Climate Scientists and the Consensus on Climate Change: The Bray and von Storch Surveys, 1996-2008

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The international surveys of climate scientists conducted by Bray and von Storch in 1996, 2003 and 2008 represent the longest continuing series of such surveys to date. This paper outlines the main findings. It identifies propositions about climate change on which there appears to be a consensus as well as propositions, including 'alarmist' propositions, on which there is not. Since the surveys use Likert-type items, the paper identifies propositions on which there appears to be not just a consensus but also a strong consensus. There is a strong consensus around a series of key, inter-related, propositions: that climate change is happening, that climate change has anthropogenic causes, that human-induced climate change poses a serious threat to humanity, and that the threat is not likely to be met by voluntary action. Insofar as the surveys can be compared, the consensus was stronger in 2008 than in 1996. Nonetheless, consensus should not be mistaken for unanimity. Respondents acknowledged that 'climate science' was 'an extremely complicated subject, full of uncertainties.'

Introduction

Do climate scientists believe in global warming? If so, do they think that global warming is anthropogenic? More generally, how confident are climate scientists about the science of climate change? And do they feel the work the Intergovernmental Panel on Climate Change (IPCC) fairly represents the findings on climate science? There have been several attempts since the mid-1990s to answer these and related questions (see, in particular, Lichter 2008; Doran and Zimmerman 2009; Anderegg et al 2010). But the longest running set of international surveys has been the series conducted by two members of the Institute of Coastal Research at the GKSS Research Centre in Germany - Dennis Bray, a sociologist and Hans von Storch, a meteorologist.

Their first survey was conducted in 1996. Written in five languages and conducted by mail it sought the opinions of scientists associated with relevant scientific organisations in Germany, North America, Italy and Denmark. Samples were generated through the EarthQuest mailing list, which provided access to the names of scientists working in North America, and the mailing lists of the Deutsche Meteorlogische Gesellschaft, the Danish Meteorological Society and the Obsservatori Astronomico di Roma. The overall response rate was 40 per cent; this was judged 'favourable' when compared to response rates for 'similar surveys' (Bray and von Storch 2007, 1-2; Bray 2010, 4). Of the 546 respondents (some tables report n = 549), 228 came from

Germany, 149 from the USA, 73 from Italy, 35 from Canada and 33 from Denmark; 28 were working in other countries (Bray 2010, 6; Bray and von Storch 1999, for the sub-group drawn from Canada, the USA and Germany).

A second survey, organised in 2003 and run over the Internet achieved a more international reach, notwithstanding that it was conducted exclusively in English. 'The existence of the survey was posted in the Bulletin of the American Meteorological Society, the Climlist server, and...sent to institutional lists in Germany and Denmark'. Respondents (n = 558) came 'from some 30 countries', with fewer from Europe than in 1996. The method of sampling, sometimes known as 'saturation sampling', meant the response rate couldn't be calculated. To limit access, the survey was password protected, the password being contained in the message distributed via the lists (Bray and von Storch 2007, 3). After critics had expressed concern that the survey had been 'posted on a sceptics mailing' (Lambert 2005) the authors compared the 1996 and 2003 samples to reassure themselves and their readers that the second survey was not biased. For 34 of the 67 variables common to the two surveys the Kolmogorov-Smirnov tests showed 'no discernible differences'. In relation to all variables except one the Wald-Wolfowitz test produced results that were inconclusive - 'it did not indicate differences and it did not indicate no differences'; the exception indicated no difference. Under these circumstances the authors concluded 'that the two samples were similar enough to make meaningful comparison' (Bray, pers. comm.) In addition, 'the demographic features of the two samples tend to demonstrate much in common' (Bray and von Storch 2007, 3-4).

The third and most recent survey was also the most ambitious. Conducted in 2008, again via the internet, the sample was drawn from three groups working in 35 countries. One group consisted of authors of articles in 'climate journals with the 10 highest ISI impact ratings' over the previous ten years; of the 546 approached, 148 responded – a response rate of 27 per cent. Another group was made up of the authors identified by Oreskes (2004) in her review of 928 abstracts from papers on 'global climate change' in peer-reviewed journals; of the 732 approached, 76 responded – a response rate of 10 per cent. A third group were 'climate scientists drawn from readily available email lists on institute websites (i.e. NCAR, MPI, AMS, etc)'; of the 780 approached, 149 responded – a response rate of 19 per cent. Of the 375 scientists in total, 147 did 'most' of their work in the United States, 61 worked mainly in Germany, 57 in the UK, 22 in Australia, 14 in Canada and 10 in Italy; of these, 293 said their work was concerned with 'the physics of the climate system, modelling, model development, data acquisition or theory development'. Measures, including the elimination of duplicate names, were taken to ensure 'only one survey response per invitee' (Bray 2010, 4; Bray and Storch 2008, 2 and 5, for the response rates and locations of the respondents).

There are a number of short-comings with each of these surveys that the authors acknowledge and seek to address. One is the 'less than ideal' use of 'non-probability convenience sampling' (Bray 2010, 4), virtually unavoidable where the population from which the samples are drawn (the world's climate scientists, however defined) cannot be enumerated – lists of various kinds

notwithstanding. Whether, for example, the proportion of respondents working in different countries reflects the distribution of climate scientists across these countries is difficult to say.

Another problem is what Bray calls the problem of 'self-selection' (Bray 2010, 5), but what might better be called response bias; here, the possibility that those with particular positions on climate science were more likely than others to respond. The authors were particularly concerned about whether the views of those who participated in the IPCC's deliberations differed from the views of those that did not - in relation to items about whether climate change was taking place, whether climate change was anthropogenic and whether the IPCC reports were soundly based. They concluded that the 2008 survey showed either minimal evidence or no statistically significant evidence of differences of this kind (Bray 2010, 5, 13-15).

The Findings

Each of the surveys Bray and von Storch conducted contained batteries of questions on the science of climate change, on whether it was happening, whether it had anthropogenic roots, what might be done to tackle it (adaptation or mitigation) and how difficult changes of various kinds would be. With few exceptions these questions were presented as Likert items that offered seven possible responses along a continuum ranging from (1) 'strong' agreement (or whatever), through (4), a neutral mid-point usually not labelled as such, to (7) 'strong' disagreement (or whatever). In every case items included three 'positive' options and three 'negative' options. The researchers were able to judge the distribution of opinion (and calculate the standard deviation of the distribution), its central tendency (mean) and its strength (the proportion at or near each of the ends). Where items were repeated in different surveys the ends of the continuum were sometimes reversed, so that instead of running, say, from 'strong agreement' to 'strong disagreement' it ran from 'strong disagreement' to 'strong agreement'. This gives us some handle on acquiescence bias, the tendency of an otherwise unknown proportion of respondents to agree with a proposition. However, none of the items were aggregated to form Likert scales. This means we can't judge how consistent respondents were across items of a similar kind. The data allow us to judge the patterns of opinion among groups not among individuals.

Do climate scientists believe in climate change; more specifically, do they believe in global warming?

Most climate scientists, on the evidence of these surveys, believe not just in climate change - an issue which hardly separates 'denialists' from 'alarmists' - but also in global warming; those who think the evidence is unclear appear to be an ever-smaller minority. Asked in 1996 and again in 2003 whether 'We can say for certain that global warming is a process already underway' the answer increasingly was that 'we' could: 62% agreed in 1996, 82% in 2003; only 24% in 1996 and 12% in 2003 disagreed (2007, fig 28). In 2008, no fewer than 93% agreed 'that climate change, whether natural or anthropogenic, is occurring now' (2008, fig. 20); but, given that

climate variability as a natural phenomenon is hardly in dispute, responses to this question don't tell us much.

Consistent with the view that global warming was happening, an increasing proportion of respondents said they were beginning to experience the 'effects' or 'impacts' of what the researchers described as 'climate change'. In 2003, two-thirds (69%) of the respondents thought they were 'beginning to experience the effects of climate change' (2007, fig 27), a term the researchers presumably assumed identified something new; and in 2008 three-quarters (78%) of the respondents agreed that 'we' were 'beginning to experience the more gradual impacts of climate change', whether 'anthropogenic or otherwise' (2008, fig. 23).

***Do climate scientists think that global warming is anthropogenic or human-induced*?**

The survey evidence also suggests that most climate scientists think global warming is at least partly the result of human activity. Asked in 2003 to what extent 'new scientific discovery in the last decade' had confirmed 'the anthropogenic influence on climate', three-quarters (74%) agreed that this had provided a 'significant amount' of evidence (2007, fig. 20).

Evidence about whether climate scientists believe anthropogenic causes are responsible not for some of the global warming but for most of it, though mixed in the first two surveys has now become much clearer. Asked in 1996 'whether climate change is mostly the result of anthropogenic causes', less than half (40%) of the respondents said it was. But in 2003 the figure rose to more than half (53%) (2007, fig. 30). At the same time, three-quarters of the respondents (74% in 1996, 76% in 2003) agreed that 'without change in human behavior, global warming will definitely occur sometime in the future' (2007, fig 31). In 2008, an even greater proportion (84%) was 'convinced' that 'most of recent or near future climate change is, or will be, a result of anthropogenic causes' (2008, fig. 21; emphasis added).

Do climate scientists see climate change as important?

One way of answering the question about the importance climate scientists attach to climate change is to see how they prioritise it as a problem. Respondents in all three surveys saw 'global climate change' as a leading problem. More than that, a large and increasing proportion saw 'global climate change as one of the leading problems facing humanity' (1996, 2003) or at least saw its 'potential impact' as 'as one of the leading problems' (2008): 65% in 1996, 69% in 2003, and 83% in 2008 saw it in these terms (2007, fig. 29; 2008, fig. 28).

Another way of answering the question is to see what events climate scientists attribute to climate change, what they think would happen if precautionary action were not taken, or whether they think the time for action is still some way off. A third (32%) of the respondents in the 2008 survey wanted to 'attribute recent climate related disasters'- none of them specified - 'to climate change' (2008, fig. 24). A third (36%) of respondents in the 1996 survey – 44% in the 2003 poll

- agreed that if 'climate change' were to occur it would 'occur so suddenly that a lack of preparation could result in devastation of some areas of the world' (2007, fig. 33). In short, only a minority was alarmist. But few agreed (15% in 1996 and 15% in 2003) that there was 'enough uncertainty about the phenomenon of global warming' that there was 'no need for immediate policy decisions' (2007, fig. 34).

What do climate scientists think about the challenges of adaptation and mitigation?

Given a choice between 'adaptation' and 'mitigation' as 'the best approach to resolving the problems related to climate change', respondents in the 2008 survey favoured 'mitigation' over 'adaptation' (41:27); another third (30%) wanted 'equal' weight given to both (2008, fig 29). Again, in 2003, a slightly greater proportion of respondents thought 'mitigation' a 'feasible' global option than thought 'adaptation' a 'feasible' global option (52:41) (2007, figs 74, 75). And asked where 'future research efforts and funding should focus', 'detection' (44%) was narrowly favoured over 'adaptation' (30%) (2007, fig 88).

However, on the question of what priority should be accorded to science in the policy process - a contest between 'scientific expertise', on the one side, and 'the opinions of industry and commerce', 'political opinion' or 'public opinion', on the other – there was wide agreement, not surprisingly, that expertise should prevail. Scientific opinion trumped the opinions of industry and commerce on adaptation (77: 3) and mitigation (77:6), it trumped political opinion (82:4 and 82:5) and it trumped public opinion (81:5 and 83:4) (2007, figs 30-35). However, this was not what respondents thought was happening. 'Given our current state of knowledge', nearly half the respondents (45%) agreed, 'climate change' was 'now mostly a political issue' rather than a 'scientific issue' (17%), though nearly a third (30%) were undecided (2007, fig 37).

In 2003, the majority (57%) thought it would be possible 'for most societies to adapt to climate change without having to make any substantial changes'. This view was shared by rather fewer (42%) in 1996 (2007, fig 35). Just as well, perhaps, for in 1996 and again in 2003 more than three-quarters of the respondents (82% and 78% respectively) agreed that 'stabilizing C02 emissions will require a fundamental restructuring of the global economy' (2007, fig 43).

While opinion was evenly divided (41:39) over whether 'adaptation as a global option' was 'feasible', most (75%) of the respondents agreed that 'adaptation to climate change' was a 'feasible' option for the societies in which they lived (2007, figs 73, 74). Roughly two-thirds of the respondents thought it would be 'easy' rather than 'difficult' for the 'general daily routine of the people' that lived in their 'nation' (59%) or 'local region' (66%) 'to adapt to climate change'; that it would be 'easy' rather than 'difficult' for the 'tourism' (76%) and 'manufacturing' in their nation 'to adapt to climate change'; and that it would be 'easy' rather than 'difficult' for the transportation' (62%) and the housing design' (71%) in their region 'to adapt to climate change' (2007, figs 77, 78, 80, 81, 86, 87). Half the respondents (50%) thought it would be 'easy' for 'the public utilities of natural gas or heating and air conditioning fuels' or 'public utility electricity' in

their region ‘to adapt to climate change’; about a third (28% and 35% respectively) thought it would be ‘difficult’(2007, figs 83, 84). And a plurality thought it would be ‘easy’ rather than ‘difficult’ for their nation’s ‘forestry’ to adapt (40:32), for their region’s ‘agriculture’ to adapt (41:35) or for their region’s ‘public water utilities’ to adapt (44:40) (2007, figs 79, 82, 85).

But the concepts of ‘easy’ and ‘difficult’ need a context. Asked, in 2008, about the best approach to ‘the mitigation of anthropogenic climate change’, three-quarters of the respondents (78%) chose ‘enforced regulation’ over ‘voluntary action’ (2008, fig. 36).

Do climate scientists see climate change having positive as well as negative consequences?

Respondents saw ‘global climate change’ as a social and economic problem and they saw it as a problem for eco-systems. Three-quarters of the respondents in 1996 (80%) and in 2003 (76%) agreed that ‘global climate change’ was ‘a problem that concerns the social and economic aspects of societies’ (2007, fig. 51). In 2008, 78% agreed that ‘climate change poses a very serious and dangerous threat to humanity’ (2008, fig 22). Similar proportions agreed that ‘the potential impact of global climate change’ was ‘one of the leading problems for humanity in terms of social and economic issues (77%) and ‘for eco-systems (i.e. species extinction, land degradation, etc.)’ (83%) (2008, figs 28a, 28b).

Detrimental effects – as well as positive effects - of ‘climate change’ for ‘some societies’ were more readily acknowledged than for the respondents’ own society. Thus, in 1996 and again in 2003 while more than three-quarters (83%) of the respondents agreed that ‘climate change will have detrimental effects for some societies’ less than half (46% in 1996 and 48% in 2003) thought it would ‘have a detrimental effect’ on the society in which they lived (2007, figs. 24, 25). And in 2003, while three-quarters (77%) of the respondents thought ‘that climate change might have some positive effects for some societies’ (the same question in 1996 generated too many missing values to be meaningful) only a third (31%; 22% in 1996) thought this was likely to be the case in the societies in which they lived (2007, figs. 26, 27). In the 2008 survey the proportion (37%) anticipating ‘some positive effects’ for the country in which they lived again was lower than the proportion (45%) that anticipated ‘positive effects’ for ‘other parts of the world’. A similar question about detrimental effects was not asked (2008, figs. 27a, 27b).

What do climate scientists think of the reports produced by the IPCC?

Climate scientists, according to these surveys, support the work of the IPCC, see it influencing the areas of research that come to be considered ‘worthy’ and recognise it as feeding into public policy – but without seeing ‘external politics’ affecting the direction of the research. While they are far from unanimous about whether the IPCC’s reports ‘accurately reflect the consensus of thought within the scientific community’, perhaps because they have doubts about the extent to which a consensus exists, respondents are more inclined to think the IPCC underestimated rather than overestimated the impacts resulting from various aspects of climate change - temperature,

precipitation, rising sea levels, and extreme events - and more inclined to believe that the IPCC underestimates rather than overestimates the magnitude of future changes in each.

Asked in 2008 whether they agreed that 'the IPCC reports are of great use to the advancement of climate science', three-quarters of the respondents (78 per cent) agreed that they were (2008, fig. 38); this was greater than the proportion agreeing in 2003 (72%) and 1996 (64%) (2007, fig. 36). In addition, two-thirds of the respondents (65%) in 2008 were 'satisfied' to some extent with 'the IPCC review process' and the majority of responds (57%) were 'satisfied' to a greater or lesser degree 'with the process by which the IPCC Summary for Policy Makers are produced', only 20% being not satisfied in some way (2008, figs 43 and 44).

Asked 'how much influence' they thought the IPCC had 'over what areas come to be considered as worthy research topics' respondents overwhelmingly thought they did have an influence. In 1996 and again in 2008, the proportion inclined to deny this was14%, in 2003 just 9% (2007, fig 62; 2008, fig 42).

In both 1996 and 2003, the majority of respondents (57 per cent) thought the IPCC reports were more likely to be used than not used 'in the decision making process of climate related policy issues' (2007, fig. 53). This was one way, perhaps, in which they saw the IPCC being used 'to the advancement of climate science'. Concrete evidence of what respondents had in mind might lie in the fact that half (50% in 1996, 54% in 2003) agreed that C02 would have 'controlled emission levels in the near future' (2007, fig 41). But respondents did not see this as necessarily setting up a feedback loop. In 1996, 2003 and 2008 relatively few respondents (16-20%) thought 'the direction of research in the climate change sciences' had been 'influenced by external politics' (2007, fig 23) or by 'external politics in the last 10 years' (2008, fig 9).

Overwhelmingly, respondents in the 2008 survey denied that the IPCC reports over-estimated 'the magnitude of the impacts' of changes in key measures; on the contrary, there was more support for the view that the reports under-estimated the impacts than over-estimated them. In relation to changes in temperature, 84% of respondents agreed that the IPCC report was either accurate (64%) or underestimated (20%) the impact; in relation to precipitation, the figure was 84% (58% + 26%), sea rise level 83% (51% + 32%) and extreme events 77 per cent (42% + 35%) (2008, figs 39a-39d). There was a similar pattern of response in relation to IPCC estimates of the magnitude of 'future change': 83% agreed that the IPCC report was either accurate (62%) or underestimated (20%) the magnitude of future changes to temperature, 58% (33% + 24%) held this to be so in relation to precipitation, 83% (47% + 37%) in relation to sea rise level and 78% (44% + 35%) in relation to extreme events (2008, figs 41a-41d).

Support for the view that 'the IPCC reports accurately reflect the consensus of scientific thought' in these areas was similar to support for the view that the IPCC report was accurate: 59% for temperature, 49% for precipitation, 46% for sea rise level and 43% for extreme events. Except in relation to precipitation, the level of support for the view that the IPCC report was not an

accurate reflection of 'the consensus of scientific thought' was similar to the level of support for the view that the IPCC had overestimated 'the magnitude of the impacts' of changes in key measures: 13% on temperature (18% thought the IPCC overestimated 'the magnitude of future changes'), 18% on precipitation (43% thought the IPCC overestimated) , 22% on sea rise levels (16%) and 25% on extreme events (21%). Roughly a third on each of these measures(29-33%) neither agreed nor disagreed that 'the IPCC reports accurately reflect the consensus of scientific thought' in these areas (2008, figs 40a-40d).

When a similar but more general question was asked in 1996 and 2003, one that didn't refer to any specific measures on which the IPCC had reported, two-thirds of the respondents (66% in 1996, 68% in 2003) agreed that 'the IPCC reports accurately reflect the consensus of thought within the scientific community' (2007, fig. 37).

What do climate scientists think about the state of climate science?

Notwithstanding their generally favourable views of the IPCC, respondents acknowledged that 'climate science' was 'an extremely complicated subject, full of uncertainties' - a science that allowed 'for a greater range of interpretation than many other scientific endeavours'; over three-quarters (81%) said this in 1996 and over three-quarters (78%) said it in 2003 (2007, fig 38), notwithstanding that the majority (58%) in 2003 thought 'the uncertainty regarding climate change' had 'been reduced in the last ten years' (2007, fig 71). One reason that climate science was seen as complicated and uncertain might have been the sense – shared by nearly half (45-47%) of the respondents in 1996, 2003 and 2008 - that climate science had not 'remained [sic] a value-neutral science' (2007, fig 60; 2008, fig 10).

In turn, respondents' opinions about the state of climate science were mixed. In 2003 the majority of respondents (62%) agreed that 'climate science' had 'advanced in the understanding of climate change in the last 5 years' (2007, fig 69). But in 2008 opinion was evenly divided over whether 'the state of theoretical understanding of climate change phenomena' was 'adequate' (41%) or 'inadequate' (42%), whether the 'current theory development for climate change' was 'adequate' (40%) or 'inadequate' (36%), whether 'data collection efforts' were currently 'adequate' (39%) or 'inadequate' (38%) and whether the data available for climate change analysis was 'adequate' (41%) or 'inadequate' (40%) (2008, figs 11a-11b).

And while climate science might have advanced by 2003 the majority of respondents were not prepared to endorse the efficacy of some of the models. A plurality of respondents agreed that 'climate models 'accurately verif[ied] the climate conditions for which they were calibrated' (46% in 2003, 45% in 1996), and thought that 'the current state of scientific knowledge' was 'able to provide reasonable predictions of inter-annual variability' (44% in 2003, 28% in 1996; 2007, figs 16, 18). But only a minority agreed that 'climate models' could 'accurately predict climatic conditions of the future' (34% in 2003, 29% in 1996) or that 'the current state of scientific knowledge' was 'able to provide reasonable predictions of climate variability of time

scales of 10 years' (31% in 2003, 20% in 1996), let alone '100 years' (25% in 2003, 18% in 1996), or 'greater than 100 years' (19% 2003, 16% 1996) (2007, figs 17, 19-21).

Asked in 1996, 2003 and 2008 whether 'the current state of scientific knowledge is developed well enough to allow for a reasonable assessment' of various aspects of climate change, the pattern of response depended on the phenomenon in question. Majorities agreed that the science was well enough developed in relation to 'green-house gasses emitted from anthropogenic sources' (59-65%) and 'surface albedo' (57-64%) but not in relation to 'turbulence' (23-32%), 'land surface processes' (26-42%) or 'sea-ice' (33-41%). Moreover, there was no evidence that agreement was growing; in none of these cases did the 2008 survey provide the highest level of agreement (2007, figs 11-15; 2008, figs 15a-15e).

On the question of 'how well' they thought 'atmospheric climate models' (the word 'climate' was omitted in 2008) could deal with 'radiation' almost two-thirds of the respondents (61-64%) thought the models could deal with it 'adequately' or better. About half (49-59%) thought this was also true in relation to 'hydrodynamics'. But only a minority felt this way in relation to 'vapour in the atmosphere' (31-39%), the 'influence of clouds' (20-24%), 'precipitation' (13-21%) or 'atmospheric convection' (17-28%). In none of these cases was the figure for 2008 significantly greater than it was in 1996 (2007, fig 1; 2008, figs 12a-12f). Respondents reckoned 'ocean models', too, dealt better with 'hydrodynamics' (45-58% rating the models as at least 'adequate') than with 'heat transport in the ocean' (35-54%) or 'oceanic convection' (16-29%); in every case the 2008 figure was lower than the corresponding figure in 1996 or 2003 (2007, figs 7-9; 2008, figs 13a-13c). Asked about 'the ability to couple atmospheric and ocean models' (in 1996 and 2003 the question was about the extent to which 'ocean models can deal with the coupling of atmospheric models and ocean models'), only 20% (1996) rising to 36% (2008) rated the performance of the models as at least 'adequate' (2007, fig 10; 2008, fig 14).

Asked whether 'the users of the information produced by General Circulation Models are most often aware of the uncertainties associated with such models', opinion was divided: 45: 42 in 1996; 48: 39 in 2003. But the majority (50% in 1996, 54% in 2003) agreed 'that in general, those scientists producing GCMs are knowledgeable about what data are needed by those scientists that endeavour to study the impacts of climate change' (2007, figs 39 and 40). In 2003, 82% of respondents agreed that 'the study of paleoclimatology' was 'relevant' to an 'understanding of 'climate sensitivity' and 68% thought it relevant as well to an 'understanding of anthropogenic induced climate change' (2008, figs 18a and 18b), but only 38% gave a positive as against a negative rating to 'the ability of paleo models to reproduce proxy temperature observations' and just 12% did this in relation to the models' ability 'to reproduce proxy precipitation observations' (2008, figs 19a and 19b).

In 2008, 'the ability of *global* climate models' to 'reproduce temperature observations' was rated positively by 77% of respondents, but other measures were rated positively by fewer than half. While a plurality (45%) rated the ability of global climate models to 'model temperature values

for the next ten years' positively, a plurality (40%) rated the ability of global climate models to 'model temperature values for the next 50 years' negatively. On the ability of global climate models to 'model sea level rise in the next 10 years' opinion was more evenly divided, 35% rating it positively and 35% negatively. On other measures the ability of global climate models to 'reproduce precipitation observations' (rated positively by 15%), to 'model sea level rises for the next 50 years' (19%), to 'model precipitation values for the next 10 years' (11%) or '50 years' (9%), and to 'model extreme events for the next 20 years' (11%) or '50 years' (7%) was rated positively by relatively few (2008, figs 16a – 16j).

The pattern of response in relation to *regional* climate models was similar. The only differences of note have to do with measures on which regional models fared worse: the ability to 'reproduce temperature observations' (59%; cf. 77% for global models); the ability to 'model temperature values for the next ten years' (36%; cf. 45%) or 'the next 50 years' (25%; cf. 34%); and the ability to 'model sea level rises for the next 50 years' (12%; cf.19%; 2008, figs 17a-17j).

Asked in 1996 and again in 2003 'to what degree' they thought that 'through the process of downscaling' it was 'now possible to determine local climate impacts' few respondents (16% in 1996, 19% in 2003) thought it possible to any great degree at all (2007, fig 22). The proportion that thought it possible to 'explicitly state the detrimental effects that climate change' would 'have on society', while still a minority - 36% in 1996 and 39% in 2003 - was greater (2007, fig 23).

Though respondents were split down the middle on the question – 40: 46 (1996), 44: 43 (2003) – the proportion agreeing that 'natural scientists have established enough physical evidence to turn the issue of global climate change over to social scientists for matters of policy discussion' was substantial (2007, fig 42). Climate scientists didn't necessarily see themselves as 'well attuned to the sensitivity of human social systems to climate impacts', less than half (45%) thinking of climate scientists in these terms in 1996 and barely a quarter (24%) doing so in 2003 (2007, fig 45). But how far they thought social scientists might get is moot, with only a third (35% in 1996, 34% in 2003) agreeing that 'the climate sciences are developed well enough to provide information for local social impact assessments' (2007, fig 44).

Discussion

Those who conduct surveys of this kind are sometimes thought to have hidden agendas; here, perhaps, the reporting of a consensus designed to discourage dissent. But each of the reports of these three surveys notes points where there is no consensus as well as points of consensus - increasingly evident - that support the case for anthropogenic climate change (ACC). Areas in which the surveys find no consensus include whether priority should be given to adaptation over mitigation, whether climate change might have some positive effects in the countries where the respondents lived, support for some of the more alarmist views about anthropogenic climate change and whether the IPCC accurately reflected the consensus of scientific thought in relation

to changes in precipitation, sea rise level and extreme events, with some thinking the IPCC overestimates the overall consensus on climate change and others thinking it underestimates it.

Dealing with opinion surveys on ACC, one can think of consensus in three different ways. First, in terms of a particular proportion endorsing or rejecting a particular position; short of a unanimity rule, whereby every respondent has to agree if there is to be a consensus, fixing on a certain proportion inevitably opens up an argument about where to make the cut-off – 50%, 66%, 75% and so on. Second one can focus on the strength of opinion. With Likert items this might be specified in terms of the proportion at the extreme ends of the range (here 1 or 7) or the proportion at or near the extreme ends of the range (here 1 and 2, 6 and 7). Third, one can insist that to have a consensus about climate change the distribution of opinion should not only satisfy the first or second of these conditions; it should cover a range of items – not all items necessarily but items regarded in some sense as fundamental to the case.

The notion of some proportion favouring a particular position is the simplest, most widely used, notion of *consensus*. Note, however, that whatever definition of consensus one adopts - 50%, 100% or something in between - this measure goes to the distribution of opinion not its strength. The second notion of consensus goes to the strength of opinion; we might call this *strong consensus*. The third, which may incorporate either of the others, goes to the breadth of issues about which there is agreement. We might call this a *comprehensive consensus*.

That the surveys undertaken by Doran and von Storch - certainly the most recent - show a consensus on key issues in the first of our three senses seems clear; short of setting the bar at an extraordinary high level this is a finding that cannot be gainsaid. A large majority of respondents believe not just in global warming but in anthropogenic global warming and they think it likely to get worse. Most respondents think of global warming as a social and economic problem as well as a problem for eco-systems. They think the problem serious but potentially manageable, via regulation and adaptation, at least in the societies in which they live. While they think there might be benefits in climate change for some societies they aren't inclined to see benefits for their own. And they support the work of the IPCC; if anything, they regard its reports as underestimating the impacts of climate change even as they acknowledge the complexities and uncertainties of climate science and doubt that climate science is an area marked by consensus – an understanding of the state of play that appeals implicitly to our third notion of consensus rather than to either of the other two.

Moreover, on a number of important items agreement is strong. Asked, in the most recent survey, '[h]ow convinced' they were 'that climate change, whether natural or anthropogenic' was 'occurring now', two-thirds (67%) of the respondents answered 'very much', the strongest response allowed on the seven-point scale; if we add those who selected the slightly less emphatic response, the proportion strongly affirming climate change rises to 86% (2008, fig 20). Asked how 'convinced' they were 'that most of recent or near future change is, or will be, a result of anthropogenic causes' the corresponding figures are 35% and 32% a total of 67% (2008,

fig 21). And asked '[h]ow convinced' they were 'that climate change poses a very serious and dangerous threat to humanity' the pattern of response was similar: 35% and 28% (63%) placed themselves at the 'very' concerned end of the spectrum (2008, fig 22), with a strong majority (61%) saying that 'the potential impact of global climate change' was 'one of the leading problems for eco-systems (i.e. species extinction, land degradation, etc.)' and a strong majority saying that 'the potential impact of global climate change' was 'one of the leading problems for humanity in terms of social and economic issues' (2008, fig. 28a, 28b). Nor did respondents think the potential impact would be met best by 'voluntary action'; on the contrary, a strong majority (55%) thought 'the mitigation of anthropogenic climate change' should be based on 'enforced regulation' (2008, fig 36).

Since climate scientists also stress the areas where the science is uncertain, it is important to note the larger number of items where there are majorities but not strong ones. In the 2008 survey these include items on whether we are 'beginning to experience the more gradual impacts of climate change anthropogenic or otherwise' (44% at points 6 and 7 on the scale) and on whether '[t]he 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' (33%). They also include items on the IPCC: on 'the IPCC review process' (42% at or around the 'very satisfied' end of the scale), 'the process by which the IPCC Summary for Policy Makers reports are produced' (35%), and whether 'the IPCC reports accurately reflect the consensus of scientific thought pertaining to temperature' (44% at or around the 'strongly agree' end of the scale).

And, of course, there are limits to how comprehensive the consensus is. This is partly a function of whether one thinks of consensus in terms of simple or qualified majorities (the most basic notion of consensus) or whether one requires that plus strong majorities (our second notion). It is also a function of what beliefs are considered fundamental and what beliefs are considered to be of less than fundamental importance; weak agreement about matters that are hardly fundamental is quite different from strong agreement about matters that go to the heart of the matter. In that sense evidence from the surveys of strong agreement that climate change is happening, that these changes have anthropogenic causes and that this poses a serious threat to humanity not likely to be met by voluntary action point to the existence of a comprehensive consensus on issues widely accepted as fundamental. Nonetheless, to generalise a point made by Bray (2010, 340), consensus is not the same as unanimity.

References

Anderegg, W.R.L., Prall, J.W., Harold, J. and Schneider, S.H. (2010) 'Expert credibility in climate change', *Proc Natl Acad Sci USA*, 107 (27) 12107-09, http://www.pnas.org/content/early/2010/06/04/1003187107.abstract, accessed 28 February 2011.

Bray, D. (2010) 'The scientific consensus on climate change revisited', *Environment Science & Policy* 13, 340-50, http://dvsun3.gkss.de/journals/2010/Bray-envscipol.pdf, accessed 28 February 2011.

Bray, D. and H. von Storch (2008) 'CliSci2008: A Survey of the Perspectives of Climate Scientists
Concerning Climate Science and Climate Change', http://coast.gkss.de/staff/storch/pdf/CliSci2008.pdf, accessed 28 February 2011.

Bray, D. and H. von Storch (2007) 'The perspectives of climate scientists on global climate change', http://dvsun3.gkss.de/BERICHTE/GKSS_Berichte_2007/GKSS_2007_11.pdf, accessed 28 February 2011.

Bray, D. and H. von Storch (1999) 'Climate science and the transfer of knowledge to public and political realms', in H. von Storch and G. Flöser (eds) *Anthropogenic Climate Change*, Springer, Berlin.

Doran, P. T. and M.K. Zimmerman (2009) 'Examining the scientific consensus on climate change', *EOS*, 90 (3) 22-3 http://tigger.uic.edu/~pdoran/012009_Doran_final.pdf, accessed 28 February 2011.

Lambert, T. (2005) 'Useless on-line survey of climate scientists', http://scienceblogs.com/deltoid/2005/05/bray.php, accessed 28 February 2011.

Lichter, S.R. (2008) 'Climate scientists agree on warming, disagree on dangers, and don't trust the media's coverage of climate change', STATS, George Mason Universityhttp://stats.org/stories/2008/global_warming_survey_apr23_08.html accessed 8 March 2011.

Oreskes, N. (2004) 'The scientific consensus on climate change', *Science* 306, No. 5702, 1686 http://www.sciencemag.org/content/306/5702/1686.full, accessed 28 February 2011.