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Learning from the U.S. National Assessment of Climate Change Impacts

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The U.S. National Assessment of the Potential Consequences of Climate Variability and Change was a federally coordinated nationwide effort that involved thousands of experts and stakeholders. To draw lessons from this effort, the 10 authors of this paper, half of whom were not involved in the Assessment, developed and administered an extensive survey, prepared a series of working papers, and conducted an invitational workshop in Washington, DC, on April 29, 2004. Considering all these sources, the authors conclude that the Assessment was largely successful in implementing its basic design of distributed stakeholder involvement and in achieving its basic objectives. Future assessments could be significantly improved if greater attention were devoted to developing a collective understanding of objectives, preparing guidance materials and providing training for assessment participants, developing a budgeting mechanism which would allow greater freedom in allocating resources across various assessment activities, and creating an environment in which assessments were part of an ongoing process.

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1. Introduction

Across most of the earth, climate, the average of the regional weather, is always changing. Some of these changes occur on time scales of many thousands of years due to natural processes, such as the precession of the earth's axis that contributes to the coming and going of ice ages. Some natural changes occur rather rapidly as when a large volcanic eruption injects many tons of fine particles into the stratosphere, leading to a period of months or years of cooling. Others occur on times scales of a few years or decades, brought on, for example, by the natural oscillations in the earth's complex ocean-atmosphere system. Examples of the latter include the El Niño-Southern Oscillation and the North Atlantic Oscillation, both of which have large impacts on regional climate, agriculture, and fisheries. Sometimes the changes, and their impacts, result from a combination of natural variation and human activities as when extended drought, and years of poor agricultural practice, together led to the decade-long Dust Bowl in the southern U.S. Great Plains during the 1930s.

Since the beginning of the Industrial Revolution humans have been releasing ever growing quantities of gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and various fluorocarbons, all of which trap infrared energy and tend to warm the planet, as well as various fine particles, which, depending on composition and location, can contribute to cooling or warming. The Third Assessment of the Intergovernmental Panel on Climate Change (IPCC) of the United Nations Environmental Program and the World Meteorological Program reported that over the 20th century the global average surface temperature increased by 0.6 ± 0.2°C and that "the global average surface temperature is projected to increase by 1.4 to 5.8°C over the period 1990 to 2100" (*1*).

The U.S. National Assessment of the Potential Consequences of Climate Variability and Change (*2*) was a large, congressionally mandated (*3*) effort to examine the impacts that variability and secular change in climate might have on the United States. This undertaking began in 1998 and involved several thousand expert and nonexpert participants, the direct participation of eight federal agencies plus OSTP, 20 regional workshops, assessments of 16 regions (also combined into nine "megaregions") and five sectors, and a federal advisory committee, the National Assessment Synthesis Team (NAST), which summarized much of the work in "overview" and "foundation" reports (*4*, *5*). Most of the regions and sectors have now produced separate reports. An up-to-date list of these is available in the Supporting Information to this paper.

As MacCracken has explained, the assessment process was financially supported in a shared manner by a set of federal agencies, "with each agency assuming responsibilities for which they had particular interests" (*6*). The process was coordinated by an interagency committee. The overview and foundation reports were subjected to an extensive four-part public and expert review, culminating in review by an 11-member "Independent Review Board" of the President's Committee of Advisors on Science and Technology (PCAST).

Beginning in 2001, the 10 coauthors of this paper (only half of whom had been participants in the National Assessment) undertook a process to draw lessons from the National Assessment experience. To this end, we formed ourselves into a coordinating committee. To obtain a wide range of perspectives and inputs, we developed and administered a detailed survey to a large number of people drawn from the

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Assessment's mailing lists and analyzed the responses, many of which were qualitative. Drawing partly on these results and partly on our own knowledge of the Assessment, we prepared a series of 12 short discussion notes, and then organized and convened an invitational workshop of 45 people. Some of those invited had been participants in the Assessment, some were potential users of this or similar assessment products, and some were domain or policy experts who had not been involved in the Assessment. The workshop was held in Washington, DC, on April 29, 2004.

While we have been informed by all of these activities, in this paper we report our personal conclusions about lessons from the National Assessment. We recognize that the Assessment faced a variety of constraints. In what follows, we make no argument that a better outcome could have resulted given the situation faced. Rather, we ask what we can learn from this experience that could improve similar assessment activities in the future. We believe that this paper provides the first systematic effort to provide general insights from the National Assessment. [Several years ago the U.S. EPA ran a two-day workshop to draw internal lessons for the Agency. The National Research Council is now undertaking an effort to draw lessons from the Assessment experience.]

2. Survey

We designed the survey primarily to generate ideas and perspectives for stimulating discussion at the subsequent workshop. Our objective from the outset was not to obtain a statistical evaluative "sample" but rather to identify ideas and views for subsequent discussion in our own analysis and in the workshop. Accordingly, the survey included many opportunities for respondents to offer comments.

The instrument was 13 pages long; many respondents reported that it took over 1 h to complete. Its 10 sections posed questions about (1) the respondent's background, (2) the nature and level of the respondent's involvement in the National Assessment, (3) the Assessment's organization and administration, (4) the respondent's self-assessment of their familiarity with eight different categories of scientific literature before and after the Assessment, (5) how future climate was characterized, (6) how social and economic impacts were assessed, (7) how uncertainty was characterized and treated, (8) an exercise that involved assigning letter grades to 20 separate aspects of the National Assessment, (9) the strengths and weaknesses of the Assessment, and (10) things that should be done differently in a future assessment. A copy of the survey is provided in the Supporting Information to this paper.

The content of the survey was developed and refined iteratively by the authors and then administered in a pilot form to 10 respondents who subsequently were interviewed to seek advice about how the questions should be refined. Once finalized, the instrument was mailed to a list of 2081 people on the contact mailing list compiled by the National Assessment. Many of these people had little or no involvement in the Assessment. A total of 182 responses were returned. Responses were received from nearly all of those who were involved in the preparation of NAST's overview and foundation reports. Just under half of the respondents (48%) were involved as reviewers of some product of the set of Assessment activities. A total of 86 respondents had been involved in the preparation of regional or sectoral reports, and 28 participated in two or more major workshops as well as in the preparation of one or more of the reports. We designated these latter respondents as "heavily involved", and denoted them separately so that particular attention could be given to their responses.

Full quantitative and qualitative details on responses are available in Supporting Information to this paper.

Results from the survey and from the April 29 workshop are discussed throughout the balance of this paper. While some of these results identify problems or raise concerns, overall the central message from the survey is that a large majority of the respondents saw the National Assessment as an essential first step in that it shed light not only on the impacts of a changing climate and adaptive responses but also on the process of engaging stakeholders, regions, and sectors in grappling with a major and complex social challenge. The majority of survey respondents and participants at the April 29 workshop believe that the Assessment was a learning experience, and as such, they also believe that society has benefited and can continue to benefit from this experience. Toward realizing these benefits, it is important that lessons from the experience be used to improve the process in the future. In the discussion that follows, we have used several verbatim quotations from survey responses. In selecting those quotations, we have been careful to reflect views that were also expressed during the workshop deliberations.

3. Objectives of the National Assessment

The U.S. Global Change Research Act of 1990 specified that, in addition to conducting research on climate change and its impacts, the U.S. Global Change Research Program (USGCRP) should do the following (*3*):

...prepare and submit to the President and the Congress an assessment which:

1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;

2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and

3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The National Assessment was one part of USGCRP's efforts to fulfill this mandate. While there had been earlier planning and assessment activities in several agencies and the USGCRP, the operational model for the Assessment was the brainchild of Jerry Melillo, who was then Associate Director for Environment in the White House Office of Science and Technology Policy. At a week-long workshop held in Aspen in the summer of 1997, Melillo articulated a vision of environmental policy assessment grounded in dialogues at the regional and local levels between regional experts and regional stakeholders, such as farmers, ranchers, local business people, local government leaders, local interest groups, and citizens at large. Activated by the regional workshops, Melillo argued that this consultation would raise the level of awareness of local citizens of climate change issues, encourage them to consider vulnerabilities to possible impacts, and then provide the basis to identify the major issues at the regional scale from the point of view of citizens and voters. Out of this democratic process of information exchange would come a picture of vulnerabilities of the United States to impacts of climate change and variability—not as a function of scenarios or local climate change forecasts that could result simply in arguments about assumptions, but as a robust set of views from the grass roots across the country.

Moreover, this would not be a one-time process. The regional workshops and subsequent regional assessments would catalyze the development of stakeholder networks that would support a continuing process of information exchange,

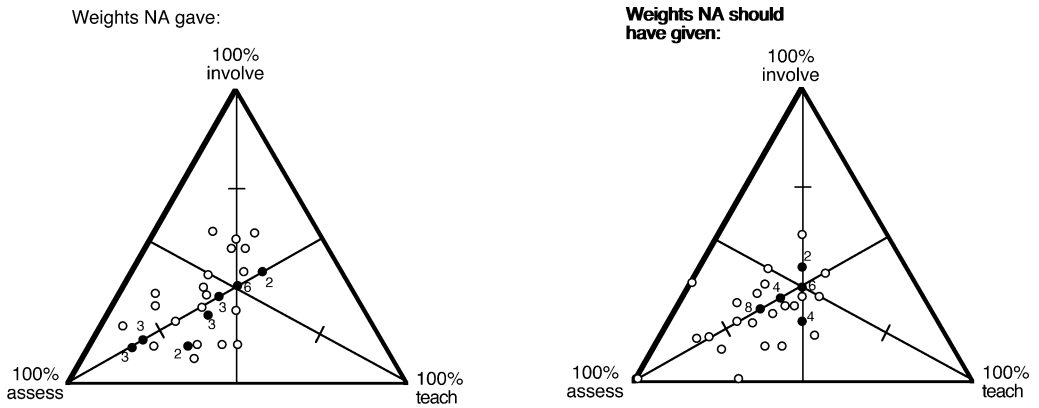

FIGURE 1. Distribution of responses to the survey question that asked respondents to allocate 100 points across the three attributes assess, teach, and involve to characterize what the National Assessment actually did (left) and should have done (right). While individual respondents showed some modest movement between the two cases, most respondents gave similar weights for the two conditions. Solid points are for more than one response (numbers shown). To avoid an overly complicated diagram, only the first 50 respondents are shown. Percentages cited in the text are for the entire sample.

education, and outreach related to climate change issues. In fact, this approach might well serve as a model for addressing other thorny environmental policy issues in the United States in the future.

While the reality proved more complicated, the basic structure of the assessment conformed to this vision.

Assessments are undertaken for a variety of reasons, and to serve a variety of objectives. These include to *assess*, that is, to develop improved insight and understanding about impacts and what might be done to prevent them or adapt to them, to *teach*, that is, to educate and inform participants who are not familiar with possible changes, impacts, and responses, and to *involve*, that is, to engage, motivate, and organize constituencies to take actions. Actions can range from inducing improved private sector anticipatory decision making to promoting political action at a variety of levels.

Our survey asked respondents to indicate the relative weighting that they believe *was* and *should have* been given to these three objectives by asking them to allocate 100 points across the three objectives. While individual respondents displayed some differences in their judgments between what they thought occurred and what they thought should have occurred, the difference between the two sets of responses was negligible. Average results suggest that respondents believe that a heavier emphasis was and should have been given to the assess objective (was, 47%; should, 43%) relative to those efforts given to teach (was, 27%; should, 28%) and to involve (was, 26%; should, 28%), Figure 1. The participants in the subsequent workshop shared this evaluation, as do we. Hence, we conclude that the National Assessment was successful in achieving an appropriate balance among these basic objectives.

It is clear that the Assessment raised the awareness and understanding of many of the participants. This is confirmed both by comments from participants in the April 29 workshop and in responses to the survey questions that asked for the respondents' self-assessment of "how familiar you were with various climate-related scientific subjects before the assessment, and now after the assessment"; on a five-point scale ranging from "none" to "expert", responses in the top two categories went from 52% to 82% for climate change, from 47% to 85% for ecosystem impacts, and from 24% to 36% for socioeconomic impacts. Similar increases were observed in the other five categories studied. But while respondents themselves learned a lot, both participants in the workshop and several survey respondents noted that they thought the efforts in general public education were not sufficient. Respondent 60 wrote, "I would like to see the 'teach' objective have a much higher emphasis on public education (not just participant education)...." Respondent 85 wrote, "With regard to teaching, I think that there was a good degree of success in getting researchers in climate-impacted disciplines involved and informed. The lower score reflects the lesser success in reaching the general public." Respondent 103 wrote, "I just think there was little done to educate the public. Other than those participating, it's still hard to find anyone who knows this process ever happened!" Respondent 163 wrote, "Many of the participants did not need much assessing and teaching (I did), so, perhaps we must contemplate how to transport the knowledge base to the public at large through the talent assembled at the National Assessment."

These evaluations were reflected in responses obtained in a part of the survey that asked respondents to assign letter grades to 19 different aspects of the Assessment. The Assessment was judged to have done well in "involving a large number of people in considering the issue of climate change", yielding an average grade of B across all respondents and of B+ for respondents who were heavily involved in the assessment process. It also received B grades on "educating participants about climate change" (B−, B+). It received somewhat lower grades for "educating the U.S. public about climate change" (C−, C), "informing local and regional decision makers about climate change" (C, C+), and "informing national decision makers about climate change" (C, C+). These evaluations were reported to the workshop, where no counter arguments were advanced.

The Assessment's limited success in outreach and public education resulted in significant measure from the lack of adequate funding to support such activities, and from the fact that the Bush administration chose to cancel a number of those activities that had been planned.

While we believe that a ratio of roughly 50:25:25 for assess:teach:involve is appropriate for general assessments, it is important to note that other ratios are more appropriate in other contexts. For example, much of the Assessment work supported by research programs at NSF, DoE, and NOAA has focused on developing and demonstrating new and useful assessment methods and approaches. Clearly, less emphasis on teach and involve is appropriate in such research settings. However, even then, if new methods are actually to prove useful to decision makers, involvement of, and feedback from, potential users is essential throughout the process, lest the methods become so esoteric as to be of little use.

Clearly, one other objective of most assessments should be to identify research needs which would support better assessment activities in the future. In addition to a brief chapter on research needs in the report of the NAST, the

authors of the NAST also prepared and published a more elaborated discussion of research needs (*7*).

4. Assessment in a Political Environment

Given the history of the issue of climate change, it is inevitable that any national or regional assessment activity supported by government will have, or at least be perceived by some to have, significant political overtones.

The National Assessment was certainly no exception. While Vice President Al Gore clearly had a strong interest in the issue of climate change, there was also the wide perception that the Assessment was motivated in significant part by Mr. Gore's presidential ambitions, and that the substantial focus on outreach and broad citizen involvement was part of a deliberate strategy by the Vice President's office to build a wider community of concern and a political ground swell of support for what might have been the climate policy of a subsequent Gore Administration.

After the release of the Assessment, there were unsuccessful legal and lobbying efforts to persuade the Bush Administration to repudiate and withdraw the Assessment. [See, for example, http://www.thecre.com/quality/20020211_climate-letter.html.] These efforts were based largely on claims of uncertainty about future climate, and arguments that the assessment methods adopted in the National Assessment did not comply with the requirements of the Federal Data Quality Act. The discussion notes we prepared for the April 29 workshop included a note titled "Politics and Assessment". Participants in the breakout group that addressed this note held a long discussion about whether some of the strong ideological reaction to the National Assessment at the national level was a result of, or exacerbated by, the extensive stakeholder involvement. Several argued that a major motivation for the effort to have the Assessment repudiated sprang from the fact that the Assessment was at least partly successful in meeting its objectives of involving regional stakeholders and of achieving the objectives of teach and involve.

While survey respondents indicated that they believe that an assessment should have a significant element of teach and involve, we note that support for these two objectives is not the same as agreeing that it should advance any specific political agenda.

Some workshop participants identified political tensions as a source of frustration for Assessment participants. They noted that those involved at the national level were often challenged by questions about whether the objective was good analysis for regional and sectoral planning and resource management, or the advancement of a specific normative agenda. In contrast, other workshop participants argued that such questions rarely arose among those working at the regional or local levels, where curiosity about insights from available science, identification of vulnerabilities, and engagement in problem solving predominated.

In part to minimize political tensions over the more contentious issues of emissions control [the enabling legislation did not mention emissions control and we are told that at least some agencies did not believe they had authority to spend money studying this issue], the Assessment focused only on impacts. While acknowledging this motivation in limiting the scope of the Assessment, a number of workshop participants argued strongly that this limitation rather severely hampered the work of the Assessment. Others offered the view that adding considerations of control, and an expanded treatment of options for adaptation, would have made the scope of the Assessment impossibly large for the limited time and resources that were available. We discuss these issues at greater length in section 12.

Contributing to the tension over political intent, there were equally challenging issues surrounding the funding for the National Assessment. Because it was organized rather quickly, and perhaps too because it might have been difficult to get a budget appropriation specifically for the Assessment (even though the Assessment was mandated by a previous Congress), the Assessment was largely funded by directing various Executive Branch agencies to take responsibility for the assessment of specific regions and/or sectors. This meant that funding allocation across the various tasks was uneven—sometimes differing by as much as a factor of 10. In addition, since Executive Branch agencies have their own policy and administrative interests and agendas, some have argued that this administrative mechanism resulted in differing pressures and influences on different parts of the Assessment.

In future assessments, it would clearly be desirable to have funding that could be allocated in accordance to the relative needs and costs of different assessment activities. It would also be desirable if assessments could be an ongoing activity so that progress made in one iteration could provide the foundation for the next, and define a research agenda to support future assessment activity. Whether U.S. state or national political environments would ever make this possible is unclear. In the future, various public-private or fully private arrangements probably also warrant consideration if they could achieve more appropriate allocation of resources and greater continuity.

5. Training Members of Assessment Teams

One of the great strengths of the National Assessment, clearly reflected in the results of the survey, was its success in bringing many individuals into a complex, interdisciplinary, problem-driven assessment for the first time. A substantial majority of those responding to the survey speak positively of the wisdom and dedication of the people they met working on the National Assessment. A few refer to the National Assessment as a life-changing experience.

That said, it is also clear that many of the expert and nonexpert participants in the Assessment were unfamiliar with basic ideas and methods that are central to modern policy analysis or the process of assessment. While there was some "learning-by-doing", this lack of understanding of such basic ideas and methods as parametric analysis, working backward from outcomes to inputs, benefit-cost analysis, decision analysis, multiattribute utility, and the behavioral literature on risk perception and time preference, as well as the limits that these and similar tools face when applied to the climate problem (*8*), was a serious constraint that prevented the Assessment from achieving its full potential.

There is also a thread running through a significant minority of the survey responses, and articulated in some of the Assessment's workshops, which suggests a lack of understanding about the importance of including a wide variety of disciplines and stakeholder perspectives in such an assessment activity. Many of these views come from natural scientists who were dismissive of the technical ignorance of many of those they had to deal with in the National Assessment. From the other side, some practitioners appeared to make a blanket dismissal of the irrelevance of "academic" science. And a number of both academics and practitioners faulted the National Assessment for "inappropriately" allowing the Assessment to be too much of a compromise, too much of a mix of facts and values. While such criticism represents a minority view, the minority is large enough to warrant attention. It represents a kind of response to assessments that is bound to resurface in future efforts to harness science in support of decisions bearing on global change. It also represents a lack of comfort by some researchers with working within a multidisciplinary research team, with including traditional and local knowledge within an assessment process, and with the need to explicitly incorporate a consideration of values in the assessment

process. Understanding where the complaints come from, and what might be done to reduce them, therefore seems worthwhile. This has also led some to suggest that care must be taken in choosing assessment team leaders and members to ensure openness to a broader and more comprehensive assessment approach.

We believe that future efforts such as the National Assessment should arrange to spend time in the early stages of the effort preparing a coherent and comprehensive series of guidance documents and training the assessors about what it means to do a complex, interdisciplinary, problem-driven assessment. This is not a call for top-down control, but rather for more centrally coordinated guidance. While much could be done at the outset to improve assessment, it is also important to take an adaptive approach to guidance since inevitably learning will occur as any assessment proceeds. Also it is important to differentiate methodological guidance from substantive guidance. Often participants involved in sectoral or regional assessments will have access to more or better information than folks at the top who are coordinating a broad assessment.

Related suggestions that came forward for improving the capacity of participants include training or knowledge-sharing workshops and mentoring or coaching to increase comfort with the guidance and to illustrate the power of various approaches. It has also been suggested that a more open and transparent process for developing guidance, involving assessment team members, would increase comfort and decrease criticism of the process. Two areas that were particularly highlighted as requiring further and more timely guidance and training were the use of socioeconomic scenarios and stakeholder involvement. It was noted by many that among the various assessment leads and scientists there were differing capacities and degrees of comfort with integrating these into the Assessment, as for some these represented a break from traditional research approaches.

Several subsequent sections of this paper discuss issues we believe should be covered in guidance documents. While the National Assessment Synthesis Team took some modest steps toward drafting such guidance, timing and resource constraints were such that the effort was too little and too late.

Future assessments should also spend more time at the outset working on developing buy-in on the vision of the assessment and clearly defining and articulating the goals and expected outcomes. In addition, time should be spent upfront developing an understanding among assessors of the multiple parts that have to work together and support one another if the goals are to be achieved. Such assessments, especially when undertaken on a politically charged topic, are extraordinarily difficult to do well. Formal results from very sophisticated global research programs need to be combined with tacit knowledge drawn from experience in particular sectors and places—in ways that respond to but are not derailed by stakeholders involved in a vigorous and high-stakes political debate. In the case of the National Assessment, as in most such cases, the whole exercise was made more difficult by acute constraints of time and money and the evolution of the scope of the assessment process that undermined prospects for learning-while-doing.

No country has a good track record in carrying out such assessments, though the Canadians, Australians, and some European countries are ahead of the United States in trying to learn to do so (*9*−*15*). One way to develop a shared vision of the objective of assessment is through a critical analysis of other relatively successful assessments. Past efforts to do this at Harvard's Kennedy School appear to have gotten across the message that successful assessments are not just about credibility, but also about *saliency* (i.e., relevance to decision) and *legitimacy* (i.e., fairness of process in hearing all sides and stakeholders in both the setup of questions and the analysis of data) (*16*). Most successful assessments of hot issues succeed not by optimizing on one of these dimensions, but by balancing across them to create an assessment process and product that is seen to be credible, salient, and legitimate by multiple stakeholders simultaneously (*9*, *13*). As hard as this dynamic balance is to accomplish in practice, the survey results suggest that a subset of those involved in the National Assessment did not even see it as something that needed to be tried.

6. Assessing Future Climates

Officially, the National Assessment adopted three strategies for characterizing possible future climates: historical records of past climate variability and change, scenario analysis using large-scale general circulation models (GCMs), and sensitivity analysis that asked "what degree of climate change would cause significant impacts to natural and human systems" of interest.

Survey responses from Assessment participants suggest that all three approaches were used (57% GCMs, 45% data on past climates, 44% "what if" analysis). However, in our view, two GCM runs, based on a single emissions scenario (the IPCC scenario IS92a), predominated as the vehicle used to explore possible future climate in the National Assessment. This view is reinforced by an examination of the reports of the NAST and a reading of the detailed responses to the participant survey. A number of respondents noted that participants in their group had greatest familiarity with using GCMs. Respondent 49 wrote, "Our group used GCM scenarios based on [the] belief that they are the only credible basis for projecting future climate change." However, respondent 68 noted, "There was a belief among stakeholders that the GCMs were actual predictions and this confused many of them. Others may have lost faith in the process because of reliance on GCM output."

There have been complaints about the specific GCM models used, and the fact that only one emission scenario was employed to drive those models. MacCracken et al. (*17*) have responded, arguing that these limitations have been exaggerated, or were forced by limitations in the availability of relevant model results.

However, the question of whether the right GCMs were used, and whether they were driven by the right emissions scenario(s), is of second-order importance compared with the more fundamental question of how an appropriate range of future climates should be identified and explored in national and regional assessments. While they suffer from known, and probably unknown, limitations and do a poor job of modeling many details of regional climate and of estimating key variables such as precipitation, GCMs produce spatially consistent and visually compelling graphical output. Further, there is a large community of modelers heavily invested in their development and use. For these, and probably other reasons, there are strong pressures to use GCM outputs as the basis for climate impact assessments.

While survey respondent 101 correctly noted that the "very limited set of [climate change] scenarios [used]...failed to do an accurate job of portraying existing uncertainties", it is clear from the survey responses and discussions with lay participants that there is a tendency to view the range of outputs from GCMs as providing a reasonable indication of the range of uncertainty about future climate. However, this is unlikely to be true even given outputs from a much wider set of GCMs, and a range of alternative emissions scenarios, because the results would share assumptions and parametrizations that might be inadequate.

It was because of such considerations that the NAST identified *three* different strategies for exploring future climate. Several groups that did go beyond using GCMs to try other strategies reported success. Respondent 13 noted,

"We took advantage of [a] long climate record...for defining trends. GCMs provided alternative answers/sensitivity analyses." While very much in a minority, respondent 9 noted their group used historical data because "participants could have confidence in scenarios based on historical data. The focus was on building hazard resistant and resilient communities." Respondent 116 reported, "Our qualitative 'what if' analysis worked quite well. The participants were satisfied with the results."

There was a strong inclination in most groups to approach the problem of assessment in a front-to-back manner (emissions → climate → impacts), rather than, for example, identifying key thresholds or nonlinearities in natural and social systems of concern and working backward to let those drive the work of the climate scientists and the choices of climates to be examined. At the Washington workshop on learning from the Assessment, the breakout group that considered this issue noted that there is "a big difference between driving an assessment from possible climate futures all the way to impacts as opposed to starting with people trying to manage messes in the world...".

While such a threshold or parametric analysis may make sense to experienced policy analysts, it is clear from the National Assessment experience that such an approach is not readily comprehended by most nonexperts and does not come naturally to many natural and social scientists who are used to working forward through a causal chain. Thus, we conclude that an important element of preassessment guidance papers, and a training program, should be a tutorial in such methods, illustrated with concrete examples drawn from previous applications.

That said, it is also important to note that, in many of the regional assessments, experts in those particular areas had climate change and impact-related projections that were arguably better than what was being provided top-down. This does not reflect a difference between experts and nonexperts but a difference between the perspectives and information sources of global/national-scale analysts and regional/local-scale analysts. Thus, while guidance materials can help familiarize participants with alternative analytical approaches, it would be wrong to assume that it will always be a source of superior substantive guidance. It would be a mistake if guidance material were to force regional people to ignore information that they have a valid reason to believe is better than what is being supplied.

Finally, respondent 136 noted, "Real events were more powerful than graphs or numbers. Our best example of global warming was the shrinkage of glaciers in Glacier National Park. The animation was convincing." As climate change becomes more apparent, the availability of such examples will grow. However, the problem of attribution, of distinguishing climate variability from true anthropogenically induced secular change, will remain large for many decades.

In the letter grade portion of the survey, the average grade given to "characterizing future climate" across all respondents was C+. The average grade given by respondents who had been heavily involved in the Assessment was the same.

7. Assessing Social and Economic Impacts

Several teams involved in the National Assessment made extensive use of advanced analytical tools to model climate change (using output from the Canadian and Hadley general circulation models), or to examine its likely large-scale ecological impacts (using models such as VEMAP (*18*) and DISTRIB (*19*)). However, the level of analysis of social and economic impacts was considerably less sophisticated. Indeed, participants in the April 29 workshop breakout group "felt that it was not very satisfying to have socioeconomic impacts treated as sort of a secondary issue to be handled *ad hoc*, rather than being a central concern from the outset".

Several research teams have built integrated assessment models that contain socioeconomic modules to study the impacts of climate change (*20*−*22*). However, the NAST concluded that it was unrealistic to try to employ such models in the work of the National Assessment because of the limited time available, and the relatively limited experience of many participants in the assessment process.

The NAST commissioned its own national projections of U.S. population, employment, labor productivity, and gross domestic product to 2100 (for details see pp 30−33 of ref *4* and Chapter 3 of ref *5*). Responses to the survey make it clear that the use of these projections was uneven. A guidance document was distributed by the NAST, recommending that teams select one or two additional factors, besides the demographic and economic variables, which they judged would have the most direct effect on each impact of interest, and then vary those factors through a range they judged to be plausible (without spelling out the details of what social and other processes might lead to such changes). As the National Assessment Synthesis Report explains, "teams found the complexity of even this simplified approach challenging, and made limited use of it beyond the basic scenarios" (*4*). When asked in the survey, "Did you ever see that guidance?", only 45% of those who answered said yes. While most respondents apparently did not make use of this guidance, three-quarters of those who did try to follow the guidance reported that they considered the effort successful (63%) or partly successful (12%).

Discussions at the Assessment's July 1998 workshop in Monterey, CA, clearly demonstrated the difficulty that many people have in thinking about how socioeconomic systems could evolve in the future. Many participants seemed intent on believing that the future would be pretty much like the present in all respects except for a changed climate. Other participants (mostly physical scientists) took the position that, given the very high levels of uncertainty about socioeconomic processes, there is no way to say anything that is useful about socioeconomic issues more than a few years into the future. Under these circumstances, given the time constraints on the process, the Assessment leadership concluded that they needed to shorten the time horizon on the socioeconomic impact assessments. The breakout group that considered this issue at our April 29 workshop on learning from the National Assessment noted that a lot of issues relevant to the Assessment, particularly those about impacts over long time periods, lie outside of the usual decision-making processes of public institutions or the day-to-day concerns of stakeholders. They observed that some stakeholder processes break down when the stakeholders are asked to focus on longer-term issues with which they have little or no experience. They concluded that as a consequence some degree of top-down instruction and direction is unavoidable for an assessment to adequately consider alternative socioeconomic futures.

Almost 60% of the respondents indicated that, if another assessment were done, social and economic impacts should be handled differently from how they were handled in the part of the Assessment in which they participated. However, the survey results show little agreement among respondents about just how to improve the treatment of social and economic impacts in future assessments.

We read this experience as a compelling case for careful preparation of guidance materials, which both contain general discussions of strategies for thinking about the future as well as specific examples and illustrate the application of specific methods, focusing especially on simple strategies such as parametric analysis.

One strategy widely proposed to deal with socioeconomic impacts is the development of scenarios. For example, the IPCC (*23*) has developed a series of scenarios illustrating a

range of possible future emissions of greenhouse gases, based on a set of fairly complex story lines about the future.

Scenarios can be a useful device. However, because they can be cognitively compelling, they can also be dangerous. As a result of cognitive heuristics, such as availability (*24*), as a scenario is made longer and more detailed, people judge it as more plausible, and assign a higher probability to its occurring. That is, long detailed scenarios, which are subsets of much simpler scenarios, are judged more likely, while in fact they are far less likely (*25*).

Scenarios that describe just some single point in the space of possible future outcomes are of limited use and logically cannot be assigned a probability. If scenarios are to be used, it is better to span the space of interest. In this case, subjective probabilities can logically be assigned to each.

A few investigators have used computer models to generate very large numbers of plausible futures, with the objective of testing the relative robustness of alternative policies in the face of an inherently uncertain future (*26*, *27*). Such methods might hold promise in future assessments, but would require much more prior preparation and training of assessors than was possible in the National Assessment.

In the letter grade portion of the survey, the average grade given to "assessing social and economic impacts" across all respondents was C. The average grade given by respondents who had been heavily involved in the Assessment was the same.

8. Assessing Ecological Impacts

Societies in the developed world probably can adapt to most climate change. After all, U.S. society manages to successfully operate in both Fairbanks, AK, and Key West, FL. In contrast, many species and ecosystems will likely find it difficult or impossible to adapt or move as climate changes.

In contrast to the analysis of socioeconomic impacts, the National Assessment was able to employ state-of-the art modeling tools in its analysis of ecological impacts through the efforts of Vegetation/Ecosystem Modeling and Analysis Project II (VEMAP II). This effort made use of three biogeochemistry models (BIOME-BGG, CENTURY, and TEM) and three biogeography models (LPJ, MAPSS, and MC1). Using climatic inputs from the Canadian and Hadley GCMs, the models were then run to estimate changes in carbon storage and vegetation distribution, parametrically across the different models. Detailed results are presented in Chapter 2 of the National Assessment Synthesis Team's foundation report (*5*).

At the regional level, assessment teams were encouraged to use three general approaches to analyzing the potential impacts of climate variability and change on ecological systems: (1) consideration of past impacts attributed to climate variability and change, (2) results from the coupled modeling studies, and (3) identification of ecological thresholds associated with climate variability and change that, when crossed, would lead to ecological consequences, some positive and some negative, some reversible and others not.

Responses to the survey suggest that the assessment of ecological impacts was viewed by participants as fairly successful. It was judged to have increased the participants' familiarity with the subject, but not to have done very well in educating the general public about the subject.

Survey results revealed several concerns. Some respondents complained that there was too much emphasis on the linked climate model-ecological model outputs. A key issue here is the concern that the climate models cannot supply reliable information at the spatial and temporal scales needed for analyses of ecological impacts. The tension between the concepts of "predictions" and "plausible alternative futures" is mixed into this concern.

Some survey respondents also felt that there was too much focus on the ecological effects of changes in mean climate conditions and not enough focus on the effects of changes in the frequency of extreme events. Much of the discussion of extreme events and ecological impacts in the National Assessment was about past events or about general responses that might be expected in the future. Little was done in the scenarios to incorporate regional and subregional climate extremes, so ecological analyses of the impacts of extreme events were not represented in the outputs from the biogeochemistry and biogeography models used in the National Assessment.

Respondents also noted the Assessment's limited success in placing the climate-change-related impacts on ecosystems in the context of other stresses, and poor connection between social and economic factors that govern phenomena such as land-cover and land-use change and ecological impacts. The concept of global change includes, in addition to climate change, changes in land cover and land use, the chemistry of the atmosphere and precipitation, and the deliberate and inadvertent redistribution of living organisms across the globe. While some knowledge is available on how these factors interact (sometimes synergistically and sometimes antagonistically), there surely will be many surprises. Appropriate representation of these interactions in an impacts assessment remains a challenge and must include a better way of dealing with the human dimensions of the problem.

Section 6 notes that the National Assessment performed well behind the state of the art in assessment methods for socioeconomic impacts. In contrast, the concerns about assessing ecological impacts reflect limitations to the current portfolio of analytical tools available in the research community. The basic strategies used in the National Assessment appear to have been sound, even though a future assessment should take steps to perform sophisticated ecological analysis in a more timely manner so that results are available to regional teams with adequate time to reflect on their implications and incorporate them into their local analysis.

In the letter grade portion of the survey, the average grade given to "assessing ecological impacts" across all respondents was B−. The average grade given by respondents who had been heavily involved in the Assessment was the same.

9. Characterization and Treatment of Uncertainty

Climate change and variability, and their impacts, inherently involve great uncertainty. So too do attempts to project how human societies are likely to change over coming decades. Thus, any national, regional, or sectoral assessment must deal in some way with uncertainty.

The treatment of uncertainty was very uneven across the different groups involved in the National Assessment. In most cases, when uncertainty was discussed, it was done so without any quantification. There is strong empirical evidence that uncertainty words such as "likely" and "unlikely" can mean very different things in different contexts (*28*, *29*). Survey results, and our own reading of the regional and sectoral reports, show that, with the exception of the NAST, which developed a mapping of qualitative words into quantitative ranges of subjective probability, most groups were not systematic in how they used such words, and few made any attempt at quantification. Further, just under half of the survey respondents indicated that they were not aware of the effort made by the NAST to assign numerical values to probability words and then use those words consistently throughout their report. This may be the result of timing since the NAST developed its formulation rather late in the process.

We believe that at least five factors contributed to this uneven treatment of uncertainty: (1) Many Assessment participants were new to this kind of activity and were

unfamiliar both with the issues of thinking in a formal way about uncertainty and with analytical tools for dealing with uncertainty. (2) Most respondents had no knowledge of the compelling evidence in experimental psychology that indicates that probability words (such as "likely" and "unlikely") can mean dramatically different things to different people, and to the same people in different contexts. (3) In contrast to recent IPCC practice, no guidance document on how to deal with uncertainty was distributed to participants in the National Assessment. (4) The computer models used by some assessment teams did not lend themselves to probabilistic treatment or other forms of uncertainty analysis. (5) So much time was spent on organizational and other issues that teams did not have an opportunity to think about issues of uncertainty until it was too late to do very much about it.

We believe that future assessments should adopt a more adequate and systematic characterization and treatment of uncertainty. At the April 29 workshop it was suggested that a consistent lexicon be developed and used throughout the Assessment. In developing this lexicon, the words chosen to convey levels of likelihood and levels of confidence (and uncertainty) should be meaningful to the target audience(s) and not just within the scientific community. Furthermore, future assessments need to be more successful at communicating risks. This would require more consistent use of multiple scenarios and greater focus on identifying and evaluating key vulnerabilities. Both of these would mean further guidance to the assessment teams. After the NAST effort, Moss and Schneider (*30*) developed such guidance for authors in the IPCC Third Assessment. As a result, the summary for policymakers of Working Group I (*1*) maps probability words into numerical value. While progress has been slow, and the impact uneven, clearly such guidance can help.

10. Commonalities

The foregoing discussions suggest several themes that are common across the domains discussed.

The first involves *the allure of quantitative and complex models*. Quantification and formal analysis can be powerful vehicles to organize and understand a complex problem. But they are not always the best or only way to gain insight.

When more than one method was available for elucidating possible alternative futures, many groups contributing to the Assessment automatically opted for the most quantitative method, assuming it to be the most reliable (e.g., GCM runs versus more qualitative projections of historic climate trends). Where rigorous quantitative analysis was unavailable, more rather than less detailed descriptions were assumed to be better (e.g., detailed scenarios versus parametric analysis in a few key variables). A preference for the more quantitative and complex is not always the best route to insight in the assessment of climate and similar complex problems (*31*–*33*). Future preassessment training and guidance should include information on the applicability and limitations of quantitative and complex modeling and scenario building, along with information on the advantages and limitations of alternative methods for thinking about the future.

A second issue involves *the relative tractability of modeling physical systems*. In general, participants in the Assessment assumed that making projections about the climatic system was a more tractable enterprise than making similar projections about the global ecological system. Projections about both were deemed more tractable than making projections about socioeconomic systems. This is in part due to the privileged position given to quantitative models and in part due to perceptions about uncertainty (both reducible and irreducible) assumed to plague the different systems (see section 9 above). However, there is mounting evidence that physical, ecological, and social systems alike can all exhibit both long-term inertia (e.g., persistent demographic influences and slowly changing cultures) and the possibility for rapid change to alternative states (e.g., U.S. politics before and after the terrorist attacks of Sept 11). Future assessments need to work harder to sensitize participants to these issues and overcome prior assumptions about tractability when they are not appropriate.

A third issue involves the *challenges of reverse causation and nonlinearities*. In general, participants in the Assessment were much more comfortable working from the present to the future, from cause to effect (e.g., emissions → climate → impacts), than in imagining possible futures and then working backward to the present actions that might bring about (or avoid) those futures. Related to this was the attraction of thinking about relatively smooth well-behaved cause and effect chains, rather than possible "break points", thresholds, or nonlinear changes that might render tomorrow's world very different from today's. We suspect that most people, including most academically trained analysts, are better equipped to analyze incremental rather than revolutionary change. Nonetheless, if a reasonable range of plausible futures is to be crafted in future assessments, participants will have to increase their comfort with employing diverse methods of assessing both smooth and nonlinear trajectories and working backward from end states of concern to ask, "Through what alternative combinations of physical, ecological and social developments might we get here?"

11. Organization of the National Assessment

The survey asked respondents to use a five-part scale to evaluate the organization and administration of each part of the Assessment in which they were involved. The question was posed in four categories (counts, from "poor" to "excellent", in brackets): "overall organization" [4, 4, 29, 38, 25], "objectives well defined" [6, 11, 26, 42, 15], "leadership provided" [4, 10, 28, 30, 25], and "administrative support" [4, 10, 23, 37, 21].

These evaluations are rather positive. However, both qualitative responses and discussion at the April 29 workshop make clear that there was considerable frustration over time constraints, lack of resources, and limited, or ineffectual, coordination.

The fact that the funding and administrative oversight of regional and sectoral assessments were farmed out to a number of different federal agencies led to considerable differences in the level of resources available to different assessment groups and the terms under which they operated. The report from the breakout group that considered these issues at the April 29 workshop asked whether "...the Assessment [would] have been more effective and better supported if agencies had pooled their financial resources instead of having individual agencies bearing the cost of particular pieces? The group agreed that pooling might have helped, but it is a nearly impossible proposition given the way agency budgets are authorized. Did making agencies step up to the plate after a decision to proceed and without new funding make OSTP an ogre in the process? Some people thought this might be the main reason why there are bad feelings about OSTP and its role in the process."

12. What the National Assessment Did Not Assess

As we briefly noted in section 4, the National Assessment excluded a consideration of strategies for abating greenhouse gas emissions, and devoted relatively little effort to identifying and analyzing strategies for adaptation. Adding these dimensions to the Assessment, and treating them in a comprehensive and systematic way, would have vastly expanded the work of the Assessment, and even if it had

been politically acceptable, it probably would not have been feasible given the time and resources available. Nevertheless, frustration over the arbitrary boundary imposed on the Assessment surfaced in both the survey responses and in the discussions at the April 29 workshop. For example, participants in several of the regional assessments felt strongly that their assessments should have included possible impacts of abatement strategies (e.g., economic impacts on Pennsylvania or West Virginia of reduced production of coal).

Many believe that, in scoping out a policy-relevant assessment, one should begin by defining the bottom line from the target audiences' (stakeholders) perspective. Arbitrarily bounding the assessment by taking off the table consideration of greenhouse gas abatement took away the direct link to the bottom lines of many of the stakeholders, limiting their interest and thus involvement in the assessment process. Participants in the April 29 workshop suggested that more success could have been achieved through using a stakeholder definition of scope and providing a consistent approach/framework for incorporation of these bottom lines. It was also suggested, as mentioned earlier, that performance of an assessment through a third party partnership may also allow for incorporation of politically sensitive issues such as greenhouse gas abatement.

It would probably be easier to incorporate a more systematic consideration of adaptation in a future impact assessment than it would be to incorporate a consideration of abatement. However, both are clearly legitimate topics for national and regional assessment activities. Perhaps the U.S. should consider undertaking a separate national assessment of abatement options. Such an assessment could be done in two stages. First, a group of engineers, economists, and other social scientists and business experts could work up detailed cost and performance characterizations of a range of technologies and policies which might be used for abatement. This could then be followed by a set of regional and sectoral assessments, similar in character to those conducted in the National Assessment, which work through the implications in each specific geographical or economic context.

13. Discussion

On the basis of our own assessment, and the survey and workshop results, we believe that the Assessment was largely successful in implementing its basic design of distributed stakeholder involvement and in achieving its basic objectives. In the survey, respondents who were heavily involved in the Assessment process graded its performance significantly better than respondents who had little or no involvement, Figure 2. While this may partly reflect buy-in arising from past investments of time and energy, on many of the metrics it is more probably the result of better familiarity with the assessment's actual accomplishments and performance.

Future assessments could be significantly improved if greater attention were devoted to developing a collective understanding of objectives prior to embarking on the assessment process.

While the Assessment clearly demonstrated the value of substantial grass-roots participation, it also made clear that such involvement could be improved with greater central coordination and with basic tutorials and guidance on assessment objectives and methods, including alternative strategies for thinking about the future, for performing parametric and "what if" analysis, and for thinking about and dealing with uncertainty.

Including issues of emission control, and an examination of how policies for emissions control might impact future social and economic systems, is clearly important. They were not included in the National Assessment for understandable reasons, but in the future, they should not be left out. However, a good case can be made that, rather than folding them into a single large assessment, they should be treated separately as another part of an ongoing process of performing national, regional, and sectoral assessments.

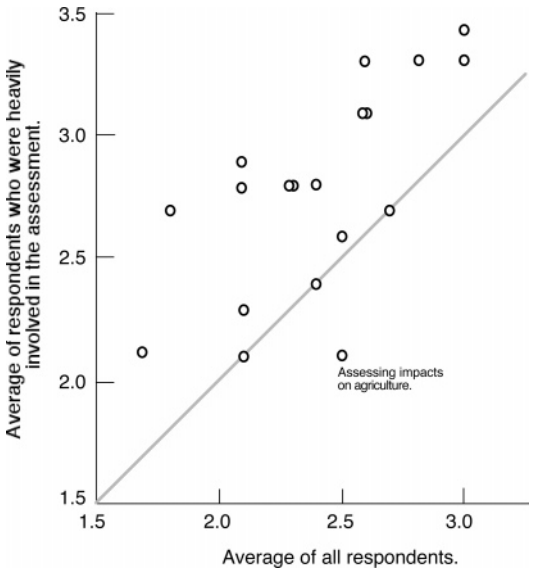

FIGURE 2. Survey respondents were asked to grade the assessment using standard letter grades (A−F) on 19 different dimensions. Heavily involved respondents, defined as those who participated in two of the major workshops *and* were involved in the production of one of the major reports, gave consistently higher grades on all dimensions except assessing impacts on agriculture. In this scatter plot, A = 4.0 and F = 0.

The budgetary and other restrictions imposed by the multiagency funding process resulted in a number of limitations in the current assessment that it would be desirable to avoid in the future. Whether future U.S. state or national political environments will make this possible is unclear. In the future, various public-private or fully private arrangements probably also warrant consideration, if they could achieve more appropriate allocation of resources and greater continuity.

In summary, despite a variety of difficulties, not the least of which was a contentious national and international political environment, the U.S. National Assessment of the Potential Consequences of Climate Variability and Change clearly demonstrated the value of distributed participatory assessment that involves experts, stakeholders, and other interested citizens. We hope that it will inspire many future efforts that build on the successes of this first undertaking, and on the many lessons that it provides.

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Supporting Information Available

An up-to-date list of regional and sectoral reports, a copy of the survey, and full quantitative and qualitative details on responses. This material is available free of charge via the Internet at http://pubs.acs.org.

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