Springer Climate

Katharine Jacobs
Susanne Moser
James Buizer *Editors*

The US National Climate Assessment

Innovations in Science and Engagement

Springer

Springer Climate

Series editor

John Dodson, Menai, Australia

Springer Climate is an interdisciplinary book series dedicated on all climate research. This includes climatology, climate change impacts, climate change management, climate change policy, regional climate, climate monitoring and modeling, palaeoclimatology etc. The series hosts high quality research monographs and edited volumes on Climate, and is crucial reading material for Researchers and students in the field, but also policy makers, and industries dealing with climatic issues. Springer Climate books are all peer-reviewed by specialists (see Editorial Advisory board). If you wish to submit a book project to this series, please contact your Publisher (elodie.tronche@springer.com).

More information about this series at http://www.springer.com/series/11741

Katharine Jacobs • Susanne Moser • James Buizer
Editors

The US National Climate Assessment

Innovations in Science and Engagement

Previously published in *Climatic Change* Volume 135,
Issue 1, 2016

Springer

Editors
Katharine Jacobs
Institute of the Environment
University of Arizona
Tucson, Arizona, USA

James Buizer
Institute of the Environment
University of Arizona
Tucson, Arizona, USA

Susanne Moser
Susanne Moser Research and Consulting
Santa Cruz, California, USA

ISSN 2352-0698 ISSN 2352-0701 (electronic)
Springer Climate
ISBN 978-3-319-41801-8 ISBN 978-3-319-41802-5 (eBook)
DOI 10.1007/978-3-319-41802-5

Library of Congress Control Number: 2016949492

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Contents

Climatic Change (2016) 135:1–7
DOI 10.1007/s10584-016-1621-5

The third US national climate assessment: innovations in science and engagement

Katharine L. Jacobs[1] · **James L. Buizer**[2] · **Susanne C. Moser**[3,4]

Received: 15 January 2016 / Accepted: 21 January 2016 / Published online: 10 February 2016

1 Introduction

Climate change poses numerous challenges for ecosystems, communities, businesses, and government agencies, and these challenges are becoming more visible across the globe. Over the last decade, conversations focused on documenting, anticipating, and preparing for climate risks have provided significant opportunities for interdisciplinary research and for transdisciplinary community building among scientists and practitioners. While some of these opportunities have become visible to contributors to large-scale, interdisciplinary assessments such as the periodic reports issued by the Intergovernmental Panel on Climate Change (IPCC) they are increasingly evident in national- or smaller-scale assessment efforts as have been conducted in the UK, Australia, Canada, the European Union, and in the United States (US).

The Third US National Climate Assessment (NCA3) report (https://nca2014.globalchange.gov) (Melillo et al. 2014) has garnered international attention due to multiple innovations in both process and products. This Special Issue brings together key lessons learned from the NCA3, not only to inform future US assessment efforts, but also to discuss frankly and share broadly what was done, how it was done, what worked and what did not. Our hope and intention behind pulling these lessons together is that those sponsoring, designing, and assisting in assessments at the regional, national and international levels can benefit from

This article is part of a special issue on "The National Climate Assessment: Innovations in Science and Engagement" edited by Katharine Jacobs, Susanne Moser, and James Buizer.

✉ Katharine L. Jacobs
jacobsk@email.arizona.edu

[1] Center for Climate Adaptation Science and Solutions, Soil, Water and Environmental Science, University of Arizona, Tucson, AZ, USA

[2] Climate Adaptation and International Development, Institute of the Environment, School of Natural Resources and the Environment, University of Arizona, Tucson, AZ, USA

[3] Susanne Moser Research & Consulting, Stanford University, Santa Cruz, CA, USA

[4] Woods Institute for the Environment, Stanford University, Palo Alto, CA, USA

this experience. Importantly, these articles do not summarize the findings of the NCA3 report itself, but move beyond them to provide insights about the assessment process and outcomes.

2 Background on US national climate assessments

Assessments can be useful at multiple scales, from resolving specific scientific issues to broadly integrating a wide range of sources of knowledge. Climate assessments often include consideration of underlying social, economic, and environmental systems as well as projections of trends in climate-related drivers in complex systems. However, in the case of US national assessments, they also serve as the basis for regulation, policy, and decisions about how to manage risks, which means that they must be conducted with extreme care in order to avoid costly errors.

The 1990 Global Change Research Act established the U.S. Global Change Research Program (USGCRP) and included a requirement that a global change assessment be completed at least every four years that integrates, evaluates, and assesses the state of knowledge of current and projected future impacts.[1] Despite the "at least every 4-years" requirement, only two National Climate Assessments[2] were conducted between 1990 and 2009. There are a variety of reasons why these reports were not completed in a more timely manner, but an important one is that a great deal of infrastructure and social capital is required to conduct assessments properly, given the need to engage stakeholders and external experts in order to meet legal requirements. The federal government does not have the capacity to assess current and projected climate impacts within all of the required sectors without the assistance of external participants. Nor would an assessment conducted entirely within the federal government be as readily acceptable or useful to stakeholders across the US. Importantly, USGCRP has not historically maintained a staff to support timely completion of assessment reports. Rather, new infrastructure and capacity for conducting assessments have been built up each time to support each of the three NCA efforts (for more detail, see Buizer et al. 2015, this issue).

Multiple other large-scale international assessments of research on the implications of global environmental changes have been conducted over the last decades, including the Arctic Assessment (Arctic Council 2005), the Millennium Ecosystem Assessment (2005), and the Ozone Assessments (World Meteorological Organization 2010). In 2007, the National Research Council issued a report that evaluated the lessons learned across this wide array of assessment activities. The findings of this report were highly influential in the development of

[1] Text of the GCRA (1990), **Section 106. SCIENTIFIC ASSESSMENT:** On a periodic basis (not less frequently than every 4 years), the Council, through the Committee, shall 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.

[2] Though the law refers to these assessments as global change assessments, the USGCRP has chosen to refer to them as National Climate Assessments. However, the context for them is clearly broader than climate.

the strategy for the NCA3; its recommendations were explicitly considered for its process and products and are reproduced in Textbox 1:

Textbox 1: Essential Elements of Effective Assessments

- A clear strategic framing of the assessment process, including a well-articulated mandate, realistic goals consistent with the needs of decision makers, and a detailed implementation plan.
- Adequate funding that is both commensurate with the mandate and effectively managed to ensure an efficient assessment process.
- A balance between the benefits of a particular assessment and the opportunity costs (e.g., commitments of time and effort) to the scientific community.
- A timeline consistent with assessment objectives, the state of the underlying knowledge base, the resources available, and the needs of decision makers.
- Engagement and commitment of interested and affected parties, with a transparent science-policy interface and effective communication throughout the process.
- Strong leadership and an organizational structure in which responsibilities are well articulated.
- Careful design of interdisciplinary efforts to ensure integration, with specific reference to the assessment's purpose, users' needs, and available resources.
- Realistic and credible treatment of uncertainties.
- An independent review process monitored by a balanced panel of review editors.
- Maximizing the benefits of the assessment by developing tools to support use of assessment results in decision making at differing geographic scales and decision levels.
- Use of a nested assessment approach, when appropriate, using analysis of large-scale trends and identification of priority issues as the context for focused, smaller-scale impacts and response assessments at the regional or local level.

Source: NRC (2007). *Analysis of Global Change Assessments: Lessons Learned* (http://books.nap.edu/catalog.php?record_id=11868)

NCA3 was explicitly designed to address some shortcomings of previous assessments as well as to benefit from the lessons learned in National Research Council studies, including the America's Climate Choices series (NRC 2010a, b, c, d, 2011). Some of the more salient criticisms of these previous assessments focused on the limited utility of the material produced for "real-world" contexts and the failure to truly connect with the American public. The NCA3 was also very much influenced by the Obama administration's strong focus on decision-relevance, transparency, and planning for resilience, and by the 2012 Strategic Plan of the US Global Change Research Program (USGCRP 2012). That plan included "Informing Decisions" "Sustain Assessments" and "Communicate and Educate" as pillars of the research program, in addition to "Advance Science;" the latter had traditionally been the primary focus of USGCRP's 13-agency science effort. This represented a major shift in policy toward "actionable" science in addition to fundamental climate science research conducted under the auspices of the USGCRP and established a firm foundation for the NCA3's engagement strategy (see, Cloyd et al. 2015, this issue).

Another criticism of previous climate assessments was the burden placed on the scientific community from major efforts, such as the every-six-year IPCC assessment reports and previous US national assessments. The thousands of scientists and other experts who contribute to IPCC and the NCA work as volunteers, with a number of important repercussions. This dependence on volunteers affects the potential pool of available participants and the enthusiasm of the people involved, because it means that many of the same people are tapped for these processes time after time (NRC 2007). The lack of funding and other support for

assessment activities continues to plague the NCA assessment process, and was a serious issue within the NCA3. The use of professional NCA staff to provide a much higher level of support for author teams in NCA3 successfully alleviated some (but certainly not all) concerns about the burden on authors. However, through a more strategic and sustained effort, the burden on the scientific community could be further reduced (Buizer et al. 2015, this issue).

3 Overview of contributions to this special issue

This special issue explores the NCA3 as compared with previous assessments from both process and content perspectives. Among the NCA3's important contributions are its emphasis on interdisciplinary learning and the introduction of an engagement strategy that brought hundreds of public and private sector contributors and stakeholders into the assessment community. The NCA3 also included an explicit focus on building sustained assessment capacity, an adaptive approach to managing assessments, and analyzing both the impacts of climate on cross-sectoral systems and the intertwined and cascading effects across sectors. Many new lessons were learned within these efforts and they are discussed in detail in this issue. The first set of articles in this issue describe these NCA3 innovations in some detail. *Building Community, Credibility and Knowledge: the Third US National Climate Assessment* (Jacobs and Buizer 2015, this issue), includes a broad discussion of the role of assessments in general and the NCA3 in particular in framing our understanding of change. The next two papers delve further into process innovations.

Building a Sustained Assessment Process (Buizer et al. 2015, this issue) discusses the rationale for building the infrastructure and capacity for ongoing assessment activities that support a wide range of research and application goals. It provides insights beyond those included in a special report on this topic that was delivered to the USGCRP by the federal advisory committee for the NCA3: *Preparing the Nation for Change: Building a Sustained National Climate Assessment Process* (Buizer et al. 2013).

Engagement in the Third U.S. National Climate Assessment, by Cloyd et al. (2015, this issue) describes both the motivation and the approach used in the NCA3 to build a broad assessment community of scientists, contributors, and stakeholders in regions and sectors across the U.S. Partly because of the broad interest by the public, private, and non-governmental sectors in the activities and conclusions of the assessment, and partly because of the high degree of scrutiny of the process, the entire NCA3 effort was built in the context of balancing the interests of multiple kinds of decision-makers, scientists, and government agencies. A key goal of these engagement efforts was to develop active partnerships that could bring relevant information to the assessment and communicate its findings to audiences and decision-makers across sectors and regions. The authors argue that these partnerships are an essential part of building a sustained assessment process. As many assessment leaders and observers have learned over the past two decades or more, in order for assessment findings to be truly useful from a decision-maker's perspective, the decision-makers themselves need to be part of the process.

The second set of papers focuses on innovations in the assessment process itself that were intended to build assessment capacity over time. To do so, considerable investments were made in producing consistent climate histories and future projections for each of eight US regions and a national set of sea-level-rise projections to allow for comparisons across the

nation and to integrate regions and sectors within a common "risk management" framework. Kunkel and colleagues, in their paper, *Innovations in Science and Scenarios for Assessment* (2015, this issue), describe the intent, process, and challenges in doing so. To make such climate histories and projections accessible for impact assessors as well as for downstream users of such information, a significant effort was undertaken during the NCA3 to invest in data management and accessibility, as described by Waple et al. (2016, this issue) in *Innovations in Information Management and Access for Assessments.* This article describes the ongoing efforts of the federal agencies to build a global change information system and to provide transparent access to the data behind each of the major conclusions of the NCA3. The third comprehensive investment in sustained assessment capacity by federal agencies was the development (still ongoing) of an integrated set of national indicators of change across social, physical, and ecological systems and of adaptive responses as described by Kenney and colleagues in *Building an Integrated National Climate Indicators System* (2016, this issue).

The NCA3 also stands out for its considerable effort to integrate across sectors, disciplines, practitioner perspectives and different forms of knowledge systems. Various illustrations of this approach to assessing risk and the status of adaptive responses are provided in the next three articles: first, assessing ecosystem impacts and services in *Climate Change Impacts on Ecosystems and Ecosystem Services in the United States* (Grimm et al. 2015, this issue); the implications of climate change on indigenous peoples and their lands and traditional cultural resources in *Engagement with Indigenous Peoples and Honoring Traditional Knowledge Systems* (Maldonado et al. 2015, this issue); and the integrated social, physical and ecological implications of climate change in coastal areas in *The Third National Climate Assessment's Coastal Chapter* (Moser and Davidson 2015, this issue). Each author team in this set pursued a different path to the goal of providing new insights on the complexities of climate change impacts in the "real world." The collective lessons learned are useful in putting together future assessment teams, designing and supporting assessments, and for connecting these assessments to adaptation processes both within the US and internationally.

Specifically on the question of how assessments should be framed to elevate their decision-relevance and increase their ability to support decisions, Moss (2015, this issue) describes in *Assessing Decision Support Systems and Levels of Confidence to Narrow the Climate Information "Usability Gap"* how important, and yet how difficult it was for NCA3 to improve on past approaches and conventions for assessing scientific confidence and uncertainty. The article makes a strong case for why sustained assessment capacity needs to be built, and why learning from ongoing decision-support efforts, successes, and failures, must be an integral part in improving assessments over time. The article also reviews challenges and approaches for characterizing uncertainties and communicating confidence of lead authors in findings based on the best available—but still incomplete—scientific evidence.

A critical reason for ongoing assessment of the state of knowledge is that both the climate and our understanding of the mechanisms of change are evolving. It is important to evaluate how assessments can support adaptation and adaptive management by taking the perspective of decision-makers who are working toward more resilient systems. In "*Innovations in Assessment and Adaptation,*" Howden and Jacobs (2015, this issue) explore different aspects of the adaptation process and their respective information needs, and suggest some paths forward in building future assessments that address particularly challenging aspects of adaptation.

Finally, the Liverman article (2015, this issue), *U.S. National Climate Assessment Gaps and Research Needs,* discusses critical areas for improving the underlying science foundation for

future assessments. The paper does not delineate the typical wish list of research needs from across all common climate science subfields. Rather, it brings into focus two particularly important gaps in knowledge that both limit the understanding of key future vulnerabilities of the US and could undermine adequate preparedness efforts. They are: (a) the need to identify and characterize international linkages that can either amplify or attenuate locally experienced climate risks, and (b) the significant lack of understanding of climate change impacts on the biggest sectors of the economy (such as manufacturing or service industries), as opposed to focusing only on some of the most climate-sensitive sectors (such as agriculture).

In the concluding paper for this special issue, *Aspirations and Common Tensions: Larger Lessons from the US National Climate Assessment,* Moser et al. (2015, this issue) synthesize high-level, integrative lessons from the NCA3, based on the more specific messages and recommendations outlined in each of the preceding papers. We hope these are of wider interest to future US assessment designers and participants and to the international assessment community. They focus on the key ingredients of assessments, including the process, the supporting institutional infrastructure and resource base, the scientific information and foundational data, as well as the people who carry out assessments. These reflections provide frank and detailed insights into the making of the NCA3. Clearly, many of its innovations were improvements over past approaches, building on the extensive national and international experience of its participants. But the NCA3 effort should be viewed as a benchmark and a learning experience to be further improved on in future assessments. The concluding paper points the way to further improvements and invites other assessment designers and leaders to share their experiences for collective learning.

Perhaps the most important message emanating from all the papers in this Special Issue, however, is the importance of not losing momentum in a national climate assessment process that is intended to be sustained, partly because climate risks are evolving so rapidly and partly because the concurrent information needs of users at all levels of government and beyond are also expanding over time. Our perspective is that ongoing assessment processes would be advisable elsewhere in the world as well, and thus it is important that this first "experiment" in building assessment capacity continues to make contributions to climate resilience both nationally and globally over time.

Acknowledgments The Guest Editors for this Special Issue are very grateful to the Editors of Climatic Change, Gary Yohe and Michael Oppenheimer, for their support during this process and for their particular interest in our subjects. We thank Kristin Kuntz-Duriseti and Simon Donner for working through each one of these articles with us and answering our endless questions. We are especially grateful for the help of Mary Black of the University of Arizona/Center for Climate Adaptation Science and Solutions for her expert editing support and to the reviewers for the hours spent providing thoughtful comments. Finally, but most importantly, we are so grateful to all of the authors of these papers, who generously shared their time and insights in developing this collection. Most of them were also intimately involved in the rigors of developing the Third National Climate Assessment, and we are glad that despite those adventures they were still willing to work with us on this Special Issue to harvest our collective lessons learned.

References

Arctic Council (2005) Arctic climate impact assessment—scientific report. Cambridge University Press, Cambridge, 1046 pp

Buizer J, Fleming P, Hays SL, Dow K, Field CB, Gustafson D, Luers A, Moss RH (2013) Preparing the nation for change: building a sustained National Climate Assessment process. National Climate Assessment and Development Committee, US Global Change Research Program.

Buizer JL, Dow K, Black ME, Jacobs KL, Waple A, Moss RH, Moser S, Luers A, Gustafson DI, Richmond TC, Hays SL, Field CB (2015) Building a sustained climate assessment process. Clim Chang. doi:10.1007/s10584-015-1501-4

Cloyd E, Moser SC, Maibach E, Maldonado J, Chen T (2015) Engagement in the third U.S. national climate assessment: commitment, capacity, and communication for impact. Clim Chang. doi:10.1007/s10584-015-1568-y

Grimm NB, Groffman P, Staudinger M, Tallis H (2015) Climate change impacts on ecosystems and ecosystem services in the United States: process and prospects for sustained assessment. Climatic Change. doi:10.1007/s10584-015-1547-3

Howden M, Jacobs K (2015) Innovations in assessment and adaptation: building on the US national climate assessment. Climatic Change. doi:10.1007/s10584-015-1519-7

Jacobs KL, Buizer JL (2015) Building community, credibility and knowledge: the third US national climate assessment. Clim Chang. doi:10.1007/s10584-015-1445-8

Kenney MA, Janetos AC, Lough G (2016) Building an integrated U.S. national climate indicators system. Clim Chang. doi:10.1007/s10584-016-1609-1

Kunkel KE, Moss R, Parris A (2015) Innovations in science and scenarios for assessment. Clim Chang. doi:10.1007/s10584-015-1494-z

Liverman D (2015) U.S. national climate assessment gaps and research needs: overview, the economy and the international context. Clim Chang. doi:10.1007/s10584-015-1464-5

Maldonado J, Bull Bennett TM, Chief K, Cochran P, Cozzetto K, Gough B, Hiza Redsteer M, Lynn K, Maynard N, Voggesser G (2015) Engagement with indigenous peoples and honoring traditional knowledge systems. Clim Chang. doi:10.1007/s10584-015-1535-7

Melillo JM, Richmond TC, Yohe GW (eds) (2014) Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program, 841 pp. (NCA 3 report) https://nca2014.globalchange.gov

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being. Island Press, Washington, DC

Moser SC, Davidson MA (2015) The third national climate assessment's coastal chapter: the making of an integrated assessment. Clim Chang. doi:10.1007/s10584-015-1512-1

Moser SC, Melillo JM, Jacobs KL, Moss RH, Buizer JL (2015) Aspirations and common tensions: larger lessons from the third US national climate assessment. Climatic Change. doi:10.1007/s10584-015-1530-z

Moss RH (2015) Assessing decision support systems and levels of confidence to narrow the climate information "usability gap". Clim Chang. doi:10.1007/s10584-015-1549-1

National Research Council (2007) Analysis of global change assessments: lessons learned. National Academies Press, Washington, D.C., 198 pp

National Research Council (2010a) America's climate choices: adapting the impacts of future climate change. National Academies Press, Washington, D.C., 292 pp

National Research Council (2010b) America's climate choices: advancing the science of climate change. National Academies Press, Washington, D.C., 528 pp

National Research Council (2010c) America's climate choices: informing an effective response to climate change. National Academies Press, Washington, D.C., 276 pp

National Research Council (2010d) America's climate choices: limiting the magnitude of future climate change. National Academies Press, Washington, D.C., 276 pp

National Research Council (2011) America's climate choices. National Academies Press, Washington, D.C

U.S. Global Change Research Program (2012) The National Global Change Research Plan 2012–2021: a strategic plan for the U.S. Global Change Research Program. USGCRP Report. http://data.globalchange.gov/assets/d0/67/6042585bce196769357e6501a78c/usgcrp-strategic-plan-2012.pdf

Waple AM, Champion SM, Kunkel KE, Tilmes C (2016) Innovations in information management and access for assessments. Clim Chang. doi:10.1007/s10584-015-1588-7

World Meteorological Organization (2010) Scientific assessment of ozone depletion. World Meteorological Organization, Global Ozone Research and Monitoring Project, Report no. 52. http://www.esrl.noaa.gov/csd/assessments/ozone/2010/report.htm

Climatic Change (2016) 135:9–22
DOI 10.1007/s10584-015-1445-8

Building community, credibility and knowledge: the third US National Climate Assessment

Katharine L. Jacobs[1] **· James L. Buizer**[1]

Received: 16 February 2015 / Accepted: 8 June 2015 / Published online: 11 July 2015

Abstract Assessments that are designed to be credible and useful in the eyes of potential users must rigorously evaluate the state of knowledge but also address the practical considerations—politics, economics, institutions, and procedures—that affect real-world decision processes. The Third US National Climate Assessment (NCA3) authors integrated a vast array of sources of scientific information to understand what natural, physical and social systems are most at risk from climate change. They were challenged to explore some of the potentially substantial sources of risk that occur at the intersections of social, economic, biological, and physical systems. In addition, they worked to build bridges to other ways of knowing and other sources of knowledge, including intuitive, traditional, cultural, and spiritual knowledge. For the NCA3, inclusion of a broad array of people with on-the-ground experience in various communities, sectors and regions helped in identifying issues of practical importance. The NCA3 was more than a climate assessment; it was also an experiment in testing theories of coproduction of knowledge. A deliberate focus on the assessment process as well as the products yielded important outcomes. For example, encouraging partnerships and engagement with existing networks increased learning and made the idea of a sustained assessment more realistic. The commitment to building an assessment focused on mutual learning, transparency, and engagement contributed to the credibility and legitimacy of the product, and the saliency of its contents.

1 Introduction: learning from assessments

Global change assessments by definition must incorporate both social and physical science and consider the potential implications of current and future sources of stress and opportunity

The authors are members of the development team for the Third National Climate Assessment, specifically, the Director (Jacobs) and a member of the Executive Secretariat (Buizer), and thus are not unbiased observers.

This article is part of a special issue on "The National Climate Assessment: Innovations in Science and Engagement" edited by Katharine Jacobs, Susanne Moser, and James Buizer.

✉ Katharine L. Jacobs
jacobsk@email.arizona.edu

[1] University of Arizona, Tucson, AZ, USA

(NRC 2007). The Third US National Climate Assessment (NCA3, Melillo et al. 2014) provided participants an opportunity for learning, not only about how to integrate a wide array of information, but also how to knit together different ways of knowing, and how to make assessments more relevant to decision-makers. This paper describes how this assessment—building on lessons from other US and international assessments—was designed, and the processes through which it was implemented. It delineates key elements of success and describes some challenges encountered by those involved, aiming to inform future assessment processes in the US and elsewhere.

Despite a vast array of available sources of scientific information, from satellite data and ocean observing systems, to information about human and ecosystem vulnerabilities, to social science and economics data, understanding what is most at risk from climate change is a daunting task. When these sources of data are integrated with knowledge held by on-the-ground resource managers, business executives, or policy-makers, and a range of geographic and time scales are represented, there is a virtual explosion of data sources, ways of understanding the world, and potential paths for analysis and interpretation. This challenged NCA3 authors to step outside of more familiar, traditional, and disciplinary approaches to explore some of the potentially substantial sources of risk that occur at the intersections of social, economic, biological, and physical systems. They also had to make difficult choices about which issues to emphasize, given the limits of a "manageable" final report. With initial instructions to most teams to condense their work into eight pages, only the most critical issues could be included, even if underlying foundation reports were hundreds or in some cases thousands of pages. This led to tradeoffs about perceptions of risk and personal values within each author team, and significant opportunities for learning in an interdisciplinary and transdisciplinary context.

Assessments that are designed to be credible and useful in the eyes of potential users must rigorously evaluate the state of knowledge but also address the practical considerations—politics, economics, institutions, and procedures—that affect real-world decision processes. In addition, they often must build bridges to other ways of knowing and other sources of knowledge, including intuitive, traditional, cultural, and spiritual knowledge. These need to be respected and incorporated if assessments are to be useful and meaningful to multiple audiences, including Native Americans and a range of other communities.

2 Background on the Third National Climate Assessment process

The National Climate Assessment responds to the 1990 Global Change Research Act (GCRA), Section 106, which requires that an assessment be prepared at least every 4 years that synthesizes, analyzes, evaluates, and assesses the knowledge developed within the US Global Change Research Program (USGCRP), but also identifies impacts across a series of sectors and projected timeframes. Only three such integrated assessments have been completed in the 24 years since 1990. The USGCRP, which was created by the GCRA, is a consortium of thirteen federal science agencies that is charged with coordinating and managing the substantial federal investments in climate science (https://globalchange.gov). Though these assessments are required every 4 years, only two previous assessments were completed (in 2000 and 2009), for a variety of reasons discussed elsewhere (see Buizer et al. 2013).

The first two National Climate Assessments focused primarily on summarizing outcomes of research and documenting the state of knowledge, generally focusing on a synthesis of

published, peer-reviewed literature. However, they varied significantly in the extent of stakeholder involvement. For a number of reasons (see Buizer et al. 2013) their outcomes were not as widely used as the authors had hoped. The NCA3 builds on these assessments, but also reflects a new sense of urgency from scientists, managers, and decision-makers across the country—based on growing evidence that climate change is no longer only an issue for the future, but a problem that requires action now. Because impacts are now observable in every region and sector across the country, the products and processes of this assessment were more explicitly designed to be useful in decision contexts. The increased visibility of impacts changed the tenor of the NCA3 conversation and encouraged a stronger focus on assessing response strategies than in previous assessments.

Individuals, communities and companies across the globe are now focusing on building a more resilient future. The terms they use, such as *sustainability, adaptation, resilience,* and *preparedness,* imply a wide variety of activities, but those working in these arenas have a great deal in common. They may work in their communities to reduce use of fossil fuels, promote health care for the urban poor, or manage invasive species in a wildlife refuge, but all are concerned about the health of the planet and of human and natural systems in the face of disruption and change. The NCA3 brought together people with diverse interests and expertise; some participants had engaged in previous assessments, others were specifically included to bring new capacity and new ideas into the process. A deliberate focus on community-building within the NCA3 allowed new relationships to be forged among those who otherwise might never have met. The investments in relationship-building within the assessment recognized the interdisciplinary nature of the scientific challenges, but was also intended help sustain the assessment process beyond the report and improve the relevance of the final products in connecting science to decision-making. Consequently, this assessment was "owned" by a much larger group of individuals because of the NCA network of partner organizations and the outreach efforts through NGOs and professional societies (Cloyd et al., Submitted for publication in this special issue).

3 Building the NCA3 process

Initial partners in the NCA3, especially federal agency representatives, staff in the US Global Change Research Program Coordination Office, and the NCA3 federal advisory committee, created a common mission and vision statement based on the perceived need to support decisions and be inclusive and useful to a broad audience of decision-makers and citizens across the US and the globe (USGCRP 2011). They quite consciously worked to create and test innovative and collaborative products and processes that would be useful and possible at this time in US history, recognizing the growing need for "actionable information" to support adaptation and mitigation.

Building the capacity for this type of assessment meant involving people who know how to remove the barriers between scientific disciplines and those who can build connections with user communities in regions and sectors that may use very different language and terminology. Facilitators, communicators, and "boundary spanners" (those who help connect scientists and scientific information with decision-makers and the public) (Guston 2001; Carr and Wilkinson 2005; Hoppe 2010; Lemos et al. 2012) were deliberately incorporated in the NCA3 process because of the need to bridge the gap between scientists and decision-makers in public and private organizations, government agencies, and businesses. The lessons learned over the last decade about the importance of managing the boundary between science and decision-making, e.g., in the context of the National Oceanographic and Atmospheric Administration's (NOAA)

Regional Integrated Science Assessments (RISAs), and many others were explicitly incorporated into the design of the NCA3. In that sense, the NCA3 can be viewed as a large-scale experiment designed to test theories about knowledge networks (Jacobs et al. 2010; Bidwell et al. 2013) and knowledge-to-action research.

The authors, federal advisory committee members, and staff of the NCA3 felt that building the interdisciplinary and regional capacity to *sustain* this effort would be critical to ensuring that its findings are useful in decision-making. Stakeholders who participated in NCA3 town halls across the country indicated that they were more likely to use the results of the NCA3 if they knew that they could count on the NCA process to produce rigorous and relevant information over time. From their perspective, relevance of the information produced was directly related to their own ability to access, understand, and contribute to the process. Similarly, the importance of building relationships among scientists and stakeholders during the assessment process was recognized as essential in ensuring credible outcomes that are also perceived as relevant and usable. More than a report based on peer-reviewed literature, the inclusive process itself was viewed from the beginning as an important outcome of the NCA3 effort.

4 The National Climate Assessment Development and Advisory Committee (NCADAC): lessons learned

In part because of the decision to make the NCA3 assessment more inclusive and transparent than previous national assessments, the federal advisory committee that took responsibility for producing the NCA3, the National Climate Assessment Development and Advisory Committee (NCADAC) was unusually large, including 44 non-federal participants and 16 federal agency ex-officio representatives. Establishing this committee took 18 months – far more than the original 6—month estimate. This significantly impacted the overall schedule for the assessment and reduced the time available to get the report done: rather than the 4 years allotted by statute to complete the assessment, the NCADAC essentially had only 2.5 years. These regulatory and political transaction costs need to be understood and factored into future assessment planning to minimize barriers to progress and optimize outputs and outcomes from ongoing assessment processes.

Although establishing the NCADAC caused a major delay in the report development, the time in the "holding pattern" was well spent. Because the advisory committee was not yet in place, no decisions could be made—so a series of methodology workshops were set up as "listening sessions" to help inform the process. These NCA methodology workshops (NCA report series, https://globalchange.gov) established a foundation of common knowledge among participants and built capacity for subsequent assessment activities. They gave the participants time to assess priorities, solidify goals and objectives of the NCA3 effort, build knowledge of assessment processes, and broaden the participant community so there could be a collective path forward. In fact, separate communities started to evolve around the workshop topics, including information management, communications, indicators of change, scenarios and modeling, vulnerability assessment, and valuation techniques. Most visible and active of these communities today is the group that focused on indicators; it has developed a broad vision and a pilot demonstration within USGCRP for social, physical, and environmental indicators of climate change (Kenney and Janetos, Submitted for publication in this special issue).

Based on its size, there were fears that the NCADAC would be unwieldy and expensive to support, but surprisingly few major problems arose. This was in part because of strong leadership, which included three experienced chairs and a 12-member Executive Secretariat. The latter

included individuals with significant experience in previous assessments who had a wide range of disciplinary, legal, and engagement expertise. Executive Secretariat input was solicited on all process and content issues prior to presentation of these ideas for review and decision by the broader committee. Inclusion of a range of people on the NCADAC who were process experts was another unusual aspect of this advisory committee that served the overall assessment extremely well. Because webinars and conference calls were frequently used instead of in-person meetings and the in-person meetings themselves could be generously characterized as "frugal," the costs of supporting the NCADAC were far lower than anticipated.

Another critical decision was to include the USGCRP agencies, the chair of the USGCRP, the White House Council on Environmental Quality (CEQ), and the Department of Homeland Security as full participants in the NCADAC, albeit as non-voting members.[1] Given that the full NCADAC agreed to make decisions by consensus rather than by vote, the limitation on voting by the 16 federal members was not as significant as it might otherwise have been. But having the federal agencies engaged as equal participants and encouraging them to make their scientific and other resources available to support the process was critical to achieving approval of the final document. Although they could not participate in the consensus decision to approve the final draft report, government scientists played important roles in providing scientific expertise on multiple topics and were active in author teams. This balance worked in favor of a more credible and defensible product. Without government input in the process of developing the draft NCA3 report, it is highly unlikely that a consensus could have been reached (or as easily reached) on the ultimate product. Without such a consensus, the document might not have been accepted and released as a government document.

5 Leadership

Not surprisingly, the NCA3 products and process reflected the values and experience of those who led it and of the 30 author teams[2] who were selected by the NCADAC. Running a process that had so much visibility and such high expectations can be a daunting task even with a small group of participants; the involvement of 60 people on the NCADAC and of hundreds to thousands more in authoring underlying documents raised the stakes substantially. As with both previous US assessments, navigating the scientific and policy issues that arose almost daily over a two-and-a-half-year period was a major challenge. The assignment was to develop an unassailable scientific document through a transparent and inclusive process while avoiding potential political pitfalls and practical irrelevance. Enlisting authors and reviewers who were as representative as possible of their respective expert or stakeholder communities and who had impeccable credentials was critical to the ultimate success of the endeavor. Balancing many different interests and scientific disciplines required a delicate hand and chapter authors who were willing to step outside of their comfort zone to experiment with new ways of learning and knowing.

[1] The Council on Environmental Quality provides oversight on regulatory and policy matters related to natural resources and the environment. It is parallel to the Office of Science and Technology Policy within the White House. The Department of Homeland Security—which includes the Federal Emergency Management Agency—did not exist at the time of the formation of the USGCRP in 1990, but is now very engaged in climate-related matters and chose to join the NCADAC as a non-USGCRP agency.

[2] Each chapter was led by two coordinating lead authors and typically had 6 additional authors, resulting in a total of approximately 240 primary plus ~60 contributing authors of the whole report.

The NCADAC was led by a trio of very experienced leaders. The chair, Dr. Jerry Melillo of the Marine Biological Laboratory at Woods Hole, co-led the two previous NCAs and has had a distinguished career as an ecologist spanning decades of work on climate-related topics. As an economist,, co-chair, Dr. Gary Yohe (Wesleyan University), provided important insight on costs and consequences of climate impacts, while also providing important linkages to the IPCC Fifth Assessment. Terese (T.C.) Richmond, the second co-chair and a natural resources lawyer from Seattle, represented stakeholder and private sector interests on the leadership team and worked to ensure that outcomes were useful for decision-makers. In many ways she took on the role of an ombudsman, ensuring that concerns of individual NCADAC members, authors, and staff were properly addressed.

Another element that contributed to meeting the strategic goals of the assessment was the willingness of the leadership to argue strongly for positions, yet compromise for the good of the process at the right moment. Given the ambitious expectations, there had to be trust among participants and an awareness that the collective outcome was more important than winning personal battles. Matching the capacity of the leadership to the nature of the challenge is important to the success of assessments, especially as the nature of these challenges changes over time.

The leadership also had to balance the ambitious goals of the NCADAC, author teams, and staff with what was actually "doable" from the perspective of the authors and the federal agencies. For example, NCADAC members suggested that each author team should have expert observers/assessment specialists who could assist with the consistent characterization of uncertainties, but this was not possible due to a lack of time and resources. Many decisions made during the assessment represented a compromise between an optimal approach and what was possible, balancing scheduling constraints with concerns about quality and accuracy.

6 Sources of knowledge

NCA3 took advantage of multiple sources of knowledge, ranging from traditional ecological knowledge of Indigenous Nations to the latest satellite technology. Recent advancements in understanding climate communication, public perceptions, and information systems were incorporated as well. Many participants noted the richness of the conversation that took place within author teams, due at least in part to the transdisciplinary nature of the assignment. Explicitly focusing on sources of risk and topics of greatest concern within regions and sectors, as opposed to starting with climate drivers, was very helpful in reframing conversations in ways that were more meaningful to decision-makers. A team of communication experts provided advice on a wide range of issues, not the least of which were how to explain complex issues simply and how to focus on communication outcomes that could reach a wide range of audiences. For example, there was an effort to make sure the graphics and associated captions painted a coherent picture that reinforced the text across the whole report, because many people learn visually or by examples rather than through reading text carefully.

A benefit of the large advisory committee was its topical diversity, providing the NCA3 with subject expertise and sources of information not only on climate science and regional and economic sector impacts but also other important topics and issues, such as decision support, adaptation, and mitigation. The wide range of strategies, participants, and contributors, along with the highly transparent approach to conducting this assessment, probably contributed to the overall credibility of the final report and its broad appeal across the US. Further, the strong emphasis on diversity on the NCADAC and the inclusivity of the engagement strategy may have contributed to the absence of legal challenges to date.

7 Documenting scientific findings and levels of certainty: traceable accounts

Another way to understand how different sources of knowledge were integrated into individual chapters of the NCA3 is through the traceable accounts, an NCA3 innovation designed to document the process that the authors used to reach their conclusions and describe their level of certainty. Authors were asked to go beyond standard referencing conventions that documented their scientific sources and describe how they selected the key issues, which literature they depended on most, and which scientific uncertainties are most important now and in the future. This highly transparent approach enhanced the clarity of the process and avoided heavy reliance on terms like "likely" and "virtually certain" used in the text of other assessments to characterize certainty in ways that most audiences either do not understand or interpret in widely different ways (Ekwurzel et al. 2011; Morgan et al. 2009). It will be interesting to see if subsequent assessment processes take advantage of this approach.

Inclusion of direct links to data used to support conclusions and to the references for each climate science graphic reinforced the robust nature of the report's conclusions. Documenting both the thought processes and the data used built the credibility of the NCA3 and provided information of interest to more sophisticated users. Though hard to evaluate, it would be good to know whether potential critics of the NCA3 process accessed the data and found it convincing. The transparent documentation avoided the accusation made in past assessments, however, that the science was a "black box."

8 Coproduction and assessment

The term "coproduction of knowledge" is useful in describing mutual learning between scientists and stakeholders (Lemos and Morehouse 2005; Mauser et al. 2013). The theory behind it—that if a scientific product is intended to be used by decision-makers, the decision-makers need to be involved in the problem definition, the discussion of solutions, and creation of the product—was definitely supported in the context of this assessment. A primary motivation for collaborative knowledge production in an applied context is to facilitate access to the facts for decision-makers and to help scientists understand how that information is used. Identifying what motivates stakeholders to feel ownership and see value in the information is a challenge, but one way to enhance both the perception and the reality of relevance to decision processes is to engage them in generating that information. Experience in NOAA RISAs (e.g., Dilling and Lemos 2011; Lemos et al. 2014; McNie 2008) has shown that scientists tend to be viewed as more legitimate sources of information if they actively engage in long-term relationships with stakeholders, build their own understanding of the tacit knowledge of practitioners, and come to be trusted by them.

The concept of coproduction as an approach to engagement was reinforced by experience in the NCA3 effort: the NCA3 report itself served as a convening point for conversations between stakeholders and scientists. They negotiated over which topics to cover, what the evidence was, and where the remaining uncertainties were. As a result, communities formed that can be the core of a sustained assessment process (Buizer et al. 2013). An example of the community-building effort was the facilitated engagement of author teams in sorting through multiple technical input documents and peer-reviewed literature in order to agree on chapter key messages and a process for writing the supporting material (e.g., Moser and Davidson, Submitted for publication in this special issue).