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The scientific consensus of climate change revisited

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ABSTRACT

This paper first reviews previous work undertaken to assess the level of scientific consensus concerning climate change, concluding that studies of scientific consensus concerning climate change have tended to measure different things. Three dimensions of consensus are determined: manifestation, attribution and legitimation. Consensus concerning these dimensions are explored in detail using a time series of data from surveys of climate scientists. In most cases, little difference is discerned between those who have participated in the IPCC process and those who have not. Consensus, however, in both groups does not amount to unanimity. Results also suggest rather than a single group proclaiming the IPCC does not represent consensus, there are now two groups, one claiming the IPCC makes overestimations (a group previously labeled skeptics, deniers, etc.) and a relatively new formation of a group (many of whom have participated in the IPCC process) proclaiming that IPCC tends to underestimate some climate related phenomena.

1. Introduction

In terms of providing future projection of the global climate, the most significant player in setting the agenda is the Intergovernmental Panel on Climate Change (IPCC). It is typically assumed that the IPCC, consisting of some 2500 climate scientists, after weighing the evidence, arrived at a consensus that global temperatures are rising and the most plausible cause is anthropogenic in nature. The last in the series of reports from the IPCC (FAR: AR4) states:

> Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1,300 years. (p. 9)
>
> It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica (see Figure SPM.4). (p. 10)
>
> The observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is *extremely unlikely* that global climate change of the past 50 years can be explained without external forcing, and *very likely* that it is not due to known natural causes alone. (A Report of Working Group I of the Intergovernmental Panel on Climate Change Summary for Policymakers, 2007. p. 10.)

No where does it say 'all scientists agree' but there is a significant number of scientists involved in the construction of the reports. The IPCC bills the report as '2500+ SCIENTIFIC EXPERT REVIEWERS 800+ CONTRIBUTING AUTHORS AND 450+ LEAD AUTHORS FROM 130+ COUNTRIES 6 YEARS WORK 1 REPORT 2007 The IPCC 4th Assessment Report is coming out. A picture of climate change the current state of understanding.'

According to Oreskes (2004) 'There is a scientific consensus on the fact that Earth's climate is heating up and human activities are part of the reason. [. . .] The scientific consensus is clearly expressed in the reports of the Intergovernmental Panel on Climate Change. . . . and the IPCC accurately reflects the state of the art in climate science research'. But how should consensus be represented, for example, should it be a simple level of agreement with all aspects of the reports, some

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aspects of the reports, etc.? Climate change, as any climate scientist will attest, is a very complicated issue and expertise is dispersed accordingly. One would expect that within any complex issue requiring multiple levels of expertise there would be matters where a consensus exists and matters where there is little or no consensus, or at least, some doubt. Section 2 of the paper looks at work that has been done concerning consensus in the climate change issue, identifying that investigators sometime consider different 'consensus'. Section 3 of the paper looks at the 'dimensions' of consensus extracted from Section 2. Section 4 of the paper considers consensus and dissensus in 2008. This is followed by a conclusion (Section 5) briefly restating the findings.

2. Empirical investigations of consensus in climate science

This section assesses empirical attempts to measure levels of consensus concerning climate change, providing a summary of work to date. There have been empirical attempts, albeit limited in number, to assess consensus within the climate science community. Most have been met with criticism from one polar perspective or another: there is a consensus, there is not a consensus, it is caused by humans, it is not caused by humans, it is happening now, nothing has changed, etc. The most recent survey to assess the scientific consensus concerning climate change appears to have been conducted in 2009 by Doran and Zimmermann. They asked 2 questions to 10,257 'earth' scientists and received 3146 responses. By their own admission, of the 3146 responses only 79 were from climate scientists proper. They state: 'In our survey, the most specialized and knowledgeable respondents (with regard to climate change) are those who listed climate science as their area of expertise and who also have published more than 50% of their recent peer-reviewed papers on the subject of climate change (79 individuals in total).' Doran and Zimmermann asked the sample to respond to two questions: '1. When compared with pre-1800s levels, do you think that mean global temperatures have generally risen, fallen, or remained relatively constant? and 2. Do you think human activity is a significant contributing factor in changing mean global temperatures? [...] Of these specialists, 96.2% (76 of 79) answered ''risen'' to question 1 and 97.4% (75 of 77) answered yes to question 2.'

In 2007, Harris Interactive (Lichter, 2008) surveyed 489 randomly selected members of the American Meteorological Society and the American Geophysical Union. While the response rate is not given, the following findings are presented: 'In 1991 only 60% of climate scientists believed that average global temperatures were up, compared to 97% today. [...] Eighty-four percent say they personally believe human-induced warming is occurring [...] but this is confused by the finding that only ''A slight majority (54%) believe the warming measured over the last 100 years is not within the range of natural temperature fluctuation.''' (Lichter, 2008)

In 'Beyond the Ivory Tower, the scientific consensus on climate change', Oreskes (2004) conducted a qualitative analysis of 928 abstracts of papers in refereed scientific journals published between 1993 and 2003 concluding 'The scientific consensus is clearly expressed in the reports of the Intergovernmental Panel on Climate Change (IPCC).' and that the consensus is 'In its most recent assessment, IPCC states unequivocally that the consensus of scientific opinion is that Earth's climate is being affected by human activities.' Oreskes states 'Of all the papers, 75% fell into the first three categories, either explicitly or implicitly accepting the consensus view; 25% dealt with methods or paleoclimate, taking no position on current anthropogenic climate change. Remarkably, none of the papers disagreed with the consensus position.'

3. Dimensions of consensus

Scrutinizing the claims made by scientists attempting to measure the consensus, it becomes obvious that often the researchers (of the consensus) have been concerned with, and measured, different things. Doran and Zimmermann for example focus on rise in temperatures: '1. When compared with pre-1800s levels, do you think that mean global temperatures have generally risen, fallen, or remained relatively constant?' which relates to a level of consensus concerning *manifestation* of climate change, and; 2. 'Do you think human activity is a significant contributing factor in changing mean global temperatures?' which relates to consensus concerning the *attribution* of climate change. Harris Interactive discovered 'In 1991 only 60% of climate scientists believed that average global temperatures were up, compared to 97% today.' again, emphasizing *manifestation* of climate change. The IPCC itself addresses the issues of *manifestation* and *attribution*. Oreskes (2004) adds a third dimensions of consensus, namely 'The scientific consensus is clearly expressed in the reports of the Intergovernmental Panel on Climate Change (IPCC).', which could be considered the dimension of *legitimation* by scientific authority (i.e. the IPCC is the official UN panel dealing with climate change). From the above then, it is possible to draw three dimensions of consensus, as it pertains to climate change science: 1. manifestation, 2. attribution, and 3. legitimation.

In addition to the above work aimed at measuring consensus in climate science, three surveys of climate scientists were conducted by Bray and von Storch (1996, 2003, 2008) and serve as the basis for the following analysis. Concern is not with debating the existence of a consensus but to: 1. clarify that consensus has dimensions, and 2. given the complexity of these dimensions, to assess consensus of some simple measures. The series of surveys conducted by Bray and von Storch each addressed all three dimensions noted above: manifestation, attribution and legitimation. Among the questions asked in the surveys, 3 pertain explicitly to the task at hand.

The 1996 survey was an anonymous, self administered questionnaire in the 5 languages of the recipients, consisting of 74 questions distributed by post to 5 countries, 500 to North American scientists and 740 to European scientists. The response rate was 546 or approximately 40%, with 28 scientist claiming to work in other than the 5 countries employed in the study.

The 2003 survey was made know through various list servers (i.e. ClimList, American Meteorological Society, various climate science research institutes). As saturation sampling was employed, which Bradly (1999) argues, is a

technique that overcomes any lack of reliable sampling frame, no response rate was calculable. The number of respondents was 558 from 28 countries. Claims were made that it was possible for respondents to submit more than one completed survey thereby pushing the results one way or the other. (This however did not seem to be the case, or, if indeed it was, bias was towards the claim that the 'science was in'.)

The 2008 survey was conducted using email invitations which contained measures to ensure only one survey response per invitee. The 2008 sample was composed of a list of authors drawn from climate journals with the 10 highest ISI impact ratings for the last 10 years, the list of authors who contributed to Oreskes' conclusions concerning consensus, obtainable online at the following links: http://www.staff.livjm.ac.uk/spsbpeis/Oreskes1993.htm.through/Oreskes.2002.htm, and climate scientists drawn from readily available email lists on institute web sites (i.e. NCAR, MPI, AMS, etc.). Duplicates in the three lists were removed before distribution. The combined invitation list numbered a potential 2677 respondents; defunct email addresses reduced the valid mail out to 2059. The response rate for ISI authors list was approximately 27%, for Oreskes' list, approximately 10%, and from the Institute list, approximately 19%, for a combined response rate of 18% (375 responses).

All three surveys employed non-probability convenience sampling. Convenience sampling provides an inexpensive approximation of truth. Quite simply, the sample is selected because it is convenient. The respondents were 'preselected' in as much as they were included as they met specific criteria, i.e. had authored papers concerning climate change and published them in significant climate science journals, were currently employed in climate research institutes or have previously been used as a sample in publishable results concerning climate change consensus among scientists (i.e. Oreskes list).

Sampling special groups (in this case, climate scientists) often results in a comparatively difficult sample selection and a comparatively low response rate. The difficulty of selecting such a sample is discussed in the Committee on Assessing Fundamental Attitudes of Life Scientists as a Basis for Biosecurity Education, National Research Council's (2009) report 'A Survey of Attitudes and Actions on Dual Use Research in Life Sciences'. Here the target population was US life scientists. The report notes, as in the case of the Bray–von Storch surveys, no complete list of the population was available or even known. The alternative chosen was to find a sample through the use of professional societies. An email invitation to partake in the survey was eventually sent to a list of 10,000 life scientists. The response rate for completed surveys was 15.7%.

Concerning the response rate of 18% to the 2008 Bray–von Storch 2008 Survey, Hamilton (no date given) produced a white paper that analyzed 199 surveys. The total response rate of these surveys, calculated using the total number of surveys sent out in the 199 surveys and the total number of responses for the 199 surveys was 13.35%. He also noted that large invitations lists, >1000, tend to be associated with lower individual response rates.

Furthermore, Viser et al. (1996) showed that surveys with lower response rates (near 20%) tended to produce more accurate results than surveys with higher response rates. Although, it is doubtful that this could be generalized to all surveys. In as much, Holbrook et al. (2007) concluded that a low response rate does not necessarily equate to a lower level of accuracy but simply indicates a risk of lower accuracy.

Harris Interactive, a well established organization specializing in web-based surveys, used a convenience sample of 70,932 California residents in a survey of attitudes towards healthcare. As with the survey of scientists (Bray and von Storch, 2008) an email was sent to potential respondents with a link to a web survey and non-respondents received one reminder email. The response rate for the Harris Interactive survey was 2%. Consequently the sampling method and the response rate for the surveys of climate scientists do not appear distinct from other such undertakings.

Of these 375 respondents to the 2008 Bray–von Storch survey, 293 (78.1%) claimed the nature of their work to be concerned with 'physics of the climate system, modelling, model development, data acquisition or theory development.' (the response to the survey question: 'The nature of your work is best described as being concerned with: a. physics of the climate system (modelling, model development, data acquisition); b. theory development, etc.; c. impacts of climate change (ecological, economic, social, etc.); d. climate change policy analysis; e. climate change and health; f. climate change communication; g. science administration; h. other). Only those claiming to work on the physics of the climate system (response category a) were selected for further analysis. No breakdown of which aspect of climate physics by respondent is possible. Such distinction was not asked as the resulting number of sub topics would likely be so great as to warrant the distinctions meaningless. Subsequent analysis of the 2008 survey in this paper will only include this subsample of the 293 respondents.

There is also the question of self selection, that is, who would be likely to respond to the survey, those favouring the IPCC conclusions or those opposing IPCC conclusions. Table 2 indicates that in all variables pertaining particularly to the question of the IPCC being representative of scientific consensus, the mean is fairly central on the scale of 1 = strongly disagree and 7 = strongly agree, with minimal differences between those who have participated in the IPCC process and those who have not. Furthermore, Figs. 3a–d and 4a–d suggest that no polar position is overly favoured within the sample and that the questions raised concerning self selection can be deemed moot.

It should also be noted that the three surveys of climate scientists do *not* constitute a panel study but rather a repeated survey and that this does not hinder any longitudinal analysis. To investigate change (in this case the perception of the scientific consensus concerning global warming/climate change) the goal is to measure that same thing (measure of consensus) at different points in time. Repeated surveys collect the data from different samples. Panel studies submit the survey questions to the same people over a period of time. Panel studies, then, follow individuals over time. The purpose of the surveys of climate scientists, forming the basis of this analysis, was to follow the opinion of a collective body over time. Repeated surveys do not capture the actual change of opinion within the individual scientist, i.e. a shift from one

Table 1 – Frequency by country: 'Perspectives of Climate Scientists on Global Climate Change'.

Country	1996		2003		2008	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Argentina			1	0.2		
Australia			21	3.8	22	5.9
Austria			3	0.5	3	0.8
Belgium					1	0.3
Brazil			1	0.2	4	1.1
Bulgaria			1	0.2		
Canada	35	6.4	14	2.5	13	3.5
China					1	0.3
Croatia					3	0.8
Cyprus					2	0.5
Czech Rep.					3	0.8
Denmark	33	6.0	5	0.9	1	0.3
Estonia			1	0.2	1	0.3
Ethiopia						
Finland			3	0.5	5	1.3
France			5	0.9	5	1.3
Germany	228	41.8	56	10.1	61	16.3
Global					1	0.3
Greece					1	0.3
Hungary					1	0.3
India			3	0.5	1	0.3
Israel					2	0.5
Italy	73	13.4	14	2.5	10	2.7
Japan			3	0.5	6	1.6
Mexico			3	0.5	1	0.3
Netherlands			4	0.7	7	1.9
New Zealand			6	1.1	1	0.3
Norway			3	0.5	4	1.1
Poland			1	0.2	1	0.3
Russia			1	0.2	1	0.3
Serbia					1	0.3
South Africa			3	0.5	1	0.3
Spain			2	0.4	2	0.5
Sri Lanka					1	0.3
Sweden			5	0.9	2	0.5
Switzerland			7	1.3	1	0.3
Taiwan			1	0.2		
UK			18	3.2	57	15.2
USA	149	27.3	372	66.8	145	38.7
Other	28	5.1				
Missing			1	0.2	2	0.5
Total	546		558		375	

polar perspective to another polar perspective. Instead the goal is to capture the effects of all of the changes. A panel design is ill suited to estimate net change for an overall population, i.e. aggregate trends. As 'consensus' implies 'aggregate', the repeated survey was deemed to be the appropriate means to attain the goal (cf Firebaugh, 1997).

Frequency by country and year of 'Perspective of Climate Scientists on Global Climate Change' surveys (Bray and von Storch, 1996, 2003, 2008) are presented in Table 1.

Consensus concerning *legitimation* (i.e. agreement with IPCC) is captured with the responses of levels of agreement with statements: (1996, 2003) 'The IPCC Reports accurately reflect the consensus of thought within the scientific community.'': Response categories: 1 = strongly agree, 7 = strongly disagree. In an effort to capture more detail of what parts of the IPCC reports the broader scientific community agreed with, the 2008 question was broken into 4 separate parts.

For the purpose *legitimation* in 2008 in Fig. 1, only responses to 'temperature' are used. Scientists were asked to respond to the following: 'The IPCC reports accurately reflect the consensus of scientific thought pertaining to temperature' Response categories 1 = strongly disagree, 7 = strongly agree. To be able to provide summary measures of consensus from the Bray–von Storch surveys, response values 1 to 3 are consolidated into a single values, values 5 to 7 are consolidated into a single value and the value of 4 can be considered a suspended judgment.

Consensus in the assessment of *attribution* is captured with the responses of levels of agreement to the statements: (1996, 2003) 'Climate change is mostly the result of anthropogenic causes.' Response categories: 1 = strongly agree, 7 = strongly disagree; (2008) 'How convinced are you that most of recent or near future climate change is, or will be, a result of anthropogenic causes?'' Response categories: 1 = not at all,

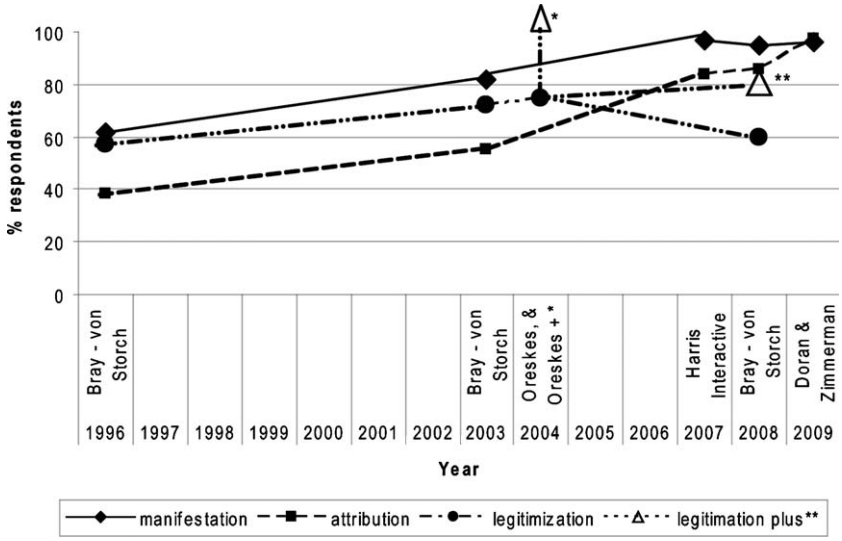

Fig. 1 – Trajectories of consensus in climate science. *75% either explicitly or implicitly accepting the consensus view + the 25% taking no position on current anthropogenic climate change, i.e. 'none of the papers disagreed with the consensus position'. **'Legitimation plus' refers to the sum of respondents who agreed that the IPCC reports accurately reflect the consensus of scientific thought pertaining to temperature plus the scientists who believed the IPCC tends to *under estimate* the magnitude of future changes to temperature (i.e. do not necessarily disagree with the IPCC). These details are discussed more thoroughly in a latter part of the paper.

7 = very much, and 'The current state of scientific knowledge is developed well enough to allow for a reasonable assessment of the effects of green-house gases emitted from anthropogenic sources, 1 = strongly agree, 7 = strongly disagree.

Consensus in the assessment of *manifestation* is captured with the responses of levels of agreement to the statements: (1996, 2003), 'We can say for certain that global warming is a process already underway.' Response categories: 1 = strongly agree, 7 = strongly disagree; (2008) 'How convinced are you that climate change, whether natural or anthropogenic, is occurring now?'. Response categories: 1 = not at all, 7 = very much, and 'How much are we beginning to experience the more gradual impacts of climate change, anthropogenic or otherwise', 1 = not at all, 7 = very much. A summary of consensus measures over time are presented in Fig. 1.

The consensus concerning *manifestation* rises until 2007 at which point it tends to level off at an approximate level of 90% agreement. Whether it can be attributed to anthropogenic causes (*attribution*) peaks in 2009 at approximately the same level of agreement as measured for *manifestation*. When it comes to *legitimation*, the measurements of the trajectory of consensus are not so linear, and only by using the lesser claim of Oreskes, is the linear pattern (more and more scientists being convinced) maintained. By using the upper limit of Oreskes' measurement, the degree of consensus becomes unanimous. With the Bray–von Storch data (2008), without the inclusion of those who feel the IPCC tends to underestimate the phenomenon, consensus that the IPCC is representative of the state of the science (*legitimation*) tends to drop. In effect, this suggests there are now two groups skeptical of IPCC reports. (Whereas before a single group stating the IPCC made over estimations was singled out as the skeptics, now two opposing groups tend to disagree with the IPCC. Note, this is disagreement that the IPCC is representative of the science (*legitimation*), *not* disagreement that of climate change as an important issue.)

What is interesting here is that the increase in the level of consensus concerning the matter that climate change is underway (*manifestation*) and that it is likely a result of anthropogenic influences (*attribution*) is not mimicked in the notion that the IPCC represents scientific consensus (*legitimation*). This is likely due to the fact that the IPCC reports entail a summary of a number of climate science sub-issues. The Bray and von Storch 2008 survey was designed to capture a greater level of detail concerning the perspective that the IPCC represented the consensus of the broader scientific community, allowing these sub-issues to be explored.

4. Consensus and dissensus in 2008

Throughout the following section of the analysis, for reasons of comparison, the distinction is maintained between those who have in some way participated in the IPCC process (lead author, contributing author and/or reviewer) and those who have not participated in IPCC activities. Furthermore, as noted previously, the sample is also limited to those scientists working in the physics of climate change. Two respondents from this group chose not to complete the questions concerning IPCC involvements, resulting in the inclusion of 99 scientists who claimed to be working in the physics/modelling of climate change *and* to have been involved in the IPCC process and 192 scientists who claimed to be working in the physics/modelling of climate change *and* also claimed *not* to have been involved in the IPCC process. By maintaining this distinction it is possible to assess if, and to what degree,

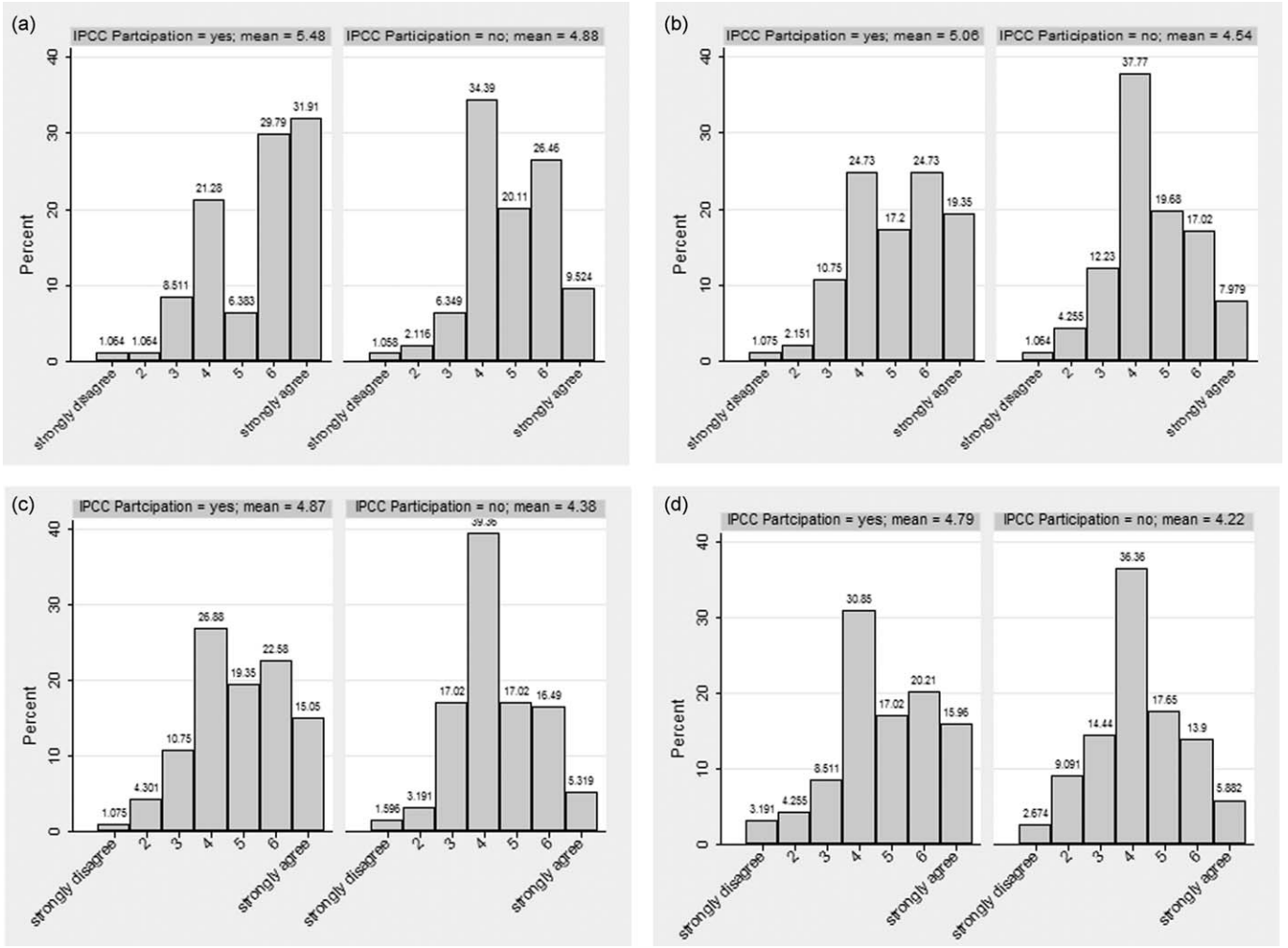

Fig. 2 – Legitimation of IPCC consensus. (The IPCC reports accurately reflect the consensus of scientific thought pertaining to: temperature, precipitation, sea-level rise, extreme events.)

Table 2 – Independent samples test of means.

IPCC report reflect consensus pertaining to	IPCC participation	N	t-Test for equality of means: Mean 1 = strongly disagree 7 = strongly agree	Sig (2-tailed)
Temperature	Yes	94	5.48	.001
	No	189	4.88	
Precipitation	Yes	93	5.06	.003
	No	188	4.54	
Sea-level	Yes	93	4.87	.006
	No	188	4.38	
Extreme events	Yes	94	4.79	.003
	No	187	4.22	

dissensus is also found among those who are or have been active participants in the IPCC process.

Concerning *legitimation* in 2008, in Bray and von Storch 2008 respondents were asked to agree or disagree with the statements the IPCC reports accurately reflect the consensus of scientific thought in more detail, explicitly pertaining to: 1. temperature, 2. precipitation, 3. sea-level rise, and 4. extreme events. The results are presented in Fig. 2

Fig. 2a assesses the level of consensus concerning the IPCC claims related to temperature. Considering the distribution it is evident that those who participated in IPCC activities tend to be more prone to agree that IPCC reports accurately reflect consensus pertaining to temperature. However, only 31.9% of the respondents have no doubt, i.e. strongly agree and approximately 11% of respondents who were involved in IPCC activities, in fact, tend to disagree somewhat that the IPCC represents consensus pertaining to temperature, in contrast to approximately only 9% of those having not participated in IPCC activities and claiming the IPCC does not represent consensus. The distribution seems to suggest that, overall, those who did not participate in IPCC activities are more inclined to avoid an extreme position.

Concerning consensus regarding the representation of precipitation, Fig. 2b, it is evident that those who have participated in IPCC activities are more inclined to agree with IPCC statements on this matter. However there is still a minority of IPCC involved scientists who do not agree that the IPCC represents consensus. Fig. 2c indicates that some 16% of scientists who claim to have been involved with the IPCC (as compared to approximately 21% of those who claim no involvement with the IPCC) do not agree that the IPCC represents scientific consensus on sea level and again there is an increase in number of respondents who reserved judgment among those who claimed no participation in the IPCC process. Fig. 2d, concerning extreme events, demonstrates a similar response pattern. Of particular note in Fig. 2a–d is the lack of any sense of unanimity. Table 2 contains the means of the two groups.

Table 2 suggests a slight statistically significant difference between the means of those who have participated in IPCC activities and those who have not, with a tendency towards less agreement that the IPCC represents consensus among those who have not. However, the difference is relatively marginal suggesting that whether or not one has worked within the IPCC framework has little impact on the belief that the IPCC represents scientific consensus. The means themselves, if accepted as a measure of consensus, indicate that consensus is not strong in either groups.

However, it is the nature of the disagreement, not the mere fact of its existence, that is important, i.e. does the IPCC tend to over estimate or under estimate the magnitude of future *changes* to, or the magnitude of *impacts* of, temperature, precipitation, sea-level rise and extreme events. Fig. 3 displays the distributions of responses to scientists assessments of whether the IPCC reports tend to under estimate, accurately reflect (a value of 4) or over estimate the magnitude of future *changes* to temperature, precipitation, sea-level rise and extreme events.

With reference to changes in temperature (Fig. 3a) a majority of scientists, both IPCC participants and non-participants (64.52% and 64.13% respectively) think the IPCC reports accurately reflect the magnitude of future changes to temperature. From the IPCC participant respondents, approximately 21.5% state that the IPCC reports tend to underestimate the magnitude of change to temperature, slightly more than the 19.5% of respondents making similar claims from the group claiming no participation with the IPCC. Approximately 14% of the IPCC participation group and approximately 21% of the non-IPCC participation group claim the IPCC reports over estimate of the magnitude of change to temperature. However, there is no statistically significant difference between the means of the two groups of respondents.

The IPCC estimates of future changes to precipitation demonstrate a lower level of agreement that the IPCC represents consensus, with approximately 54% of the IPCC participation group stating that IPCC reports reflect consensus and approximately 59% of the non-IPCC participation group stating the IPCC reflects consensus, i.e. in regards to precipitation change, those who have *not participated in the IPCC are more likely to accept the IPCC consensus*. The perspective that the IPCC reports under estimate changes in precipitation is shared by approximately 31% of respondents who participated in the IPCC process and 33% of those who claim no participation. Over estimation shows similar tendencies with 15% IPCC participants and 13% of non-participants claiming that IPCC reports tend to over estimate changes in precipitation.

With regards to sea level change, there is only a strong minority of scientists who accept that the IPCC reports reflect consensus: approximately 43% of participants and 50% of the

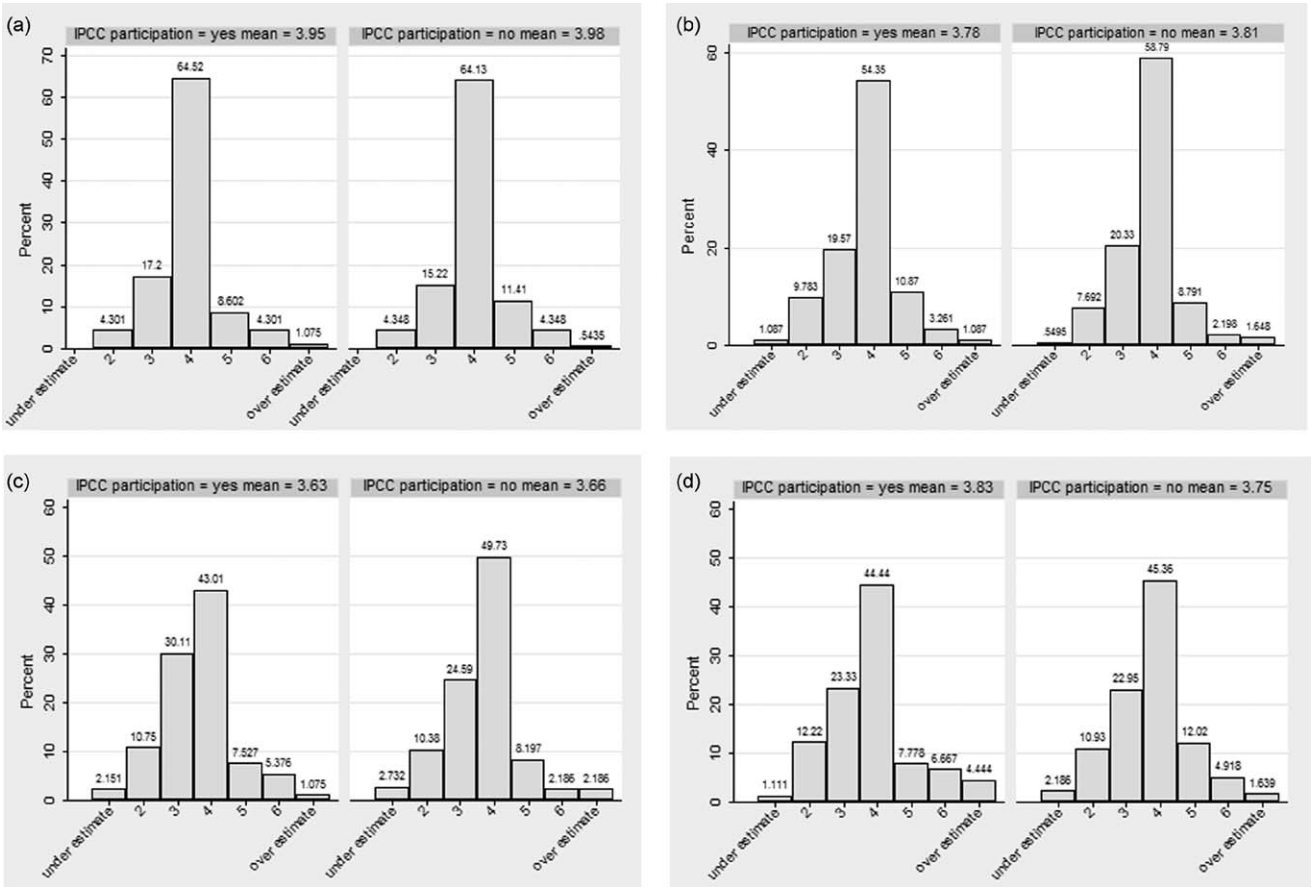

Fig. 3 – IPCC reports and consensus concerning magnitude of change. (The IPCC reports tend to under estimate, accurately reflect (a value of 4) or over estimate the magnitude of future changes to: temperature, precipitation, sea-level rise, extreme events.)

non-IPCC participants. In terms of under estimation, approximately 43% of IPCC participants claim the IPCC reports tend to under estimate sea level change and approximately 38% of non-IPCC participants claim the same. 15% of IPCC participants claim the IPCC reports over estimate changes to sea level and 12% of non-IPCC participants claim the same.

The last measure of change is in reference to changes in extreme events. Here, only 45% of IPCC participants and 45% of non-IPCC participants claim the IPCC's account of extreme events represents consensus. In terms of under estimating the magnitude of change in extreme events, approximately 37% of IPCC participants and 36% of non-IPCC participants claim the IPCC under estimates change in extreme events. As for over estimation, approximately 19% of IPCC participants and 19% of non-IPCC participants claimed the IPCC tends to over estimate changes to extreme events. In all four measures of change, there are no statistically significant differences between the means of IPCC participant group and the non-IPCC participant group.

It is also necessary to assess the level of consensus concerning the impacts of aspects of climate change. This is, after all, the impetus for policy change and emission reductions. Fig. 4 contains the distributions of responses from climate scientists pertaining to the magnitude of impacts resulting from changes to temperature, precipitation, sea-level rise and extreme events.

Again, any sense of unanimity is absent in all four measures. In terms of the impacts resulting from temperature change, 67% of IPCC participants and 65% of non-IPCC participants agreed that the IPCC reports accurately reflect the nature of impacts concerning temperature. Approximately 19% of IPCC participants and 20% of non-IPCC participants tend towards the claim that the IPCC reports underestimate the magnitude of the impacts, while approximately 14% and 16% respectively claim that the IPCC reports tend to over estimate the impacts. For impacts due to changes in precipitation, approximately 63% of IPCC participants and approximately 59% of non-IPCC participants view the IPCC reports as accurate. Approximately 23% of IPCC respondents and approximately 29% of non-IPCC participants make the claim that the IPCC reports tend to under estimate impacts from precipitation changes; approximately 14% of IPCC participants and 13% of non-participants claim the opposite, namely the IPCC reports tend to over estimate the impacts due to change in precipitation. Concerning impacts from sea level, approximately 50% of IPCC participants and 53% of non-participants claim the IPCC reports to be an accurate depiction. Some 28% of IPCC participants and 34% of non-IPCC participants claim the IPCC reports under estimate the impacts of sea level and 11% and 13% respectively claim the IPCC reports over estimate the impacts of sea-level rise.

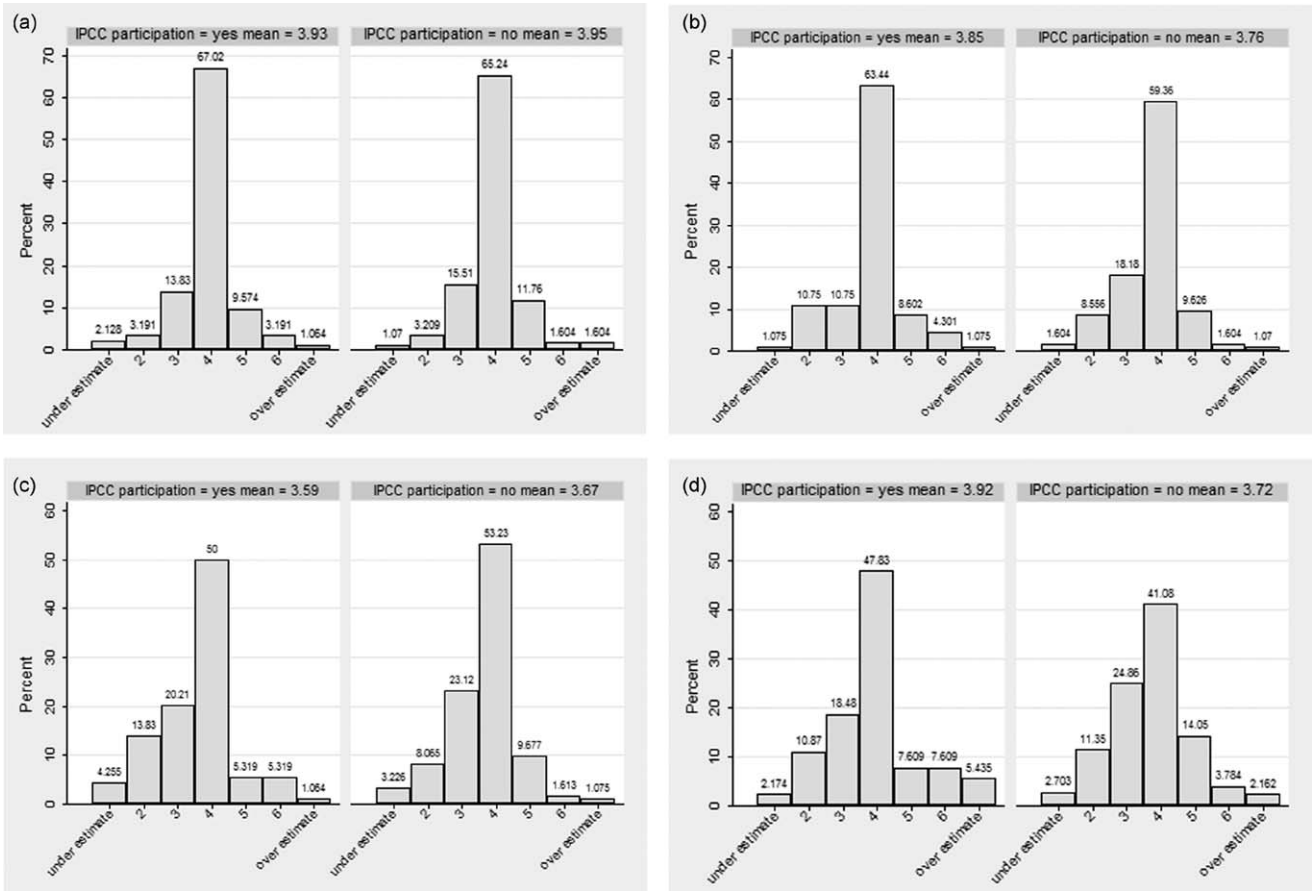

Fig. 4 – IPCC reports and consensus concerning magnitude of impacts. (The IPCC reports tend to under estimate, accurately reflect (a value of 4) or over estimate the magnitude of the impacts resulting from changes in: temperature, precipitation, sea-level rise, extreme events.)

Finally, concerning extreme events, 48% of IPCC participants 41% of non-participants agree that the IPCC accurately depicts the impacts resulting from extreme events; approximately 31% and 39% respectively claim the IPCC tends to under estimate impacts resulting from extreme events and 23% and 20% respectively claim the IPCC tends to over estimate impacts resulting from extreme events. Concerning the means, there are no statistically significant differences between the two groups.

While not explicitly concerning agreement with IPCC reports but nonetheless significant for a measure of consensus concerning global climate change, survey respondents were

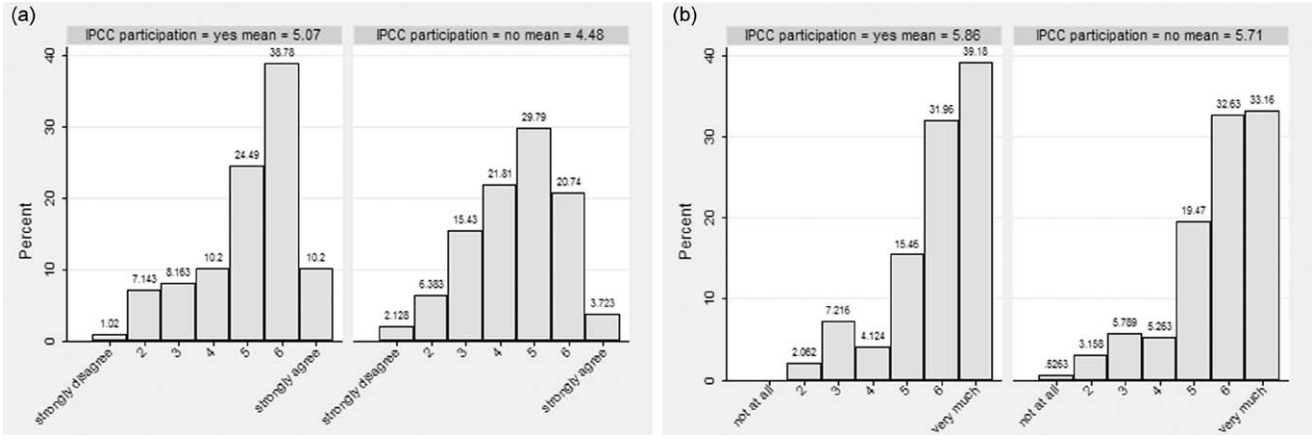

Fig. 5 – Consensus concerning attribution. (The current state of scientific knowledge is developed well enough to allow for a reasonable assessment of the effects of green-house gases emitted from anthropogenic sources; How convinced are you that most recent and near future climate change is, or will be, a result of anthropogenic causes?)

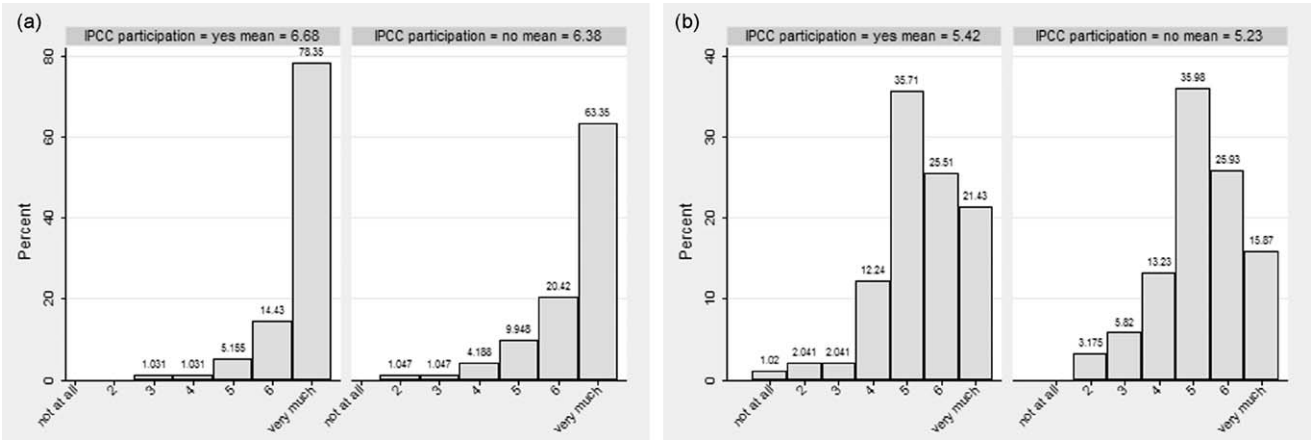

Fig. 6 – The manifestation of climate change. (How convinced are you that climate change, whether natural or anthropogenic, is occurring now?; How much are we beginning to experience the more gradual impacts of climate change, anthropogenic or otherwise?)

asked to express an opinion concerning the cause (*attribution*) of climate change. The survey employed two measures. Results are presented in Fig. 5.

For the sake of succinctness, for the discussion of attribution in Fig. 5a all values less than 4 will be treated as disagreement and all values greater than 4 will be treated as agreement. The value of 4 will be considered as a suspended judgment. In Fig. 4b values less than 4 will be treated as a measure of disagreement that climate change is caused by anthropogenic influences and values greater than 4 will be treated as a measure of agreement. Fig. 5a suggests that, of those respondents claiming IPCC participation, approximately 16% claim the current state of scientific knowledge is *not* developed well enough to allow for a reasonable assessment of the effects of green-house gases emitted from anthropogenic sources, and 24% of the non-IPCC participants make the same claim. Approximately 68% of IPCC participants and 55% of participants claim that the current state of scientific knowledge is indeed developed well enough to allow for a reasonable assessment of the effects of green-house gases emitted from anthropogenic sources. On this measure of attribution there is a statistically significant difference between the means of the two groups, however the difference between the means (5.07 and 4.48 respectively) is minimal. Concerning the second measure of attribution, approximately 9% of the IPCC participants are less than convinced that most recent and near future climate change is, or will be, a result of anthropogenic causes and approximately 10% of the non-IPCC participants share the same opinion. 86% of IPCC participants are convinced that most recent and near future climate change is, or will be, a result of anthropogenic causes and approximately 85% of non-IPCC participants make the same claim. However, if these measures are assessed in terms of absolute certainty considering only the values of 1 and 7, the data indicates that none among the IPCC participants is 100% convinced that anthropogenic sources are *not* to blame but only 39% are fully convinced that they are to blame. Among the non-IPCC participants only approximately 0.5% expressed a level of certainty that anthropogenic cause are *not* to blame but only 33% expressed absolute certainty that they are to blame. On this measure, concerning the means, there is no statistically significant difference between the groups.

4.1. *Manifestation 2008*

Manifestation is the last dimension of consensus as presented in this paper. Two measures were used in the survey to capture respondents' assessments. Results are presented in Fig. 6

All but a few exceptions, in both groups, tend to agree that climate change is a here and now phenomenon (Fig. 5a) but there seems to be less certainty as to whether we are actually experiencing the impacts (Fig. 5b). There is a statistically significant difference in the means for Fig. 5a but the actually difference between the means (6.68 vs. 6.38) is minimal.

5. Conclusion

This analysis began with a review of the use of the term 'consensus' as used in reference to climate change. Attention was then turned to attempts to empirically measure the level of scientific consensus and it was demonstrated that studies of scientific consensus have tended to measure different things. Three 'dimensions' of consensus were abstracted: *legitimation*, *attribution* and *manifestation*. Adding some results of repeated survey data pertaining to climate scientists (Bray and von Storch, 1996, 2003 and 2008) to other empirical analysis of consensus, a trajectory of consensus over time was plotted. Evidence of a second level of dissent, namely underestimation, became apparent, giving rise to two groups opposed to the claims made in the IPCC reports (*legitimation*). Dissensus, it appears, is a three way, not two way, distribution of perspectives. Following this trajectory, using the Bray–von Storch survey of 2008 the details of consensus were explored based on the three dimensions outlined above.

Analysis was undertaken using two groups, those who have participated in the IPCC process and those who have not,

for comparative purposes. *Legitimation* was assessed using 12 measures. Within these 12 measures some differences were noted between groups. However, in no cases, was there unanimous certainty or agreement that the IPCC reports reflect a 100% consensual perspective of the phenomenon. In fact, the highest measure of full agreement that the IPCC reflected consensus is found in the variable 'temperature' where only 32% of the group that participated in the IPCC process 'strongly agreed' that 'The IPCC Reports reflect the consensus of scientific thought pertaining to temperature'. Similar patterns were evident in all 12 measures.

However, having determined that there is less then unanimous agreement with the IPCC reports still demands an analysis of the nature of the disagreement; are the efforts of the IPCC perceived to over or under estimate climate related phenomena. This was addressed using measures to assess the magnitude of changes and the magnitude of impacts, in reference to temperature, precipitation, sea-level rise and extreme events. Again, the triangle of dissent was evident in both groups, with claims of under estimation, accurate estimation and over estimation. For example, in reference to the magnitude of temperature change, approximately 22% of the IPCC participant group claimed that the IPCC reports tended to under estimate the magnitude of change. 14% of the non-IPCC participant group made the same claim. Over all, on all measures, the distribution between the two groups was remarkably similar.

After a detailed look at the measures of *legitimation*, attention was turned to the matter of *attribution*. *Attribution* was addressed using 2 measures. 39% of IPCC participants and 33% non-participants responded with the highest possible measure of certainty when asked 'How convinced are you that most recent and near future climate change is, or will be, the result of anthropogenic causes'.

In reference to *manifestation*, there is a high level of consensus that climate change is occurring now, although there is less convincing evidence in terms of scientific consensus, that we are beginning to experience the impacts.

By providing a detailed analysis of a number of measures related to the dimensions of climate change consensus (as herein defined) this analysis demonstrates that consensus is a complex issue and this complexity is often over looked.

This analysis also presents levels of *shared agreement* among dissenting parties, with the possibility that they might serve as a noncontroversial basis for subsequent inquiry, and in doing so, avoid consensus based on political epistemology. That is, the intention of the paper is to suggest that the science of climate change be conducted devoid of dogma and politics, and be returned to the tenets of Science; beneficial debate and beneficial skepticism. When, as is often prematurely claimed, 'the science is settled', then, and only then, should the public and politics enter the fray. What this analysis has disclosed is that the science is NOT settled and that perhaps beneficial scientific skepticism, albeit in an infant stage, is growing and may wrest the issue from the hands of politico quasi-scientific institutions that have become fashionable in the era of 'global' studies. Perhaps apt for a parting comment and the current state of consensus on climate change is a paraphrase of a statement made by Lenin's reference to happiness: Climate change consensus, as is often reported, is perhaps the maximum agreement of reality and desire. Given the events of late 2009, and the ensuing crisis in climate science concerning transparency, it will be interesting to see whether the facts will remain constant and the truth will change or the truth will remain constant and the facts will change.

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