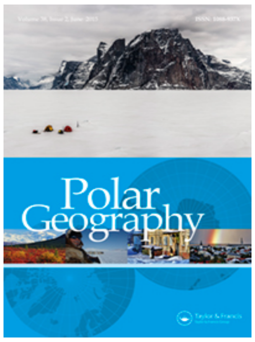


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# Polar facts in the age of polarization

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Many drivers of polar-region change originate in mid-latitude industrial societies, so public perceptions there matter. Building on earlier surveys of US public knowledge and concern, a series of New Hampshire state surveys over 2011–2015 tracked public knowledge of some basic polar facts. Analysis indicates that these facts subjectively fall into two categories: those that are or are not directly connected to beliefs about climate change. Responses to climate-linked factual questions, such as whether Arctic sea ice area has declined compared with 30 years ago, are politicized as if we were asking for climate-change opinions. Political divisions are less apparent with factual questions that do not suggest climate change, such as whether the North Pole is on land or sea ice. Only 38% of respondents could answer that question correctly, and even fewer (30%) knew or guessed correctly that melting of Greenland and Antarctic land ice, rather than Arctic sea ice, could potentially do the most to raise sea levels. At odds with the low levels of factual knowledge, most respondents say they have a moderate amount or a great deal of understanding about climate change. A combination of low knowledge with high self-assessed understanding characterizes almost half our sample and correlates with political views. The low knowledge/high understanding combination is most prevalent among Tea Party supporters, where it reaches 61%. It also occurs often (60%) among people who do not believe climate is changing. These results emphasize that diverse approaches are needed to communicate about science with people having different configurations of certainty and knowledge.

## Introduction

Polar researchers report changes across a wide range of physical, ecological and human systems. Physical systems reflect the polar amplification of climate change, manifest through warming air and waters, permafrost thaw, reduced Arctic sea ice, ice shelf attrition and mass loss from the Greenland and West Antarctic Ice Sheets (IPCC 2013). Ecological systems in turn experience shortened winter seasons, enhanced hydrological cycles and northward shifts in vegetation and animals, as winning and losing species confront the rapid pace of change (ACIA 2005; Rogers et al. 2012; IPCC 2014). Long-distance contamination, Arctic industrialization, growth of transportation and tourism, and large-scale fisheries impact polar-region ecosystems and social systems as well (e.g. Hamilton 2004). Human communities, particularly in the Arctic, cope with physical and ecological transitions alongside economic, governance, demographic, health and cultural pressures for rapid social change (Einarsson et al. 2004; Huntington et al. 2007;

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Larsen et al. 2015). Physical, ecological and social systems outside the polar regions may feel impacts from changes at the poles (Francis and Vavrus 2012; Coumou et al. 2015).

Many of the drivers for high-latitude change originate in mid-latitude industrial societies, where public perceptions affect support for climate mitigation and other policies. Unfortunately, climate change has emerged as one of the most politically disputed issues among US political leaders and public (McCright and Dunlap 2011; Boykoff 2013; Marquart-Pyatt et al. 2014; Hamilton 2014). Climate change beliefs correlate so strongly with ideology that some analysts view both as indicators for the same thing (Kahan 2015). Polarization raises formidable barriers to science communication, in a pattern Kraft et al. (2015:121) describe as 'hyperskepticism toward scientific evidence among ideologues'. Evidence of such scepticism appears widely in survey research (Gauchat 2012; McCright et al. 2013; Nadelson et al. 2014; Hamilton and Saito 2015), including surveys about polar topics.

Over the past decade, surveys have been filling in the picture of US public knowledge and concern about the polar regions. Analysis of the 2006 and 2010 General Social Survey (GSS; Smith et al. 2013) found moderate to high levels of concern about possible problems and also some indications of improving knowledge (Hamilton 2008; Hamilton et al. 2012a). Concern about polar problems generally increases with science literacy, but political orientation can modify this science-literacy effect (Hamilton et al. 2012b). Public acceptance of some basic climate-related facts, such as $CO_2$ concentrations rising, also depends on politics (Hamilton 2012). However, certain other climate-related facts, such as definition of the greenhouse effect, appear more politically neutral.

This paper presents results from a series of statewide New Hampshire surveys that carried questions about polar facts. Several of these questions have been benchmarked by comparison with a national survey, or asked repeatedly in New Hampshire. In both cases, the response patterns show surprising stability. Three of the New Hampshire surveys, conducted in summer 2014 through winter 2015, also included new polar-geography questions on basic facts that have been prominent in scientific and informed media discussions about climate change, but that behave neutrally with respect to climate-change beliefs. These factual questions provide a simple indicator for knowledge and an objective reflection on respondents' self-assessed understanding of climate change.

## Climate change, polar facts and perceptions

In 2006 and again in 2010, before and after the International Polar Year, the GSS carried a 'polar module' of questions designed by National Science Foundation researchers to assess public knowledge and concern. The knowledge items included both a standard battery of 11 science literacy questions and a 5-item test of polar knowledge. Respondents' levels of concern about polar impacts of climate change such as melting ice caps, rising sea levels or threatened species and their support for reserving the Antarctic for science instead of opening it for commercial development, are positively related to science literacy and polar knowledge (Hamilton 2008; Hamilton et al. 2012a). Ideology shows strong effects too: concern about impacts of polar climate change, and support for reserving the Antarctic, tend to be lower among conservatives. Moreover, ideology modifies the effects of science literacy, so those effects shift from positive among liberals and moderates to negative among the most conservative (Hamilton et al. 2012b).

The proposition that ideology or political views can alter or reverse the sign of education or information effects on climate beliefs was first tested in an analysis of 2006 GSS polar questions (Hamilton 2008) and independently confirmed across many other questions and data sets (Hamilton and Keim 2009; Hamilton 2011a; McCright and Dunlap 2011; Kahan et al. 2011; Shao et al. 2014) including some non-climate environmental or science topics (Hamilton et al. 2010; Hamilton and Safford 2015). Variations in these studies include alternative indicators for information (self-reported understanding, education, objectively tested science literacy or numeracy) and ideology (political party, liberal/conservative scales and worldview). The widespread discovery of information × politics type interaction effects has made it advisable to test for them routinely in environment and science-related survey research, or risk mischaracterizing the separate effects of both information and politics.

The five polar knowledge questions asked on the 2006 and 2010 GSS include three items with no direct link to what respondents believe about climate change: whether it is true or false that the Sun never shines at the South Pole, Inuit live north of the Arctic Circle, or the North Pole is on a floating sheet of ice. However, there also are two items that directly invoke climate change: whether climate or hunting is more likely to make polar bears become extinct, and whether ice caps have grown larger or smaller over the past 25 years. The hypothetical nature of the bears question and the unspecified geography or metric of the ice caps question, together with their obvious connections to climate change, complicate interpretation of these items. Responses seem partly to reflect what people believe about climate change in general, apart from whatever they know about polar regions.

Analysing data from a 2011 national survey that included more detailed knowledge questions, Hamilton (2012) found patterns again suggesting two kinds of facts. Correct answers to some questions, such as the definition of greenhouse effect and whether land ice or sea ice could potentially contribute more to sea level, appear mostly independent of political or climate-change beliefs. Answers to other equally factual questions, however, could be predicted from politics and behave more like climate-change opinions: whether Arctic sea ice declined, atmospheric $CO_2$ increased or humans have recently released more $CO_2$ than volcanoes. Furthermore, the pattern of *which wrong answers* climate-change doubters prefer for these questions seemed to reflect specific memes (such as Arctic ice recovered or volcanoes emit more $CO_2$) that had been publicized in climate-contrarian media.

These divergent responses to climate facts map roughly onto two ideas about science communication. The *information deficit* model posits that people express low concern about scientifically identified problems because they lack information that scientists could provide (Burgess et al. 1998). Applied to polar regions, we could assume that people do not know enough; therefore, scientists, educators or media should make new efforts to inform and engage them. The *biased assimilation* model on the other hand points to evidence that people seek and retain information supporting their prejudices, rejecting that which does not (Borick and Rabe 2010; Corner et al. 2011; McCright and Dunlap 2011). Better educated individuals could be particularly effective in doing so, accounting for the widely observed information × politics interactions. *Motivated scepticism* (Taber and Lodge 2006; Kraft et al.

2015), *cultural cognition* (Kahan et al. 2011) and other theoretical concepts have similar themes of information acquisition filtered by worldview or pre-existing beliefs. Applied to polar regions, for example, we see some people rejecting scientific reports about melting Arctic sea ice, and eager to accept weakly founded claims of recovery.

Although information deficit and biased assimilation can be posed as competing hypotheses, many studies find evidence for both, such as education and political effects in the same data. It seems likely that the relative balance between these processes differs among individuals, and also with attributes of the facts themselves. Wrong answers to belief-linked facts such as whether Arctic sea ice area has declined show signs of biased assimilation, whereas wrong answers to belief-neutral facts such as the sea-level potential of sea ice versus land ice mainly reflect an information deficit.

## New surveys of polar knowledge

Building on lessons from the 2006, 2010 and 2011 nationwide surveys, in 2011, we began experimenting with polar knowledge questions in the Granite State Poll (GSP), which conducts landline and cell telephone interviews with random samples of about 500 New Hampshire residents four times each year. A few polar questions were added to the GSP's usual mix of voting, opinion and background items. The GSP has proven to be a high-quality and nimble research platform, with an ideas-to-data cycle of weeks to months instead of years. GSP results become nationally prominent during election years and have supplied data for both political studies (e.g. Scala and Smith 2007) and basic research (e.g. Hamilton and Stampone 2013). Response rates average about 25%, as calculated by the stringent AAPOR (2006) definition 4. Representativeness is definitively tested in elections, where the GSP performs competitively. Probability weights calculated by standard GSP methods have been employed with all analyses in this paper, making minor adjustments for known design and sampling bias.

Table 1 defines our set of polar and climate-change questions. Several of these were introduced in previous studies based on a national survey (sea ice and sea level in Hamilton 2012) or earlier stages of the New Hampshire series (Arctic/weather in Hamilton and Lemcke-Stampone 2014). All three questions have now been repeated enough times to form series. In addition, two new questions about the North and South Poles were introduced in summer 2014. Together with the sea level item, they allow construction of a belief-neutral knowledge score.

Table 1 also defines two standard climate-change questions, shared with many other surveys. One asks for self-assessed understanding of climate change. New Hampshire residents express high confidence regarding this topic: 52% say they understand 'a moderate amount', and 26% 'a great deal' (compared with 50% and 22% on a 2011 nationwide survey; Hamilton 2011b). Another question asks for respondents' personal beliefs about climate change. One choice, 'climate change is happening now and caused mainly by human activities', corresponds to the central point of consensus statements by major science organizations (e.g. AGU 2013). Fifty-five per cent of New Hampshire respondents agree with the scientific consensus, compared with 52% on a 2011 national survey (Hamilton 2011b; more recent national surveys have been a point or two higher). Both national and New

Table 1. Polar questions carried on selected GSPs, spring 2010 to spring 2015. Total number of surveys and interviews for each question are given in brackets.

*Seaice* — Which of the following three statements do you think is more accurate? Over the past few years, the ice on the Arctic Ocean in late summer … (6 surveys, $n = 3149$)
- Covers less area than it did 30 years ago (1, 70%)
- Declined but then recovered to about the same area it had 30 years ago (0, 11%)
- Covers more area than it did 30 years ago (0, 8%)
- Don't know/no answer (0, 11%)

*Arcweath* — If the Arctic region becomes warmer in the future, do you think that will have … (8 surveys, $n = 4386$)
- No effects on the weather where you live? (0, 6%)
- Minor effects on the weather where you live? (0, 29%)
- Major effects on the weather where you live? (1, 60%)
- Don't know/no answer (0, 6%)

*Sealevel* — Which of the following possible changes would, if it happened, do the most to raise sea levels? (7 surveys, $n = 3882$)
- Melting of land ice in Greenland and the Antarctic (1, 30%)
- Melting of glaciers in the Himalaya and Alaska (0, 11%)
- Melting of sea ice on the Arctic Ocean (0, 32%)
- Don't know/no answer (0, 28%)

*Northpole* — Which of these best describes the North Pole? (3 surveys, $n = 1570$)
- Ice a few feet or yards thick, floating over a deep ocean (1, 38%)
- Ice more than a mile thick, over land (0, 38%)
- A mainly rocky, mountainous landscape (0, 6%)
- Don't know/no answer (0, 17%)

*Southpole* — Which of these best describes the South Pole? (3 surveys, $n = 1570$)
- Ice a few feet or yards thick, floating over a deep ocean (0, 19%)
- Ice more than a mile thick, over land (1, 46%)
- A mainly rocky, mountainous landscape (0, 13%)
- Don't know/no answer (0, 21%)

*Poleknow* — Number of correct answers to *sealevel*, *northpole* and *southpole*. Coded 0 (27%), 1 (40%), 2 (25%) or 3 (8%). (3 surveys, $n = 1570$)

*Understand* — How much do you feel you understand about the issue of global warming or climate change? (21 surveys, $n = 11{,}548$)
- A great deal (2, 26%)
- A moderate amount (1, 52%)
- Only a little (0, 18%)
- Nothing at all/no answer (–1, 4%)

*Climate* — Which of the following three statements do you personally believe? (21 surveys, $n = 11{,}548$)
- Climate change is happening now, caused mainly by human activities (1, 55%)
- Climate change is happening now, but caused mainly by natural forces (0, 34%)
- Climate change is NOT happening now (0, 6%)
- Don't know/no answer (0, 5%)

*Overcon* — Overconfidence, coded 1 (47%) for respondents having both a low polar facts score (*poleknow* 0 or 1) and high self-assessed understanding of climate change (*understand* 'moderate amount' or 'a great deal'). Coded 0 (53%) for those with a high polar facts score (2 or 3) and/or low self-assessed understanding.

Note: Shown with codes used for logit regression analysis.

Hampshire responses to these two climate-change questions appear roughly stable over the past four years.

In interviewing, the order of response choices to all but the question on understanding is rotated to avoid possible bias. Probability-weighted percentages, given with the definitions in Table 1, reflect the total pool of respondents who were asked each question.

### Arctic sea ice, weather and sea level

Figure 1 graphs responses to the sea ice, Arctic/weather and sea level questions. Encouragingly, 70% (of 3149 respondents over six GSP surveys) responded accurately that late-summer Arctic sea ice area has been less in recent years compared with 30 years ago. On the hypothetical Arctic/weather question, 60% (of 4386 over eight surveys) think that if the Arctic region becomes warmer in the future, this will have major effects on the weather where they live.

The sea level question asks whether respondents think that Arctic sea ice, the Greenland and Antarctic ice sheets, or Himalayan and Alaskan glaciers would do more to raise sea level if they melted. Mass calculations establish that Greenland and Antarctic ice sheets, with ultimate potential to raise global sea level by more than 70 meters, far exceed the half-meter potential from all other ice sheets and glaciers combined (Williams and Hall 1993), or the negligible contribution from sea ice. Only 30% of our survey respondents know or correctly guess this fact, however. Slightly more (32%) believe that Arctic sea ice could raise sea level more. Almost as many (28%) admit that they do not know, but obviously the true fraction is at least 70% – probably higher, if some correct answers are guesses. Public awareness of this basic geographical fact is slight, although the relationship between sea level and the great ice sheets has been a frequent topic in science and informed news media discussions of climate change.

Figure 2 plots responses to these three questions, with each data point representing one survey of about 500 interviews. Completing all the interviews for each survey takes about one week; points are plotted at the median interview date.

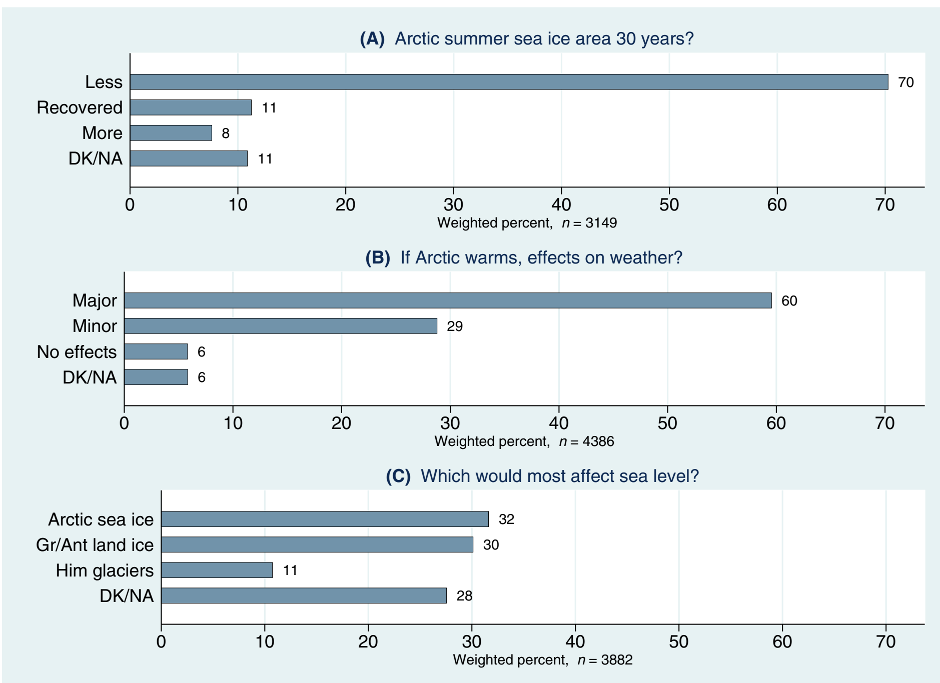


Figure 1. Response to questions about Arctic sea ice area (A), Arctic warming effects on your weather (B) and which would most affect sea level (C).

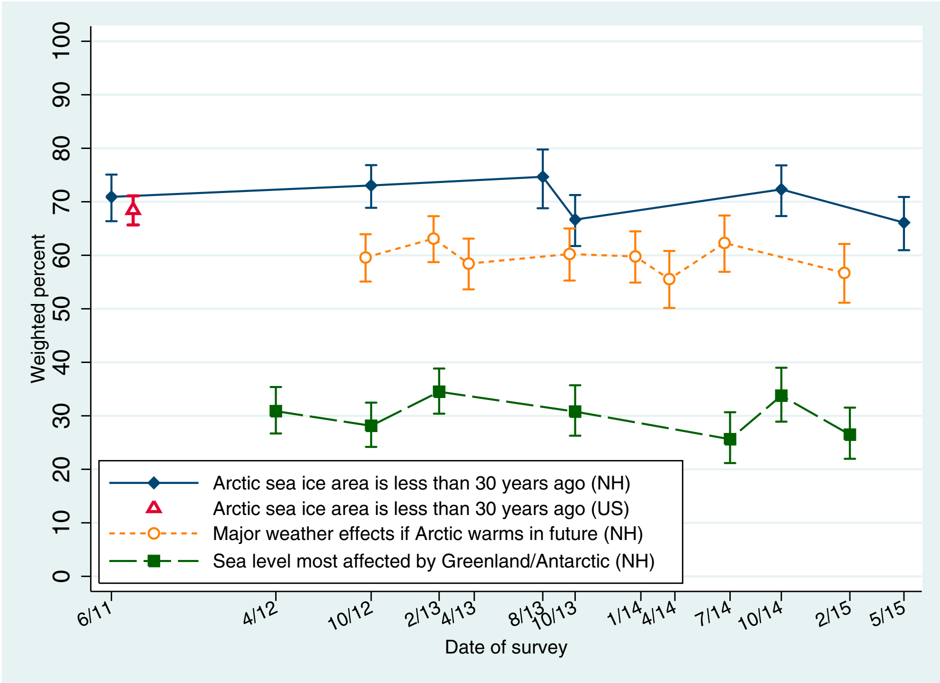


Figure 2. Percent choosing 'Arctic sea ice area less', 'Arctic warming would have major effects on weather here' or 'Greenland/Antarctic could have most effect on sea level' by date of survey.

Ninety-five per cent confidence intervals suggest that sampling variation could account for the small survey-to-survey differences. The sea ice question was also asked on a national survey in 2011 (Hamilton 2012). The national result, plotted with its confidence interval at far left, aligns closely with New Hampshire results.

Responses to all three questions in Figure 2 appear remarkably steady, given that this period spanned two election years with politically divergent outcomes, seasonal weather ranging from summer heat to winter cold, the historical-record low Arctic sea ice in September 2012 and the north-eastern US landfall of Superstorm Sandy in late October 2012 (occurring between our October 2012 and February 2013 surveys). Interviewing for the February 2015 New Hampshire survey took place during blizzards and sub-zero weather. Although there may be minor variations associated with interview-day weather, none of the larger events apparently had lasting impacts.

The sea ice question is historical and factual, whereas the Arctic/weather question invites speculation about the future. The sea level question also looks towards the future, but its answer depends not on speculation but on uncontroversial physical geography. Sea ice and Arctic/weather responses differ visibly by political views, however, whereas sea level responses do not. Figure 3 plots these three variables by political party, using a four-party scheme that separates self-identified Tea Party supporters from Democrats, Independents and Republicans. Tea Party supporters tend to be more ideological than other groups (Bullock and Hood 2012; Knowles et al. 2013; Maxwell and Parent 2012; Maxwell and Parent 2013; Skocpol and

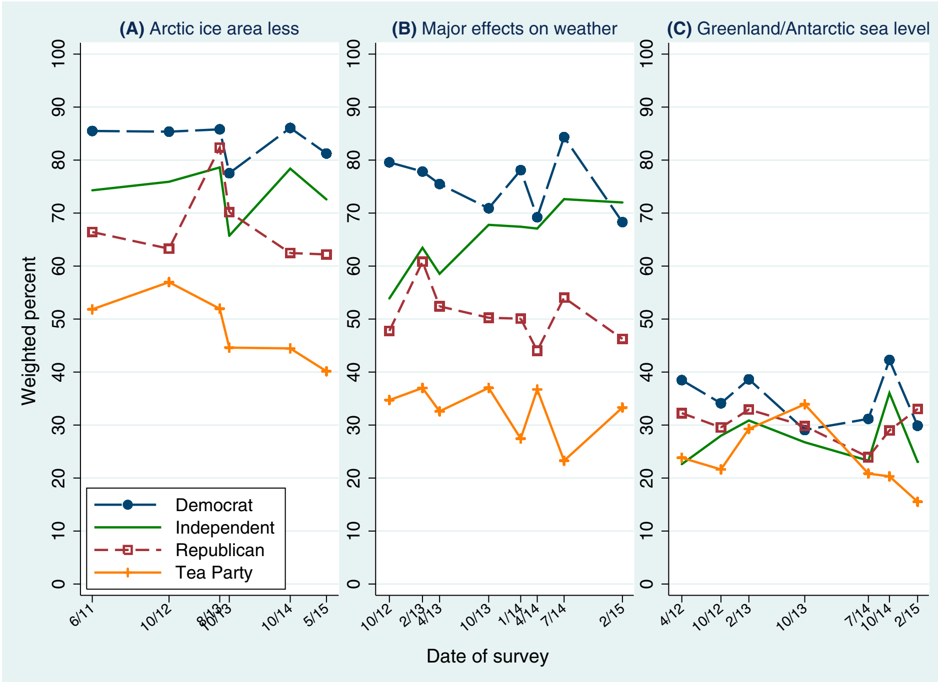


Figure 3. Percent choosing 'ice area less' (A), 'major effects on weather' (B) or 'Greenland/ Antarctic most affect sea level (C) by political party and date of survey.

Williamson 2012). They stand apart from other Republicans in expressing greater scepticism towards science and environmental problems (Hamilton and Saito 2015). Such separation is manifest on the polar questions in Figure 3A and 3B.

Across six surveys from June 2011 to May 2015, Democrats are most likely and Tea Party supporters least likely to agree with scientists that late-summer Arctic sea ice covers less area than it did 30 years ago. An even wider partisan gap across eight surveys marks responses on whether Arctic warming could affect the weather where they live. Democrats or Independents are most likely and Tea Party supporters least likely to think that, if the Arctic warms in the future, this will have major effects on their weather. Sea level responses in contrast appear closer across parties. Although the sea level question is equally basic, it represents a different kind of polar fact, not guessable from beliefs about climate change.

## Polar geography

The sea ice, Arctic/weather and sea level questions have been asked repeatedly on New Hampshire surveys since 2011 or 2012. Recognizing that sea level responses behaved less politically than the others, we added two new questions with similar attributes, regarding North and South Pole geography, to GSP surveys in summer and fall 2014 and winter 2015. Figure 4 charts responses about sea level, the North Pole and the South Pole, along with a polar knowledge score defined as the number of answers correct (0–3). For internal consistency only the summer 2014 to winter 2015 surveys (which also carried the North and South Pole questions) are shown in

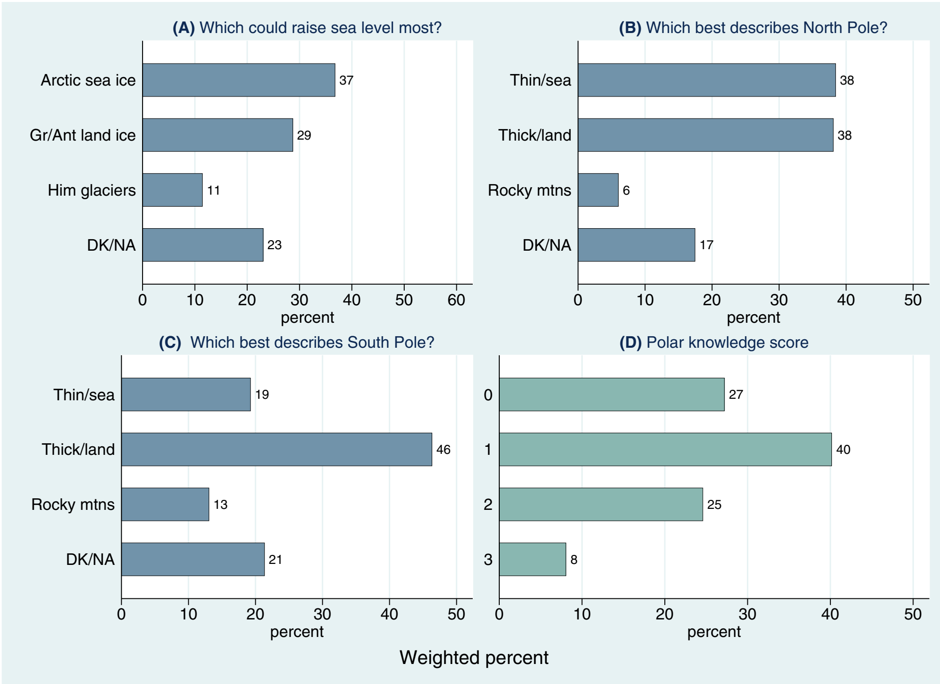


Figure 4. Response to questions about sea level (A), North Pole geography (B), South Pole geography (C) and polar knowledge score – number of answers correct (D). Results shown only from surveys asking all three questions (summer 2014 through winter 2015).

this graphic, so Figure 4A gives slightly different sea level response percentages than Figure 1C. Twenty-nine per cent in this three-survey subset (compared with 30% in the seven-survey pool of Figure 1C) answered the sea level question correctly.

Knowledge of North and South Pole geography is low. As Figure 4B shows only 38% of respondents know or guess that the North Pole is characterized by ice a few feet or yards thick, floating over a deep ocean. (In reality, North Pole ice averages around 2 or 3 meters, above an ocean 4000 meters deep.) An equal proportion believes instead that it is ice more than a mile thick, over land. Thus, although 70% answered correctly that Arctic sea ice has decreased, a mere 38% even know that the North Pole *is* on sea ice, if that is asked separately.

A slightly higher proportion, 46%, answered correctly that the South Pole is characterized by thick ice (about 2700 meters) over land (Figure 4C). Given that 38% believed the same thing about the North Pole, the higher proportion of correct South Pole answers might partly reflect a guessing bias towards 'thick ice over land'. With both North and South Pole questions (as with sea level), there are relatively minor partisan divisions in accuracy.

A fourth bar chart, Figure 4D, graphs the polar knowledge score defined as the number of answers correct among these three belief-neutral questions. Only 8% managed to answer all three correctly, and 25% got two out of three.

### The social bases of polar facts

A long-standing tradition in social-science research (from Van Liere and Dunlap 1980) studies 'the social bases of environmental concern', examining how individual characteristics predict views on the environment. This approach has been applied to polar questions on three nationwide surveys (Hamilton 2008, 2012; Hamilton et al. 2012b). Core findings from social-bases research have been the dominant roles of education and politics or ideology in shaping individual views on a wide range of topics from global to local in scale. In general, respondents with higher education tend to express greater levels of concern about environmental problems and more trust in scientists with regard to these issues. Conservative respondents tend to express lower concern and less trust in scientists.

Table 2 applies this approach to polar facts. Coefficients from weighted logistic or linear regression describe the effects on respondent accuracy from age, gender, education, political party, self-assessed understanding of climate change and personal belief about climate change. An *understand* × *party* term tests for possible interactions between self-assessed information and politics. To adjust for otherwise unexplained survey-to-survey variation, intercept dummy variables representing individual surveys are included in each model but omitted for simplicity in Table 2. Most of the survey terms are not statistically significant.

The distinction between polar facts that subjectively are linked to respondent climate beliefs (sea ice and Arctic/weather) and others that are not (sea level, North and South Poles) stands out clearly in Table 2. Personal belief in anthropogenic climate change significantly predicts both sea ice and Arctic/weather responses ($p < .001$) but none of the others. Similarly, the *understand* × *party* interaction predicts sea ice and Arctic/weather but no others. Political party exhibits a significant main effect only on Arctic/weather, which means (given the

Table 2. Coefficients from weighted linear (polar knowledge) or logistic (all others) regression of polar question responses (Table 1) on age, gender, education, political party, self-assessed understanding of climate change, *understand* × *party* interaction and personal belief that humans are changing the climate.

| | Dependent variable | | | | | |
|---|---|---|---|---|---|---|
| Predictor | Sea ice | Arctic/ weather | Sea level | North Pole | South Pole | Polar knowledge |
| Age | –0.003 | –0.001 | –0.005 | –0.001 | –0.013[b] | –0.004[a] |
| Female | –0.218 | 0.130 | –0.353[c] | –0.695[c] | –0.692[c] | –0.386[c] |
| Education | 0.181[b] | –0.017 | 0.093[a] | 0.176[a] | 0.120 | 0.057 |
| Party | –0.090 | –0.176[b] | –0.015 | –0.163 | –0.106 | –0.051 |
| Understand | 0.287[b] | 0.333[c] | 0.281[c] | 0.297[b] | 0.274[b] | 0.174[c] |
| Understand × party | –0.238[c] | –0.196[c] | –0.093 | –0.041 | 0.050 | –0.046 |
| Climate | 1.245[c] | 1.255[c] | 0.151 | 0.007 | 0.225 | 0.075 |
| number of surveys | 6 | 8 | 7 | 3 | 3 | 3 |
| estimation sample | 2906 | 4056 | 3577 | 1423 | 1423 | 1423 |

Note: All models include intercept dummy variables for individual surveys, which are estimated but not shown.
[a]$p < .05$; [b]$p < .01$; [c]$p < .001$.

coding used here) that party affects Arctic/weather responses even among those who say they have little understanding of climate change (*understand* = 0).

Self-assessed understanding of climate change significantly predicts accurate responses to all of the polar facts questions. As one might hope, individuals with more confidence in their understanding do seem to know more. Education also raises the odds of answering the sea level or North Pole items correctly. Older respondents less often know South Pole geography. The politically neutral questions all show significant gender effects, often reflecting higher proportions of 'don't know' responses by women. These patterns suggest that an information-deficit model partly explains the right and wrong answers to all questions. At the same time, the *party*, *climate* and *understand* × *party* effects on sea ice and Arctic/weather responses suggest that biased assimilation or biased guessing come into play on those two questions.

The significant *understand* × *party* interaction effects on belief that Arctic sea ice has declined, and Arctic warming would have major effects on your weather, are visualized as adjusted marginal plots in Figure 5. Among Democrats, Independents and to some degree Republicans, those with higher self-assessed understanding of climate change are more likely to know that sea ice has declined. The opposite holds among Tea Party supporters: those with higher self-assessed understanding of climate change are *less* likely to know that sea ice has declined (Figure 5A). This interaction affecting an uncontroversial physical observation parallels similar

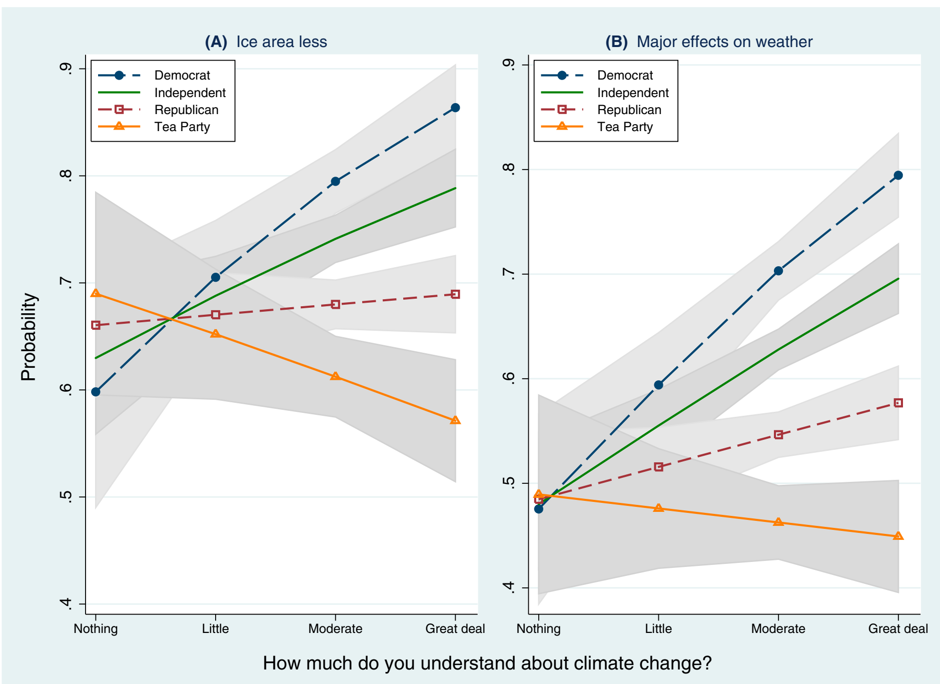


Figure 5. Predicted probability of choosing 'ice area less' (A) or 'major effects on weather' (B), as a function of political party and self-assessed understanding of climate change. Adjusted marginal plots calculated from logit regression models in first two columns of Table 2.

interactions observed elsewhere with a wide range of climate belief measures, reinforcing the conclusion that sea ice responses behave as if they were climate-change opinions.

Figure 5B graphs a similar interaction affecting whether people think that if the Arctic warms in the future, that will have major effects on their weather. The science is not settled on whether recent Arctic warming has measurably affected mid-latitude weather already (Francis and Vavrus 2012; Coumou et al. 2015), but there is broad agreement that future changes to albedo, sea ice formation and other processes will have global consequences (IPCC 2013, 2014). Among Democrats, Independents and Republicans, the probability of a 'major effects' response rises with self-assessed understanding. But Tea Party supporters who say they understand a great deal about climate change are least likely to think Arctic warming could have major effects on their weather. Curves similar in shape to those in Figure 5, suggesting 'understanding' based on biased assimilation, have been seen in other survey data sets as well (Hamilton 2011a; McCright and Dunlap 2011).

## 'Understanding' and knowledge

Our surveys find a paradoxical combination of high self-assessed understanding of climate change with generally low knowledge of basic facts. The polar questions are by no means a broad test of climate knowledge, but they involve background information that anyone moderately well informed about climate should know. Both scientific and public discussions have emphasized Arctic sea ice decline as a major symptom of change. Sea level rise, depending on the future of the great ice sheets, also has been a major and publicly dramatic point in climate-change discussions. Someone paying little attention to the issue might have less reason to know North from South Pole, but anyone who is paying attention should have seen them discussed repeatedly. Moreover, awareness of geography or the sea/land ice distinction, unlike other basic facts such as ice decline, appears unrelated to respondents' politics or climate-change beliefs. A polar knowledge score defined as the number of correct answers among sea level, North Pole and South Pole questions thus provides a limited but analytically useful marker for knowledge.

Table 3 cross-tabulates dichotomized versions of the polar knowledge and understanding variables. Twenty per cent of our respondents report having little or no understanding of climate change and answer one or none of the polar questions correctly. This realistically humble and low-information group might benefit from science communicated in accessible, innovative ways outside the classroom – for example, through game-based learning (Wu and Lee 2015) or

Table 3. Cross-tabulation of polar knowledge score by self-assessed understanding of climate change.

| | Self-assessed understanding | | |
|---|---|---|---|
| Polar knowledge score | None or little | Moderate or great | All |
| Low (0–1) | 20 | 47 | 67 |
| High (2–3) | 4 | 29 | 33 |
| All | 24 | 76 | 100 |

Note: Weighted percentages based on $n = 1570$; design-based $F$ test $p < .001$.

providing information about the level of agreement among scientists, countering the false impression of balance that may be fostered by media practices (Boykoff 2013).

Also realistic, to the extent tested here, are the 29% who report moderate or high understanding, and get two or three answers correct. These people more likely pay attention to science and might benefit from further information including new research. Only a few, 4%, claim little or no understanding but nevertheless got two or three answers correct. This group may include lucky guessers along with some who know the answers but are modest.

An impressive 47% of respondents fall into the overconfident fourth group, claiming moderate to high understanding of climate change but unable to answer more than one polar question correctly. Their sense of understanding evidently derives from sources other than knowledge about the physical world. Who are these people? Figure 6 breaks down the percent overconfident by age, gender, education, political party and personal belief about climate change.

Unlike polar knowledge itself, overconfidence appears unrelated to age ($p = .12$) or gender ($p = .47$). Overconfidence is somewhat more prevalent among respondents with postgraduate education ($p < .05$). Larger differences occur by political party and climate-change beliefs ($p < .001$). Democrats, Independents and Republicans appear roughly similar (41–47%), whereas Tea Party supporters are significantly more likely (61%) to combine high self-assessed understanding with low knowledge. Likewise, the rates of overconfidence among those who think climate is changing due to human activities or natural forces are similar, both about 48%. But a significantly higher fraction (60%) among those who think climate

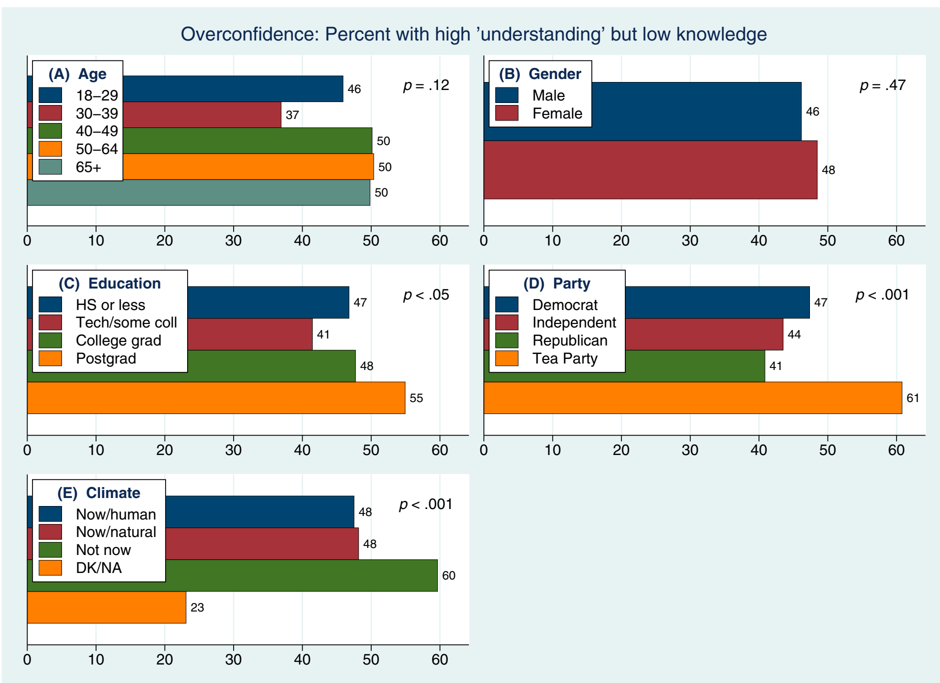


Figure 6. Percentage of overconfident respondents, or those reporting moderate/great understanding but having low knowledge scores. Probabilities are from design-based $F$ tests.

change is not happening exhibit that combination of high understanding with low knowledge. These patterns suggest that the false sense of understanding has ideological roots.

To be fair, overconfidence is quite prevalent, above 40%, among other groups too. Many of those people may also derive a false sense of understanding about climate from their own ideological perspective. The comparisons in Figure 6 simply highlight where ideology-based false confidence is the strongest.

## Discussion

In the eyes of survey respondents, there seem to be two kinds of polar facts. Some, like the sea ice/land ice distinction, or North and South Pole geography, have no obvious connection to and cannot be guessed from ideological beliefs. Despite the basic nature of our questions, and their multiple-choice format, only a third of the respondents could answer more than one correctly. Although such facts cannot be inferred from personal climate-change beliefs, they have been prominent in scientific and news media discussions about climate, and so are here viewed as a very rough but neutral indicator for knowledge.

Another kind of fact, though equally real in the physical world, evokes a different survey response. These are facts like Arctic ice decline that have more obvious connections to climate change. Non-polar examples include atmospheric $CO_2$ increase, and whether humans or volcanoes have recently emitted more $CO_2$ (Hamilton 2012). Responses to such questions behave as if we are asking for people's climate-change opinions, which have become acutely politicized (Hamilton 2011a; Leiserowitz et al. 2011; McCright and Dunlap 2011; McCright et al. 2014; Marquart-Pyatt et al. 2014; Hamilton and Saito 2015) to the extent they serve as ideological or cultural markers (Kahan et al. 2011). Put another way, many people are rejecting (or probably in some cases accepting) basic facts depending on whether they fit pre-existing beliefs – biased assimilation in action. From a scientist's standpoint, it might seem justified to construct a climate-knowledge scale using the preponderance of change-supporting facts. Such a knowledge scale would certainly predict individual belief in anthropogenic warming. Interpretation of that relationship would be complicated, however, by its subjectively tautological component. Acceptance/rejection of those facts in the first place is partly determined by people's beliefs.

Alternatively, a climate-knowledge scale might be constructed with a deliberate balance of questions that intuitively appeal to opposing climate-change beliefs (e.g. Kahan 2015). For example, instead of asking about late-summer Arctic sea ice compared with 30 years ago (falling), we might ask about midwinter Antarctic sea ice compared with 10 years ago (rising). Facts can be selected to form 'gotcha' questions in either direction. The meaning and correlates of such an offsetting-bias scale would be controlled by the mix of questions selected by the researcher, however, limiting its interpretation.

Our simpler, neutral polar-knowledge scale bypasses this limitation and thus offers a different window on biased assimilation. Biased assimilation occurs among people of all persuasions (Taber and Lodge 2006; Kraft et al. 2015), but that does not mean it is equally prevalent. Table 3 identifies a large segment, almost half our respondents, who combine high self-assessed understanding of climate change with low factual knowledge. Figure 6 shows that this combination occurs most often among Tea Party supporters, and those who do not believe climate is changing.

Previous studies found that Tea Party supporters report the highest levels of understanding about climate change (Leiserowitz et al. 2011; Hamilton and Saito 2015). That applies to the 2014–2015 surveys pooled in Figure 6 as well: 43% of Tea Party supporters, compared with just 18% of Republicans, 21% of Independents and 31% of Democrats, say they have 'a great deal' of understanding about climate change. Their polar knowledge scores, on the other hand, point in an opposite direction: only 27% of Tea Party supporters, compared with 31% of Republicans or Independents, and 39% of Democrats, answered two or three questions correctly. More directly than previous studies, these results support the conclusion that Tea Party supporters' sense of understanding about climate change disproportionately reflects ideology rather than science knowledge.

With both information-deficit and biased-assimilation processes at work, no science communication strategy will reach everyone. This analysis supports a common-sense view that we need a mix of approaches to address people with different combinations of information needs and receptiveness. Communicating the strength of scientific consensus (Ding et al. 2011; Maibach et al. 2014; Van der Linden et al. 2014) might be most helpful as a heuristic for those without much science knowledge or strong preconceptions. More detailed information including science-based response to counter-arguments could help those with some science knowledge already and openness to learn more. Certain websites (such as RealClimate.org or SkepticalScience.com) do this well, as do outreach-engaged scientists communicating through varied media from conventional news reports and op-eds to videos and science cafes. To make inroads against the hyperscepticism among ideologues noted by Kraft et al. (2015), more culturally tailored approaches (Kahan 2015) probably are needed. Ongoing polar changes give context and urgency to all of these science communication efforts.

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