the “implicit rejection” rating level.

We maintain that C13's 97% result is a robust estimate of the scientific consensus on AGW for 1991-2011. However, C13 also found a slight trend of increasing consensus over that period, so 97% could be an underestimate for Powell's later study, which covers 2013-2014.

Communicating the high degree of consensus to the public on climate change is crucial because of the so-called "consensus gap", i.e., the difference between public perception of scientific consensus and the reality of the overwhelming majority of expert conclusions about AGW. As stated in C16:

> Leiserowitz et al. (2015) found that only 12% of the US public accurately estimate the consensus at 91%–100%. Further, Plutzer et al. (2016) found that only 30% of middle-school and 45% of high-school science teachers were aware that the scientific consensus is above 80%, with 31% of teachers who teach climate change presenting contradictory messages that emphasize both the consensus and the minority position.

Clearly, the public, including science educators, is grossly misinformed about or unaware of the degree of consensus on AGW (Losh, 2016). The size of this consensus gap is little different, in practice, whether one uses Powell's 99.99% estimate, C13's 97%, or the range of expert consensus estimates of 90-100% reported in C16.

Studies by van der Linden et al. (2015, 2016b) specifically tested the efficacy of communicating the 97% consensus and found that this messaging not only improved the test subjects' understanding of the true consensus, but also led to changes in people's perceptions that climate change is real, man-made, and of concern. This response was stronger among Republicans than Democrats. Similarly, Lewandowsky et al. (2013) found that consensus messaging significantly improved perceptions of climate science, while neutralising the biasing influence of political ideology. Myers et al. (2015) showed that communicating the consensus was most effective using numbers, specifically 97% in that study. While there have been some objections to consensus messaging, several empirical studies that experimentally tested it have affirmed its efficacy in increasing acceptance of climate change (Cook, 2016).

Research by van der Linden et al. (2015) concluded that people's estimate of consensus acts as a "gateway belief". In other words, perception of expert opinion has a flow-on effect to a range of climate attitudes, including acceptance of AGW and support for climate policy.

Communicating the 97% consensus has therefore been shown to be effective in conveying understanding of mainstream climate science to the public. Further research is required to see if it would be more productive to use very high consensus estimates, derived with different methodology and assumptions, such as Powell's.

Conclusions

We fully agree with James Powell when he writes:

> Science can speak no more clearly: AGW is true. To further delay action to prevent global warming is to force science to bow to ideology and politics.

However, the current reality is that "ideology and politics" are part of the public discourse on AGW. In such a context, there is a tendency for the contributions of the small minority of scientists who reject the mainstream conclusions of climate science to be over-emphasized. The few dissenters found in the scientific literature, identified by C13 and other assessments of consensus, as summarized in C16, have not presented a single, coherent alternative theory to AGW and their objections have invariably been refuted (e.g., Abraham et al., 2014; Benestad et al., 2015; Lewandowsky et al., 2016).

Minimizing the existence of contrarian scientists using a consensus estimation methodology such as Powell's exaggerates the true level of scientific consensus on AGW. That approach, which counts only explicit rejections and assumes that all other abstracts are endorsements, misclassifies some implicit rejections of AGW. Glossing over implicit rejections in this way leaves the study of consensus vulnerable to criticism and could lead to further public confusion, particularly because contrarian scientists are awarded disproportionate prominence in the media (Boykoff, 2013). Furthermore, quibbling over whether the consensus on AGW is 97% or 99.99% risks distracting attention from the primary goal of communicating the fact that the

overwhelming majority of scientists are united in their assessment of the evidence that humans are changing the Earth's climate.

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Appendix

Method for determining plate tectonic ratings

All the abstracts for the peer-reviewed papers published in the year 2015 in *Geology* (12 volumes, 265 abstracts) and the *Journal of the Geological Society* (6 volumes, 66 abstracts) were read and rated for their degree of endorsement or rejection of plate tectonics. None of the abstracts contained explicit statements affirming the theory, nor were any abstracts found that cast doubt on the theory or its essential elements, such as plate movement, sea-floor spreading or subduction. The abstracts fell into only two categories: implicit endorsement or no-position.

An abstract was judged to contain an implicit endorsement of plate tectonics when it uncritically referred to essential elements of the theory or to geological processes that could not reasonably be explained without resort to the theory.

The aim of the study was exploratory only. To determine the consensus on plate tectonics definitively in the modern geological literature would require a much larger sample of many more journals. The two journals selected are both leading solid-Earth science journals that publish research in all aspects of geology. In *Geology*, out of 265 abstracts, 65 implicitly endorsed plate tectonics (24.5%). In the *Journal of the Geological Society*, out of 66 articles, 30 (45.5%) were judged to have endorsed plate tectonics implicitly. The variance in frequency of implicit endorsements between the two journals perhaps reflects a different editorial focus.

The ratings were done by AS and KR. They conferred, discussing rating criteria and revising their initial ratings. No time or date stamps were recorded. The names and affiliations of the authors of the abstracts were visible to the raters. Howard Lee also commented on the ratings. The contributors to this process were not neutral with respect to their own assessment of the validity of the theory of plate tectonics.

Listed in an online supplement (http://sks.to/S17-PT-ratings) are the titles of the papers that were judged to be “implicit endorsements”, along with the keywords and phrases from the abstract that were used to justify the ratings.

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