Review of the Draft Interagency Report on the Impacts of Climate Change on Human Health in the United States

DETAILS

78 pages | 8.5 x 11 | PAPERBACK | ISBN 978-0-309-37727-0

AUTHORS

Committee to Review the Draft Interagency Report on the Impacts of Climate Change on Human Health in the United States; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies; Board on Population Health and Public Health Practice; Institute of Medicine; The National Academies of Sciences, Engineering, and Medicine

Review of the Draft Interagency Report on the Impacts of Climate Change on Human Health in the United States

Committee to Review the Draft Interagency Report on the Impacts of Climate Change on Human Health in the United States

Board on Atmospheric Sciences and Climate
Division on Earth and Life Studies

Board on Population Health and Public Health Practice
Institute of Medicine

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

THE NATIONAL ACADEMIES PRESS • 500 Fifth Street, NW • Washington, DC 20001

This study was supported by the National Aeronautics and Space Administration under contract number NNH13CI84B, task NNH13CI96D. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-37727-0
International Standard Book Number-10: 0-309-37727-7

Additional copies of this report are available for sale from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Science, Engineering, and Medicine. 2015. *Review of the Draft Interagency Report on the Impacts of Climate Change on Human Health in the United States*. Washington, DC: National Academies Press.

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Ralph J. Cicerone is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. C. D. Mote, Jr., is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.national-academies.org.**

COMMITTEE TO REVIEW THE DRAFT INTERAGENCY REPORT ON THE IMPACTS OF CLIMATE CHANGE ON HUMAN HEALTH IN THE UNITED STATES

DANIEL S. GREENBAUM (*Chair*), Health Effects Institute
HEIDI E. BROWN, University of Arizona
PETER DASZAK, EcoHealth Alliance
LINDA A. MCCAULEY, Emory University
SABRINA MCCORMICK, George Washington University
CHRISTOPHER J. PORTIER, Environmental Defense Fund
ARTHUR L. REINGOLD, University of California, Berkeley
ARMISTEAD G. RUSSELL, Georgia Institute of Technology
M. CRISTINA TIRADO, University of California, Los Angeles
BENJAMIN ZAITCHIK, Johns Hopkins University

National Academies of Sciences, Engineering, and Medicine Staff:
LAUREN EVERETT, Associate Program Officer
SHELLY FREELAND, Administrative and Financial Assistant
MICHAEL HUDSON, Program Assistant
ROB GREENWAY, Program Associate

BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE

BOARD ON POPULATION HEALTH AND PUBLIC HEALTH PRACTICE

ELLEN W. CLAYTON (*Chair*), Vanderbilt University
HORTENSIA D. AMARO, University of Southern California
JULIA A. BALDWIN, University of South Florida
SHEILA P. BURKE, John F. Kennedy School of Government, Harvard University
BRUCE N. CALONGE, The Colorado Trust
SUSAN J. CURRY, The University of Iowa
CARLOS DEL RIO, Emory University
SUSAN DENTZER, Robert Wood Johnson Foundation
GARTH N. GRAHAM, Aetna Foundation
KENNETH W. KIZER, University of California, Davis
GRACE M. LEE, Harvard Pilgrim Health Care Institute
HOWARD MARKEL, University of Michigan Medical School
RICARDO MARTINEZ, North Highland Worldwide
LINDA A. MCCAULEY, Emory University
DANIEL POLSKY, University of Pennsylvania
JOHN A. RICH, Drexel University School of Public Health
JOSHUA M. SHARFSTEIN, Johns Hopkins Bloomberg School of Public Health
STEVEN M. TEUTSCH, Independent Consultant
JAMES N. WEINSTEIN, Dartmouth-Hitchcock Medical Center
WINSTON F. WONG, Kaiser Permanente
WILLIAM A. YASNOFF, National Health Information Infrastructure Advisor

National Academies of Sciences, Engineering, and Medicine Staff
ROSE MARIE MARTINEZ, Director
KATHLEEN STRATTON, Scholar
KAREN ANDERSON, Senior Program Officer
ALINA BACIU, Senior Program Officer
KAREN HELSING, Senior Program Officer
LYLA HERNANDEZ, Senior Program Officer
AMY GELLER, Program Officer
GURU MADHAVAN, Program Officer
MELISSA FRENCH, Associate Program Officer
LESLIE KWAN, Research Associate
ANDREW LEMERISE, Research Associate
ALEJANDRA MARTIN, Research Associate
ERIN RUSCH, Research Associate
KINPRITMA SANGHA, Research Associate
TINA RITTER, Research Assistant
HOPE HARE, Administrative Assistant
COLIN F. FINK, Senior Program Assistant
ANGELA MARTIN, Senior Program Assistant
ANNA MARTIN, Senior Program Assistant
EMILY VOLLBRECHT, Senior Program Assistant

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies of Sciences, Engineering, and Medicine's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in their review of this report:

Nils Daulaire, Norwegian Institute of Public Health, Oslo
Dennis Devlin, Exxon Mobil Corporation, Irving, TX
Maria Duik-Wasser, Columbia University, New York, NY
Inez Y. Fung, University of California, Berkeley
Richard C. Flagan, California Institute of Technology, Pasadena
Elizabeth Martin Perera, Sierra Club, Washington, DC
S.T. Rao, North Carolina State University, Raleigh
Connie Roser-Renouf, George Mason University, Fairfax, VA

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions nor did they see the final draft of the report before its release. The review of this report was overseen by **Lynn R. Goldman**, George Washington University, Washington, DC, appointed by the Report Review Committee, and **Robert F. Sawyer**, University of California, Berkeley, appointed by the Division on Earth and Life Studies, who were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Summary

The U.S. National Climate Assessment (NCA; Melillo et al., 2014) identified a number of ways in which climate change is affecting or is likely to affect, people, infrastructure, natural resources, and ecosystems. Those impacts in turn have the potential for important current and future consequences for human health. Research on these impacts is active, with strong evidence to support some aspects and research still in progress for others. Therefore, there is a need to assess our understanding of how the impacts of climate change on the environment can create stressors that can affect human health in a number of dimensions both now and in the future.

In response to this need, the U.S. Global Change Research Program (USGCRP) has initiated an interagency Assessment on the Impacts of Climate Change on Human Health in the United States. The Assessment is intended to inform public health authorities, other planning and policy entities, and the general public. It extends the work begun under the 2008 Synthesis and Assessment Product 4.6 (USGCRP, 2008) *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems* and the third NCA released in 2014.

The National Academies of Sciences, Engineering, and Medicine have been asked to conduct an independent review of the Draft Assessment and to address the following questions (see Appendix B):

- Does the report meet its stated goals?
- Is the report responsive to the nation's needs for information on the health impacts of climate change and their potential implications?
- Does the report accurately reflect the scientific literature? Are there any critical content areas missing from the report?
- Are the approaches to quantitative modeling reasonable and adequately supported by existing literature?
- Are the findings documented in a consistent, transparent, and credible way?
- Are the report's key messages and graphics clear and appropriate? Specifically, do they reflect supporting evidence, include an assessment of likelihood, and communicate effectively?
- Are the research needs identified in the report appropriate?

A Committee was convened to conduct the review, and this document contains an evaluation presented in answers to the Statement of Task questions, individual chapter reviews, and detailed comments compiled in Appendix A. The Committee was impressed by the tremendous amount of work undertaken to develop such an extensive scientific assessment and suggests ways to improve the document to ensure that the Assessment is responsive to the nation's needs for information on the possible health impacts of climate change and that the key messages reach a broad audience.

The Committee offers a number of overarching suggestions (in response to its Statement

of Task) on how the report authors can enhance their identification and assessment of the science and better communicate their conclusions to all of their target audiences. For example, the Committee suggests the need to:

- Clearly outline the selection process and criteria used to choose the health outcomes and literature discussed within the chapters;
- Clarify the criteria used to judge likelihood and confidence statements and consider disaggregating confidence determinations in key findings to better reflect the diversity of the evidence;
- Reorganize some key findings to improve clarity and to highlight the evidence of health impacts of climate change first and foremost;
- Enhance the discussions of vulnerability from the earliest stages of the Assessment and review the discussion of vulnerability throughout the chapters for consistency;
- Consistently discuss adaptive behavior in the context of each chapter and describe, to the extent that there is literature available, potential adaptive behaviors and interventions that could moderate the health impacts;
- Provide methods for all featured modeling results, including uncertainties and information on accessing the underlying data;
- Consider reordering the chapters to minimize overlap and to enhance opportunities for linkages between related issues;
- Enhance the overarching graphic (Figure ES-1 and similar figures) to effectively portray the key concepts and ensure uniformity of the message; and
- Consistently identify the most important research needs within each chapter.

The Committee appreciates the opportunity to comment on this important work and notes that, with attention to the suggested enhancements, this Assessment will clearly play a significant role in continued efforts to examine and explore the impacts of climate change on human health.

Introduction

The US Global Change Research Program (USGCRP), under the leadership of its Interagency Crosscutting Group on Climate Change and Human Health (CCHHG) and a subset of the Interagency National Climate Assessment (INCA) Task Force, has initiated an interagency Assessment on the Impacts of Climate Change on Human Health in the United States. The Assessment is intended to inform public health authorities, other planning and policy entities, and the general public. It has been featured in the President's Climate Action Plan and is designated as a Highly Influential Scientific Assessment (HISA) under Office of Management and Budget (OMB) peer review guidelines.

The Assessment extends the work begun under the 2008 Synthesis and Assessment Product 4.6 *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems* (USGCRP, 2008) and the third National Climate Assessment (NCA) released in May 2014. The Assessment is considered an interim product of the NCA. The Assessment is mostly comprised of a review of published literature, but also includes new quantitative analyses in four chapters.

The National Academies of Sciences, Engineering, and Medicine were asked to conduct an independent review of the Assessment. The Academies and the Board on Atmospheric Sciences and Climate (BASC) have a history of providing guidance to the USGCRP and the NCA process. Under the auspices of the Committee to Advise the USGCRP, a number of meetings and activities were held in recent years to provide ongoing advice, including a review of the draft NCA document in 2013.

A Committee was convened in March 2015 to conduct a review of the Draft USGCRP Climate and Health Assessment. The Committee is composed of members with expertise in key areas of relevance to the Draft Assessment. The Institute of Medicine's Board on Population Health and Public Health Practice also provided valuable input throughout the study process.

This Committee was specifically asked to consider the following questions (see Appendix B):

- Does the report meet its stated goals?
- Is the report responsive to the nation's needs for information on the health impacts of climate change and their potential implications?
- Does the report accurately reflect the scientific literature? Are there any critical content areas missing from the report?
- Are the approaches to quantitative modeling reasonable and adequately supported by existing literature?
- Are the findings documented in a consistent, transparent, and credible way?
- Are the report's key messages and graphics clear and appropriate? Specifically, do they reflect supporting evidence, include an assessment of likelihood, and communicate effectively?

- Are the research needs identified in the report appropriate?

Committee members had the opportunity to interact with the Assessment authors and steering committee during WebEx discussions held on March 20 and April 20, 2015. The Committee also held one in-person meeting on May 8-9, 2015 in Washington, DC and conducted additional discussions via phone, email, and WebEx to develop consensus answers to the Statement of Task Questions. The Committee formed small teams of members with relevant expertise to review the individual Assessment chapters and discussed their reviews with the group as a whole. The Committee's review was conducted at the same time as the Assessment's public comment period.

The Committee commends the USGCRP and report authors on their Draft Assessment and acknowledges the remarkable amount of time and preparation necessary to assemble a document of this scope. Consensus answers to the Statement of Task questions and reviews of the individual chapters—primarily focused on the key findings—are presented in this report. Appendix A includes more detailed comments sorted by Assessment Chapter. The Committee hopes that this report will help the report authors meet their goals for the Draft Assessment.

Answers to the Statement of Task Questions

The U.S. National Climate Assessment (NCA; Melillo et al., 2014) identified a number of ways in which climate change is affecting or is likely to affect people, infrastructure, natural resources, and ecosystems. Those impacts in turn have the potential for important current and future consequences for human health. Research on these impacts is active, with strong evidence to support some aspects and research still in progress for others. Therefore, there is a need to assess our understanding of how the impacts of climate change on the environment can create stressors that can affect human health in a number of dimensions both now and in the future.

Does the report accurately reflect the scientific literature? Are there any critical content areas missing from the report?

Throughout the Draft Assessment the authors have done a commendable job of identifying key components of and evaluating the scientific literature. The Committee identified some additional specific health impacts that could be included (detailed under the specific chapters below). The Committee also found that there were several areas where the consideration of the science could be enhanced.

The Committee has a primary concern with the authors' selection of which aspects of potential climate change impacts on human health are included in the Draft Assessment. The process of selecting the specific health outcomes and case studies that were included in each chapter (for example, Lyme disease and West Nile virus in Chapter 4 and non-cholera Vibrios and toxic algae in Chapter 5) is not clear. In preparing a report such as this one, for which there are many health outcomes that could be considered, it is reasonable that only a subset of the possible health outcomes are highlighted. For both transparency and scientific rigor, and given that the scholarship is still evolving, the rationale behind the decisions about topics to be included should be described in greater detail. Without clear explanation of this rationale, it is difficult to determine whether topics are excluded because the literature is incomplete or because the impacts have been studied and have been found to be insignificant. If the same procedures were used in all of the chapters to review the available literature and determine which aspects to include, they should be described in Chapter 1. In addition, the Committee suggests a list of references used in the report be developed and provided as an appendix to this document, if possible.

The Committee further suggests that additional details should be provided on the system and criteria by which the authors chose what literature they reviewed from amongst the broader literature:

- Did they attempt to systematically identify all relevant literature?
- Were there explicit criteria for each set of chapter authors to make those choices?
- Can the report provide a clearer explanation of how these choices were made?

A second major concern the Committee identified was the inconsistent treatment of adaptive behavior throughout the document. Adaptive behavior by individuals and communities,

including attention to forecasts of extreme weather and air quality conditions, is an important potential mitigating factor in the assessment of human health impacts from climate change. That importance is described and discussed in detail in some chapters, e.g., Chapter 2 Extreme Heat, and the discussion of infrastructure in Chapters 5 and 7, but not discussed consistently across the chapters.

Although the Draft Assessment is clearly not intended to make policy recommendations for adaptation, it is designed to provide stakeholders with "updated information on the observed and projected impacts of climate change on human health and changes in risk to health" that "may help inform adaptation decisions in the public health arena" (79 FR 7419 [February 7, 2014]). The authors should review each chapter to ensure that they consistently discuss adaptive behavior in the context of that impact and describe, to the extent that there is available literature, potential adaptive behaviors and interventions that could moderate the health impacts. Authors could also consider building on Key Messages 3 and 4 from the 2014 NCA report. These Key Messages discuss how preparedness and prevention can help protect people from some climate change impacts (Key Message 3) as well as some potential co-benefits from responding to climate change in ways that can have positive outcomes for human health (Key Message 4). Additional consideration and discussion of these important findings would strengthen the Draft Assessment.

One further concern noted by the Committee was that, in general, the authors' assessment of the literature on how climate change can alter environmental stressors is stronger than their assessment of the relationships of the stressors to human disease. The relative strength of their health assessments varies with the chapters; the Committee comments on individual chapters highlight those areas where the authors' assessment of health impacts could be enhanced.

Are the approaches to quantitative modeling reasonable and adequately supported by existing literature?

The Committee reviewed all of the major quantitative analyses conducted or commissioned by the authors. Overall, the Committee found that these analyses were well done, that they were generally placed in the context of the broader quantitative literature where appropriate, and that they made valuable contributions to the literature and the Draft Assessment.

The Committee did have specific comments on several of the analyses which are summarized below and described in more detail in the chapter specific comments. The heat and air quality modeling (Chapters 2 and 3) were particularly useful, especially the analyses which factored in planned ozone precursor reductions to better understand likely climate-related impacts. The water and disease modeling was also well done, but the Committee suggests that the strength of the evidence would be enhanced if all of the underlying, publicly-created data were made available to other analysts to further explore, perhaps in a central archive that could be accessed by members of the scientific community (something which has not been made possible to date).

As a general point, methods for all featured modeling results, including a discussion of uncertainties related to modeling approach and information on how to access underlying data, should be provided either within the appropriate chapter or in the Technical Support Document (Appendix 1 of the Draft Assessment). At this stage, the Technical Support Document has only

general discussions of these issues.

Are the findings documented in a consistent, transparent, and credible way?

The Committee was impressed by the authors' efforts to maintain a consistent approach to evaluating the evidence across a wide range of authors, agencies, and research organizations. This is no small task, and the organizers and leaders of the effort are to be praised for their efforts to maintain consistency of thinking and approach across the entire document. Having said that, the Committee found that there are several critical areas where the Draft Assessment can be enhanced:

- *The assessment of likelihood and confidence:* Although there is an effort to apply a consistent set of decision tools to assess the quality and strength of the evidence, the description (two sentences in Chapter 1) of the criteria being used to judge the likelihood and the confidence in effects that are described in this report is very limited. In addition, even though it is referenced in Chapter 1 as providing additional detail on the approaches used, the Technical Support Document provides only a general discussion of the sources of uncertainty without any additional details on how specifically that uncertainty should be applied to reaching likelihood and confidence judgments. Nor are there references to similar approaches that have been used in other settings to provide insight into the approaches used here. Report authors could consider including numerical information on the range of uncertainty, together with likelihood statements, in an effort to reduce any errors in interpretations (see Budescu et al., 2009).

  It is also unclear how these criteria for likelihood and confidence were applied in each chapter. The role played by each author in reaching these conclusions and the consistency of their applications across the multiple chapters is an important consideration here. In addition, there seems to be a disconnect in some of the chapters between the Key Findings and the text of the chapter in which "medium" findings are aggregates of findings that may be "high," "medium," and "low". There may be opportunity to disaggregate confidence determinations in key findings sentences to clarify the likelihood and confidence of sub-findings.

- *The description of likelihood and confidence:* In addition to the issues about the criteria and their application, throughout the document there is inconsistency in how the likelihood and confidence statements are communicated in the chapters. The basic formula for quantifying health impacts (top of page 35) has two critical elements for which the quality of the science and the strength of the evidence must be evaluated: expected change in exposure and the exposure-dose-response relationship. In some chapters, these individual parts are rated and presented with individual confidence/likelihood statements, whereas others provide only a single evaluation. The Committee suggests providing statements for the confidence or likelihood of each aspect of the evaluation as a way to provide greater clarity and to enable a better understanding of the overall evaluation.

  Further, there are a wide range of descriptors applied throughout the document (e.g., "will," "may," "could," "tends to," "are likely to,") to describe summary evaluations. Given that all statements of impact are accompanied by a statement of

confidence/likelihood, the Committee would suggest that the standard form throughout should be, for example, "climate change will increase" (or "is increasing" in the case of current documented effects) followed by an appropriate statement of likelihood and/or confidence.

- *The focus of this report is the health impacts of climate change*. To improve clarity, the authors should strive to describe key findings by starting with the evidence of health impact (e.g., "Climate change will increase the frequency/prevalence/other of disease X [Confidence]. Changes in environmental stressor Y will result from climate change impact Z [Confidence]. Environmental stressor Y impacts the frequency/prevalence/other of disease X [Confidence]. Key issues that have an impact on the degree to which this stressor can impact human health include . . . Vulnerable populations include A, B, C . . ." This is the structure in some chapters (e.g., Chapter 2) but not consistently throughout.

- *The order and linkages between the chapters:* There is no guidance for the reader on how the various topics were assigned to the various chapters. Given that many aspects of health and climate change can overlap, a clear early description of what is in each chapter would be advantageous to the reader. While the Committee understands the challenges of inevitable overlap and has made its chapter-specific comments below in the order that they appeared in the Draft Assessment, the Committee encourages the authors to consider a revised ordering of chapters to enhance linkages, where possible, between related issues: Temperature-Related Death and Illness; Extreme Weather; Air Quality Impacts; Vectorborne Diseases; Water-Related Illnesses; Food Safety, Nutrition, and Distribution; Mental Health and Well-Being; and Climate-Health Risk Factors and Populations of Concern (potentially renamed simply "Populations of Concern" as noted below).

  After reorganization, the authors should consider reviewing all of the chapters with the goal to improve the linkages between the chapters (e.g., making clearer the linkages between water, shellfish contamination, and food safety) and confirm that topics are dealt with as consistently as possible.

- *The Treatment of Vulnerability:* the authors made a useful and correct decision both to identify vulnerable populations in each chapter and to dedicate an entire chapter at the end to summarizing those populations and vulnerabilities. There are, however, inconsistencies in how populations of concern are identified and described in each chapter. To improve the document, the Committee suggests that the definition of vulnerability be moved to Chapter 1 and that the authors carefully review whether the discussions of vulnerability in the individual chapters are consistent with that definition and the more detailed discussion in Chapter 9.

  The Committee thought highly of the organization of Chapter 9 by type of vulnerable population, but would consider renaming it to simply "Populations of Concern" to better communicate the importance of the Chapter to broader audiences. Also, within Chapter 9, populations of color, immigrant populations, and non-English speaking populations are lumped together. The text describes in more detail specific aspects of their vulnerability, but there is considerable overlap among the groups in other aspects of vulnerability like socioeconomic status (SES) and level of English proficiency (LEP); it would be helpful to add detail further distinguishing those cases where race/ethnicity in and of itself may add vulnerability rather than being a surrogate for SES, LEP, or some other vulnerability.

Are the report's key messages and graphics clear and appropriate? Specifically, do they reflect supporting evidence, include an assessment of likelihood, and communicate effectively?

While we find little disagreement with the actual findings of the Assessment, we feel that both the key messages and the graphics could be enhanced.

- As noted above, each of the findings should be reviewed and reordered to describe the health related outcome(s) first wherever possible. Also, the Executive Summary opening pages could be enhanced by adding highlighted summary bullets of the major health impacts for which there is the highest likelihood and/or highest confidence, of both current and future effects. The rest of the Summary could then portray in concise fashion each of the specific findings (with perhaps shorter introductions).
- The Committee found that graphics, maps and graphs, which portrayed the evidence of actual or expected change in health effects (e.g., the ozone maps), were the most informative. Descriptive graphics intended to provide a roadmap from climate to health (e.g., Farm to Table in Chapter 6) seemed attractive for a broader public but do not appear to be the most effective way of communicating to the target audiences described in the Federal Register Notice (79 FR 7419 [February 7, 2014]) (i.e., public health officials, urban planners, decision makers, and other stakeholders). These descriptive graphics should be included in separate graphic material made available with the report to be used in communications with the public and others.
- The Overarching Graphic (Figure ES-1 and similar figures) needs work to ensure that the message is adequately conveyed to the desired audiences. It may be useful to have a simpler version (without the bulleted points) as the initial graphic to portray the key concepts being put forward. In addition, what are intended to be arrows linking the side compartments ("Social Determinants" and "Non-Climate Stressors") are too subtle to be obvious and should be reconsidered. Also, the title "Non-Climate Stressors" is somewhat misleading as these are environmental stressors that can exacerbate the impacts of climate drivers on environmental degradation. Finally, some of the chapters have modified this figure to use different headings and slightly different concepts; if the goal of using a single graphic across multiple chapters is intended to make the impacts easier to understand, the uniformity of the message should be carefully reviewed.

Are the research needs identified in the report appropriate?

Although identification of research gaps or a research strategy is not a principal goal of the Draft Assessment, it is evident throughout the document that there are important needs for continuing monitoring and research. The sections on "Emerging Issues" and "Research Needs" identify a number of such areas needing additional monitoring and research. However, the sections are quite inconsistent throughout with variation among the chapters in the relative significance and importance of the needs. The Committee would suggest that the authors do a more consistent job of identifying the most important continuing needs in each chapter, and the Committee provides specific suggestions in the reviews of Chapters 3, 4, 5, and 6. More consistent descriptions of research needs would make it possible for USGCRP and member

agencies to follow up with an integrated research strategy.

The Committee also notes that, given the continuing uncertainties identified in each section of the Assessment, and in many cases the paucity of data for reducing those uncertainties, the Assessment could make an overarching recommendation for enhanced monitoring of exposure pathways and health effects as climate change proceeds. New tools and technologies for such monitoring are being developed at a rapid pace and could be brought to bear on informing future decisions on adaptation and mitigation.

Does the report meet its stated goals? Is the report responsive to the nation's needs for information on the health impacts of climate change and their potential implications?

The Interagency Task Force has compiled a very good first summary and analysis of a range of potential human health effects that are being linked to or could be caused in the future by climate change. In doing that, they have sought to meet the objectives stated in the Federal Register (79 FR 7418 [February 7, 2014]):

> "The Special Report will be an evidence-based, quantitative assessment of observed and projected climate change impacts on human health in the United States. Development of the report will leverage existing activities of the CCHHG and INCA members, aggregate and assess current quantitative research on human health impacts of climate change, and summarize the current state of the science…using modeling and analysis tools to quantify, where possible, projected national-scale impacts of climate change to human health. Such analyses will attempt to identify and bound impact uncertainties, as well as better define changes in attributable epidemiological risks, particularly for vulnerable populations, with the goal of informing public health authorities and other public planning and resource management entities."

The authors have evaluated a wide range of literature and commissioned and/or taken advantage of significant new quantitative efforts to estimate the likely future impact of climate change on both environmental stressors and human health. Despite their considerable efforts, however, the Draft Assessment does not fully meet the goals as outlined in the Federal Register, and the Committee offers a number of overarching suggestions (noted above in response to its Statement of Task) on how the authors can enhance their identification and assessment of the science and better communicate the conclusions to all of their target audiences. The Committee also offers specific comments on the individual chapters in the following sections and more detailed comments and suggested edits in Appendix A. We trust that in responding to these comments and suggestions that the authors can significantly enhance their final report and meet, if not exceed, their goals and the nation's needs.

Chapter Reviews

The Committee formed small teams to review the Assessment chapters in depth. The teams focused primarily on the Key Findings, but they also provide additional suggestions for chapter authors where appropriate. Detailed, line-by-line edits are compiled in Appendix A.

CHAPTER 1
CLIMATE CHANGE AND HUMAN HEALTH

General Comments

The stated goals of this first chapter are to: (1) provide background information on climate change in the United States and, how through environmental and other stressors, this can affect human health; (2) provide an overview of approaches and methods used in the quantitative projections. There are no key findings for this chapter.

Generally, the chapter addresses the issues related to Goal 1 very well. The text is informative and written in a way that will be easily understandable by people from a range of backgrounds and experience. The chapter does an adequate job of summarizing climate change and how this relates to human health. In addition, much of the language and vocabulary that is needed in the later chapters is introduced. The definition of climate change provided on page 26, lines 2-4 is succinct and clearly defines the relevant issues that are being considered in this report.

For Goal 2, the overview is also adequate, although it contains very little detail or reference to other chapters. Most notably, while the general model used (top of page 35) is given and the models for the expected change in exposure are very well described, models of background rates for health impacts and exposure-dose-response relationships are not; they are often treated as general knowledge. Limited references are given for the nature of a relationship and very little detail is provided on how these data were reviewed to provide the relationships that appear in the later chapters (as noted previously in the "Answers to the Statement of Task Questions").

Overarching Comments

- *Missing components:* As noted in Answers to the Statement of Task Questions, Chapter 1 needs better explanations of the system(s) used to identify and select relevant literature for the Assessment and of the definition and application of criteria for likelihood and confidence. The definition of vulnerability should be moved here from Chapter 9. Further, Chapter 1 notes that the approach to quantifying uncertainty is addressed in more detail in the Technical Support Document. That document provides sources of uncertainty but does not have details on the methods used to quantify uncertainty. It is

important to provide this information in a way that can be easily understood by decision-makers and the general public.

- *The Changing Climate:* This section has done a good job of introducing the concepts associated with climate change (what is climate, how is it changing, how we know this, etc.). This section is a high level overview, and while the cited references tend to focus on IPCC, USGCRP, and EPA, it may also be useful to consider literature reviews and consensus reports beyond these organizations.
- *Human Health:* This is a very strong section and critical to the remaining document. It needs to be better referenced to clearly demonstrate those aspects that are supported by a depth of knowledge and where there are remaining uncertainties, especially concerning the evidence of health effects from current warming. Statements like "weather and climate affect the survival and movements of mosquitoes, ticks, and rodents that carry diseases like West Nile or Lyme disease" (page 27, lines 24-25) and "Some major indicators of health, such as life expectancy, are consistently improving, while others, such as obesity and diabetes, are getting worse" (page 30, lines 20-22) need to be appropriately supported by scientific references. There are numerous examples of lapses in oversight regarding literature both here and in the later chapters, including discussion of known or suspected relationships and trends with regard to health (e.g., toxic algal plumes and health, pollen and asthma) that fail to cite references. Finally, the trends in human health and the demographic shifts in the US population are nicely linked into concerns about climate and health.
- *Mortality, Morbidity, Early Death—Prevalence and Incidence:* The chapter shares a great deal of information with the audience regarding health, health trends, and climate change. While the concepts of incidence versus prevalence are widely used in the scientific literature to discuss these issues, the authors here have tried to use simpler language to present their case. However, rather than provide greater clarity, this leads to greater confusion and the authors are encouraged to use a more traditional language with definitions provided in this chapter. Also, mortality, morbidity, and reduced life expectancy are not carefully explained and the complexities involved in reaching sound conclusions regarding climate change and any of these endpoints are not clear to the reader.

CHAPTER 2

TEMPERATURE-RELATED DEATH AND ILLNESS

General Comments and Key Findings

Chapter 2 addresses the increases in both average and extreme temperatures and the potential contributions to death and illness, as well as implications of prolonged exposure to high temperature. The authors of this chapter have generally done a thoughtful and careful job of reviewing the major literature in this important area and capturing the key findings that can be drawn from this literature. The new modeling they cite (i.e., Schwartz et al., 2014) is well done and comprehensive and consistent with the series of other studies they have reviewed. At the

same time the authors have acknowledged and described the major uncertainties, and in general they have justified their judgments of the likelihood of and confidence in each finding. However, there are several ways in which the communication of the key findings can be improved.

Key Finding 1: Future Increases in Temperature-Related Deaths

> Future climate warming could lead to thousands to tens of thousands of additional deaths each year from heat in the summer, as calculated by extrapolating statistical relationships and without considering potential adaptive changes [*Very Likely, High Confidence*]. Climate warming will also lead to a decrease in deaths from cold in the winter [*Very Likely, Medium Confidence*], but this reduction in deaths is projected to be smaller than the increase in summertime heat-related deaths in most regions [*Likely, Medium Confidence*].

The modeling and analysis underlying this finding seem appropriate. The statement of the finding, however, is not consistent with the underlying text and the traceable accounts: the first sentence (and throughout) should refer to "additional premature" rather than "additional" deaths and should read: "Future climate warming could lead to thousands to tens of thousands of additional premature deaths each year from heat in the summer *by the end of the century*."

In addition, this finding is silent on the current state of evidence and understanding of the potential effects of current warming, an issue of considerable public and media interest and debate on which Chapter 1 touches in citing the National Climate Assessment (2014) (page 26, lines 20-22): "There have been changes in some other types of extreme weather events over the last several decades. Heat waves have become more frequent and intense, especially in the West. Cold waves have become less frequent and intense across the nation." This issue has also been brought further into the foreground by a paper just published (Fischer and Knutti, 2015) which suggests that there have already been substantial changes in extreme temperature and precipitation due to warming, including in the United States. Chapter 2 should explicitly address the state of knowledge of the effects of current warming and the degree of confidence that the authors have in that evidence.

Also, the discussion of deaths from cold in the winter is useful, and the conclusions, especially that reduction in such deaths is projected to be smaller than the increases in heat-related deaths, are appropriately given lower likelihood and confidence. However, while studies using International Classification of Disease (ICD) codes for cold-related deaths are likely understating effects (as noted on page 56, lines 3-15), the evidence that the heat related deaths from increased temperature will be larger than the cold related deaths avoided does seem relatively weak (only one study?) and thus might merit "low" rather than "medium" confidence. The authors might also consider the recent publication of a comprehensive multinational analysis of this question (Gasparrini et al., 2015) which, although international in scope, may provide insights for the U.S.-focused Assessment.

Finally, the conditioning of these conclusions by "without considering potential adaptive changes" is appropriate, and well discussed in Key Finding 3, but a significant uncertainty for the whole chapter.

Key Finding 2: Illness and Deaths Are Related to Deviations from Seasonal Average

Days that are hotter than normal in the summer or colder than normal in the winter are both associated with increased illness and death. While large health effects are observed for extreme temperature events, mortality effects are also seen for smaller deviations of even a few degrees from seasonal averages, and small deviations from average temperature occur much more frequently than extreme events. Due to climate change, more hot days and fewer cold days are expected in the future. [*Very Likely, High Confidence*]

Although the first part of this finding, concerning the increases in illness and death related to extreme temperature events, is well documented in the text (e.g., the Chicago 1995 example), the second part: "mortality effects are also seen for smaller deviations of even a few degrees from seasonal averages, and small deviations from average temperature occur much more frequently than extreme events" does not appear to be supported well in the accompanying text. This is also true in the Traceable Account where (at page 69, lines 7-15) the entire discussion concerns potential "mortality displacement" or "harvesting" and is silent on evidence concerning small deviations from seasonal averages. While such evidence may exist, the current text does not adequately convey it. There also does not appear to be evidence on morbidity effects (as described on page 68, lines 14-32) to justify a finding of high confidence, e.g., "Cardiovascular and respiratory illness has been most commonly examined in relation to extreme heat, but the association is more complicated for illness than for mortality." If this evidence exists, it should be better cited in this section.

Key Finding 3: Changing Tolerance to Extreme Heat

An increase in population tolerance to extreme heat [*Very Likely, High Confidence*], but not extreme cold, has been observed over time. This could be related to increased use of air conditioning, improved social responses, and/or physiological acclimatization [*Likely, Medium Confidence*]. Including this adaptation trend in human health projections will reduce but not eliminate the increase in future deaths from heat [*Likely, Low Confidence*].

This is a very useful and well documented key finding and one of the better examples of explicit discussions of the potential for adaptation— and the likely effect of that adaption on overall risk. Other Chapters should strive to have similar discussion of the potential for personal, behavioral, and societal adaptations, including information about populations of concern, where available.

Key Finding 4: Some Populations at Greater Risk

Elderly persons and people working outdoors have a higher risk of dying due to increasing frequency, intensity, and duration of future heat and heat waves. Children and working age adults have increased vulnerability to heat-related illness. The socially isolated, economically disadvantaged, some communities of color, and those with chronic illnesses are also especially vulnerable to death or illness. [*High Confidence*]

This is a useful finding and appropriately documented for those populations cited. It is especially valuable to include occupational and socially disadvantaged populations who may not have access to adaptive behaviors such as air conditioning. However, this finding and section needs to be reviewed in light of Chapter 9 (Populations of Concern) and made consistent with the descriptions of vulnerable populations there and throughout the report. The authors should also identify any populations identified in other chapters (e.g., Chapter 8 Mental Health and Well Being) that also might exhibit related impacts.

CHAPTER 3
AIR QUALITY IMPACTS

General Comments and Key Findings

This chapter briefly reviews the literature that addresses how global change will likely impact human health via air quality exposure pathways. In this case, the term "air quality" refers to both traditional air pollutants and other airborne materials, in particular aeroallergens. Human exposures may be modified by changing the contaminant level, physical/chemical characteristics of the contaminant, and/or duration of potential exposures. The authors identified two key findings: Climate change will likely impact health (1) due to increases in ozone, and (2) due to exposure to, and the potential increased reaction to, pollen-derived material. They also identified modified exposure to indoor air pollutants as an emerging issue. Recent modeling-based papers (Fann et al., 2015 and Ilacqua et al., 2015) that were directly used in the chapter were cited and provided. The authors have done a commendable job in their review of the literature, their characterization of potential changes in exposures, the additional modeling they conducted, and their careful communication of their findings. However, there are areas that require further consideration or discussion, e.g., wildland fire impacts on air quality and how our current regulatory structure is adaptive to climate change with respect to modifying the climate-air quality response.

Key Finding 1: Exacerbated Ozone Health Impacts

Changes to the climate will tend to make it harder for any given regulatory approach to reduce ground-level ozone pollution in the future as meteorological conditions become increasingly conducive to forming ozone over most of the United States. Unless offset by additional emissions reductions, these climate-driven increases in ozone will cause premature deaths, hospital visits, lost school days, and acute respiratory symptoms. [*Likely, High Confidence*]

The literature and modeling analysis provide strong support for a link between global change and ozone levels. In particular, increased temperatures and decreased ventilation lead to increased levels of ozone in most areas, as compared to levels likely to be observed in the absence of climate change and the same levels of anthropogenic emissions. Ozone is linked with

premature death and other adverse effects. While much of the discussion and review is based upon pre-existing literature, the authors also specifically use the results of a recent modeling study by Fann et al. (2015) (discussed later in more detail) for more quantitative analysis to support the "Likely" finding. Based upon the literature review and the modeling conducted, the report concludes that the impact of climate change on ozone and adverse health, in the absence of additional controls, is likely with high confidence. As the authors conclude, this is well supported both by the literature and the modeling conducted. While both their modeling analysis and the literature support their Key Finding, it should be recognized and well communicated that the models (climate, emissions, air quality and health) upon which this conclusion is derived are subject to uncertainties, particularly when applied to estimating future health impacts.

Key Finding 2: Worsened Allergy and Asthma Conditions

Changes in climate, specifically rising temperatures, altered precipitation patterns, and increasing atmospheric carbon dioxide, are expected to contribute to increasing levels of some airborne allergens and associated increases in asthma episodes and other allergic illnesses, compared to a future without climate change. *[High Confidence]*

The authors find that the literature strongly supports that climate change will impact the level, duration, and characteristics of aeroallergens, in particular pollen-derived material. Climate warming is found to increase the length of the pollen season, thus likely increasing the exposure duration and can increase levels as well. Increased atmospheric CO_2 concentrations can affect the characteristics and abundance of pollen and pollen fragments, and the literature suggests that the changes will lead to an increased allergenicity of the pollen due to physical and compositional modifications to the pollen. Global change will also lead to changes in transport and loss of pollen and pollen fragment. The health outcomes of concern are respiratory diseases (e.g., asthma) in response to exposure. The authors state that the finding of potential adverse health outcomes is of "high confidence." However, factors that may lead to reduced adverse allergic and asthmatic responses (e.g., some areas becoming drier, potential shortening of the pollen season due to plant stress) should be discussed briefly. This is particularly true as the authors did not do any quantitative modeling to assess potential future impacts. Their finding that climate change will lead to worsened allergy and asthma conditions is supported by a large body of literature on this subject, including articles that have reviewed the literature.

Climate Impacts on Particulate Matter from Wild Land Fires and Dust

The authors (appropriately) found that the literature is mixed in terms of the likely impact of global change on particulate matter (PM, in particular $PM_{2.5}$), focusing primarily on PM from traditional emission sources. This conclusion is supported by a large body of literature that has likewise found that climate warming can lead to increases and decreases in PM depending on region and time period. In this chapter, the authors discuss the potential air pollution impacts from changes in wild land fires (which can be from both intentional/prescribed and wildfires, but is often just discussed in terms of wildfires), and dust, due to climate change. These two topics are also discussed in the Extreme Weather chapter in more detail, and the linkages between those two chapters should be made clearer. In both chapters, the authors note that there is a body of

literature on the potential impacts of increased emissions from fires due to severity, number, length, etc., of both wild and prescribed fires. They state (without caveat), in the chapter, that wildfires are increasing due to climate change. There is a strong and growing body of literature on the adverse impacts to human health of biomass burning-derived pollutants. Thus, there is likelihood, and a body of literature supporting a potential finding, that global change will alter wild land fires and that this will impact air quality, including both primary and secondary PM and ozone, with resulting impacts on health. Chapter 9 of the NCA (Melillo et al., 2014) includes wildfires in the "Key Messages". The authors should consider moving this to a Key Finding, along with the choice of strength of this finding they view as appropriate. It seems as though this issue may have been overlooked, e.g., between the air quality and extreme weather chapters.

Additional Comments

The authors were careful in the wording used to characterize the response of ozone to global change in relation to changing (dramatically reducing) anthropogenic emissions. In particular, the reduced ozone precursor emissions from major anthropogenic sources will alter the response to global change (generally dampening the response). Further, the regulatory structure of the United States is "adaptive" in that if the pollutant levels exceed the National Ambient Air Quality Standards (NAAQS), further controls are required. Thus, if current and future climate changes occur, additional controls will likely be employed to further reduce emissions to meet the air quality targets. While there will be areas affected by adverse impacts on ozone, the location and extent of the impact will be a function of a complex air quality management process that is already in place and may already have started to adapt. Some additional caution may be due in terms of how the authors report the impact that climate change has had on ozone. Leibensperger et al. (2008) state: "Such a long-term decrease in mid-latitude cyclone frequency over the 1980-2006 period *may* have offset by half the ozone air quality gains in the northeastern US from reductions in anthropogenic emissions." The Leibensperger et al. (2008) discussion, like the draft chapter, notes the impact of controls. While the statement that climate change has impacted ozone is supported by the literature, the authors are advised to better explain the term "climate penalty."

Research Needs

The authors note that additional research is needed on how air quality and aeroallergens will respond to climate change and on the potential for increased exposure to contaminants indoors. The literature on this issue is not extensive at this time and does not strongly suggest that there will likely be adverse health outcomes from altered exposure to indoor air pollutants. However, the potential exists and is an area for further study; the Assessment authors therefore find that this is an emerging issue of concern, a conclusion with which the Committee agrees. They cite the need to better understand wildfire response. The research needs, while broad, are appropriate. The authors should consider noting that there are areas where current scientific knowledge limits our ability to understand the formation and fate of contaminants in the present atmosphere (e.g., secondary organic aerosol formation). This will hinder our ability to understand how air quality will respond to future changes. Further consideration of potential increase in dust-borne disease should also be included.

Comments on the Modeling

Air Quality Modeling of Ambient Air Quality Response to Climate Change

Fann et al. (2015) conducted a photochemical air quality modeling and health assessment study examining the impact of ozone formation under different climate forcing levels in the near future (2025-2035). This work followed an approach that has been used by others, i.e., downscale the results of a global climate model for an historic period and a future period, and apply a regional air quality model over both periods using a similar emissions inventory to examine how climate changes impact pollutant formation. Their modeling period is suitably long (11 years) and they use a future emissions inventory (which is not always done, but is appropriate). They find an ozone "climate penalty" of 1-5 ppb. They use the air quality model results in BenMap using a projected 2030 population. They find a potentially large number of premature deaths and increased morbidity from the increased exposure due to climate change. The modeling appears to be well done and the results align with other studies.

Indoor Air Quality Modeling

In support of their identification of indoor air quality being an emerging issue, the authors conducted an indoor air quality modeling study using a traditional infiltration/emissions mass balance approach (Ilaqua et al., 2015). The study was conducted using an appropriate approach and identified potential issues of concern, though, as noted, there are many uncertainties and variabilities that are important to assessing potential future exposures. Similarly, the modeling appears to be well done and is appropriate.

CHAPTER 4
VECTORBORNE DISEASES

General Comments and Key Findings

Chapter 4 discusses the ways in which vectorborne diseases are influenced by climate factors, including the short- and long-term effects on patterns of transmission and infection. This chapter does a nice job of balancing that for which we have empirical evidence with respect to vectorborne diseases and climate change with that which we suspect will happen, but have limited evidence. Throughout, the authors take a restrained view of the climate change and vectorborne disease modelling literature, making careful distinctions between risk from exposure to vectors and the occurrence of disease. Despite the authors' care and clarity in presenting the climate change and vectorborne disease literature, there is room to improve this chapter. First, the Key Findings should be edited to reflect the Committee's suggestions detailed above in the section on "Answers to the Statement of Task Questions." Specifically, the health-related outcome(s) should be described first wherever possible. In addition, there may be opportunities to disaggregate confidence determinations in the key findings. Addressing these concerns will help achieve consistency with other chapters. Second, the "Emerging Issues" and "Research Needs" sections should be expanded to reflect more explicitly what we do not know and to more

directly address the uncertainty described in the traceable account. For example, the uncertainty around estimating occurrence of human disease is described as related to "viral evolution, changes in vector control and human behavior," yet the Research Needs include no mention of these issues. Finally, despite the Federal Register's call for "…special attention to research that frames risk in terms of … adaptive capacity," there is limited discussion of this topic in the chapter.

Key Finding 1: Changing Distributions of Vectors and Vectorborne Diseases

Climate change is expected to alter the geographic and seasonal distributions of existing vectors and vectorborne diseases. [*Likely, High Confidence*]

This key finding is well stated and supported by the literature. Here, as throughout the chapter, the modes for attenuation through adaptive capacity are not addressed. In addition, this Key Finding and the literature to support it can be used to further delineate some of the Research Needs.

Key Finding 2: Earlier Tick Activity and Northward Range Expansion

Ticks capable of carrying the bacteria that cause Lyme disease and other pathogens will show earlier seasonal activity and a generally northward expansion in their habitat range in response to increasing temperatures associated with climate change [*Likely, High Confidence*]. Longer seasonal activity and expanding geographic range of these ticks may increase the risk of human exposure to ticks [*Low Confidence*].

Key Finding 3: Climate-Driven Mosquito-Borne Disease Dynamics

Rising temperatures, changing precipitation patterns, and a higher frequency of some extreme weather events associated with climate change will influence the distribution, abundance, and infection rate of mosquitoes that transmit West Nile virus and other pathogens by altering habitat availability and mosquito and viral reproduction rates [*Extremely Likely, High Confidence*]. Alterations in the distribution, abundance, and infection rate of mosquitoes may increase human exposure to bites from infected mosquitoes, which may increase risk for human disease [*Low Confidence*].

Key Findings 2 and 3 are similar in that the chapter takes Lyme disease (Key Finding 2) and West Nile virus (Key Finding 3) as case studies for describing the state of the science on these diseases and quantitative predictive modeling of vectorborne disease risk more generally under future climate scenarios. However, the language used for both key findings should be better coordinated with the other chapters to draw attention to the possibility of significantly higher exposure to and impacts of vectorborne diseases on human health in the near future. As implied in Key Finding 1, it seems justified (from the published evidence cited in the chapter) to state more strongly that future impacts of vectorborne diseases on human health due to climate change-induced alterations to vector populations are likely to include cases of vectorborne

disease in regions where people are unprepared to deal with them. This will, in turn, result in increased exposure to the vectors and potential increased burden of vectorborne diseases on human health.

The authors presented new modeled forecasts of climate change related extension of the Lyme disease season in support of Key Finding 2. The methods used by Monaghan et al. (2015) have been well developed and implemented and are consistent with other forecasting models of vectorborne disease risk.

Key Finding 4: Climate and Non-Climate Factors Determine Human Vulnerability

Non-climate factors that affect vulnerability to vectorborne disease (such as age, gender, socioeconomic status, geography, and occupation) also influence risk for disease occurrence. [*High Confidence*]

While this is an important characteristic of all climate change and human health concerns (as exemplified in Chapter 9: Populations of Concern), it is not clear that this is a novel key finding. The Committee suggests removing this statement as a Key Finding in order to lend greater room for the novel findings specific to this report. Text addressing populations of concern should remain in the document.

Barring removal, this Key Finding could be more clearly written; the difference between "vulnerability to vectorborne disease" and "risk for disease occurrence" is not clear. The lack of a likelihood statement is indicative of the paucity of data and should be highlighted in the section on "Research Needs." The Committee also suggests the authors review the way vectorborne diseases are addressed in Chapter 9 and in the other chapters more generally for the sake of consistency.

Key Finding 5: Emergence of New Vectorborne Pathogens

Climate change will interact with other driving factors (such as travel-related exposures or evolutionary adaptation of invasive vectors and pathogens) to influence the emergence or re-emergence of vectorborne pathogens. [*High Confidence*]

Key Finding 5 is an important finding that is somewhat lost with the number of other Key Findings of this chapter. The confidence statement comes from the bulk of review papers all suggesting a positive association, but the lack of a likelihood statement is indicative of the limited evidence base. This Key Finding could serve as the basis for structuring the "Emerging Issues" and "Research Needs" sections of the report.

Emerging Issues and Research Needs

This chapter has evaluated two diseases for which domestic human risk is great and for which there are quantitative models on the incidence of disease (compared to other models evaluating entomologic risk, vector abundance, etc.). Many questions remain about the links

between vectorborne disease more generally and climate change, as highlighted in this chapter. As noted in the section on "Emerging Issues," recent events like chikungunya in the Caribbean and dengue outbreaks along the southern border of the United States (including Yuma, AZ in 2014) bring travel-related vectorborne disease and importation risk to the minds of many Americans. As scientists try to quantify the probability of introduction, modeling of importation is an emerging discipline (e.g., Ruiz-Moreno et al., 2012). However, the introduction of vectors or vectorborne disease is not the only concern. Additional emerging issues with nascent scientific research include vector adaptation (e.g., Bradshaw and Holzapfel, 2001); understanding future risk in times of expanding vector risk (e.g., Ogden et al., 2014); and interactions with temperature, vectors, and insecticide use (e.g., Glunt et al., 2014). Moreover, with the burgeoning field of predictive vectorborne disease modeling, there emerges a need for guidance on interpreting the models with respect to where and when they can be applied.

The section on "Research Needs" states a need for better long-term human and vector data to feed into evidence-based models without highlighting a need for the empirical studies to provide those data. For example, Reiter et al. (2003) is a frequently cited paper for adaptive capacity with respect to dengue. However, it has yet to be replicated in other regions and with other vectorborne diseases. There is currently a significant increase in evidence-based models, all of which suffer from a paucity of empirical studies to parameterize the modeling efforts (see, for example, Ellis et al., 2011). The researchers conducting these empirical studies are finding that slight nuances in the experimental design have significant impacts on the model outcomes. For example, recent work shows that mosquitoes reared in fluctuating temperatures versus constant temperatures have considerable influence on temperature-dependent daily development rates—a critical driver behind most mosquito abundance models (e.g., Paaijmans et al., 2013). Similarly, as more models are developed, the field is seeing the implications of vector adaptation (e.g., Bradshaw and Holzapfel, 2001). Given the impact such studies will have on the capacity to adequately model risk, the literature on these research needs should be included.

In summary, Chapter 4 and its Traceable Accounts were well cited and explained most of the uncertainty surrounding vectorborne disease impacts from climate change. However, there are ways in which the state of the science regarding climate change and vectorborne diseases can be articulated more clearly and consistently with other chapters.

CHAPTER 5
WATER-RELATED ILLNESSES

General Comments and Key Findings

This Chapter explores some ways in which climate and weather factors can have an impact on properties of water-related pathogens and toxins as well as impacts on human exposure pathways. In general, this chapter is well-written and does an excellent job of assembling relevant information concerning the likely and possible effects of climate change, especially rising ambient temperature, on selected water-related illnesses. While the initial sections and Table 1 make mention of a fairly broad array of agents and pathways, including illnesses related to ingestion of water containing etiologic agents or their products that can cause

human illness, the authors have clearly decided to focus the chapter on pathogens associated with consumption of fish and shellfish, including illnesses resulting from ingestion of harmful algal toxins.

Key Finding 1: Seasonal and Geographic Expansion of Waterborne Illness Risk

Increases in both coastal and inland water temperatures associated with climate change will expand the seasonal windows of growth [*Very Likely, High Confidence*] and the geographic range of suitable habitat [*Likely, High Confidence*] for naturally occurring pathogens and toxin-producing harmful algae. These changes are projected to increase the risk of exposure to waterborne pathogens and algal toxins that can cause a variety of illnesses [*Medium Confidence*].

Key Finding 2: Exposure Risk from Extreme Precipitation Events

Recreational waters and sources of drinking water will be compromised by increasingly frequent and intense extreme precipitation events [*High Confidence*]. Surface runoff and flooding associated with heavy precipitation and storm surge events increase pathogen loads originating from urban, agricultural, and wildlife sources and promote blooms of harmful algae in both fresh and marine waters. Greater pathogen or algal toxin loading in drinking and recreational water sources following an extreme weather event will increase risk of human exposure to agents of water-related illness [*Medium Confidence*].

Key Finding 3: Water Infrastructure Failure or Damage

Increases in some extreme weather events and storm surge will increase the risk of failure of, or damage to, water infrastructure for drinking water, wastewater, and stormwater [*Medium Confidence*]. Aging infrastructure is particularly susceptible to failure. A breakdown in water infrastructure would contribute to increased risk of exposure to water-related pathogens, chemicals, and algal toxins.

Given the decision to focus this chapter on toxin-producing harmful algae and non-cholera Vibrios, the three key findings presented appear to be reasonable and supported by the evidence cited. One area that requires clarification and possibly revision relates to the evidence concerning climate change, especially increases in ambient temperature, and the risk of human illness caused by non-cholera Vibrio species. The discussion of the effects of rising temperatures (and other changes) on the growth and distribution of Vibrios appears to conflate the effects on the abundance of Vibrios in a given area with effects on seasonal windows and geographical range.

A further potential problem is that the non-cholera Vibrio studies do not have a particularly mature grounding in peer-reviewed literature; the primary cited paper has not yet been published, and that paper relies on self-citations for *V. vulnificus* models and on a single FDA report for *V. parahaemolyticus* models. It also appears that the *V. vulnificus* results are based on a dataset that is not publicly available for analysis by other researchers who use other

modeling methods, which is troubling for a research highlight in such a high profile Assessment report. While these studies may be fully robust, there is always risk in featuring a result when the peer-reviewed foundation is limited and potentially susceptible to rapid shifts. Following on our general recommendation for all quantitative modeling results, we urge the authors to provide a discussion of model-based uncertainties and information on how to access underlying data either in this chapter or in the Technical Support Document.

Content Areas Missing

While there is no doubt that the agents and illnesses that the authors chose to focus on are important, it is not clear why the authors chose to focus on these agents and illnesses from among the much longer list of "Agents of Water-Related Illnesses" in Table 1. It also is not clear why other such agents are missing from the table altogether. Missing from the table are the Legionella species, a substantial cause of community- and hospital-acquired pneumonia in the U.S. and many other industrialized countries. Also missing from the table are the schistosoma species that cause "swimmer's itch," a non-fatal, but common condition resulting from contamination of recreational waters in which people swim, wade, or play. Leptospires and *V. cholera* are listed in Table 1, but they receive little or no attention in the text, presumably because the illnesses caused by these organisms, while serious problems internationally, are relatively infrequent causes of illness in the United States. At the same time, however, primary amoebic meningoencephalitis caused by Naegleria receives attention, despite the fact it causes only a handful of cases in the United States each year. Other agents that can be acquired from ingesting contaminated water or shellfish, such as hepatitis A and hepatitis E viruses, are also missing from the table and receive scant mention (hepatitis A) or no mention (hepatitis E) in the text.

To the uninformed reader, the process for deciding which agents and diseases to include in Table 1 and which to make the subject of detailed discussion is opaque. One might assume that *V. cholera* and leprospires were largely excluded from consideration because the report is intended to focus on the likely effects of climate change on diseases and health in the United States; even so, it is plausible that increasing ambient temperature and other aspects of climate change could lead to them spreading to the United States and becoming more common here. The Committee urges the authors to discuss their decision making criteria more clearly within this chapter.

The exclusion from the table and text of the Legionella species and the primary illness it causes, Legionella pneumonia (i.e. Legionnaires' disease), should perhaps be reconsidered given the importance of the disease in the United States in terms of the morbidity and mortality that it causes; the clear association of the disease with inhalation of contaminated aerosols of fresh water; the effects of both temperature and the presence of other organisms, such as amoeba, on the growth of Legionella species; the clear link between large scale air conditioning systems (e.g., cooling towers and evaporative conditioners) and the risk of Legionella pneumonia; and the likelihood that increasing ambient temperatures are highly likely to lead to increased need for and use of air conditioning in large parts of the United States. The Committee acknowledges that this chapter cannot be encyclopedic in scope and can deal with only a limited number of water-related infectious diseases, but suggests that authors could add some rationale behind the

exclusion of Legionella and legionellosis, especially if the authors decide that there is not enough evidence in existing literature to support its inclusion.

Emerging Issues and Research Needs

In the section devoted to "Emerging Issues," much of the focus is on *Naegleria fowlera*, which causes no more than a handful of cases of amoebic meningoencephalitis a year in the United States. While these cases are severe, often fatal, and tragic, it is not clear that this organism and disease warrant highlighting rather than legionellosis or perhaps the growing evidence that hepatitis E virus infection is more common in the United States than previously recognized, and its link to fecally contaminated water uncertain.

In the section on "Research Needs," while the call for "sustained collection of public health…data" and "targeted studies…" (page 178, lines 36-37) appears reasonable and difficult to dispute, it is quite vague and general. While this report may not be the right forum for presenting a specific research agenda, the current section is not particularly helpful in providing guidance or setting priorities with regard to research in this area.

CHAPTER 6
FOOD SAFETY, NUTRITION, AND DISTRIBUTION

General Comments and Key Findings

This chapter reviews the literature that addresses the impacts of climate change and extreme weather events on selected food safety issues and on the distribution and access to safe food. The chapter also reviews the impacts of rising carbon dioxide on the nutritional content of foods. The chapter is organized in three main sections: how climate change and changes in weather extremes may increase the risk of selected foodborne illness by increasing the risk of microbiological and chemical contaminants in the food chain, how rising carbon dioxide lowers the nutritional value of foods, and how climate-related extreme weather events affect food distribution and access to safe and quality foods.

Important food safety issues and related foodborne diseases caused by the contamination of fish and shellfish with Vibrios, with certain chemical contaminants, and with harmful algal marine biotoxins were covered in Chapter 5. This may confuse some readers since, according to the World Health Organization (WHO), foodborne diseases (FBD) can be defined as those conditions that are commonly transmitted through ingested food[1]. The decision to include those items in Chapter 5 should be better explained and key issues should be cross referenced in both chapters.

For each Key Finding, the chapter provides a description of the evidence base, the major uncertainties, and an explanation of the judgments of likelihood and confidence. The Key Findings are well described and justified in the section on Traceable Accounts, but they need to

[1] FBD comprise a broad group of illnesses caused by enteric pathogens, parasites, chemical contaminants and biotoxins (WHO, 2007).

be better formulated, particularly as they are presented at the beginning of the chapter and many readers may only read these Findings.

One of the main issues to address in the Key Findings, and throughout the chapter, is the need to refer properly to:

- the likelihood of food contamination with microbiological or chemical hazards,
- the likelihood of human exposure through contaminated foods, and
- the risk of illness resulting from the consumption of contaminated foods (dietary exposure).

Key Finding 1: Increased Risk of Foodborne Illness

Although there are many practices to safeguard food in the United States, climate change, including rising temperatures and changes in weather extremes, is expected to intensify pathogen and toxin exposure [*Likely, High Confidence*], increasing the risk, if not the actual incidence, of foodborne illnesses [*Medium Confidence*].

Based on available research and evidence, it is important to note that rising temperatures and changes in weather extremes are expected to increase food *contamination* with pathogens and toxins (such as aflatoxins). Then, as a consequence, there may be an increased exposure to pathogens and toxins through food (depending on the risk management and risk communication strategies, such as regulatory, surveillance, and monitoring systems) and hence an associated increased risk of foodborne diseases.

Key Finding 2: Chemical Contaminants in the Food Chain

Elevated sea surface temperatures and increases in certain weather extremes associated with climate change will increase human exposure to water contaminants in food [*Likely, Medium Confidence*]. Climate change will also alter the incidence and distribution of pests, parasites, and microbes [*Very Likely, High Confidence*], which will lead to increases in the use of pesticides for crop protection, animal agriculture, and aquaculture. Increased use of pesticides may result in increased human exposure to chemical contaminants in the food chain [*High Confidence*].

The Committee does not disagree with this Key Finding, but suggests that the authors should be more explicit about the mechanisms. Elevated sea surface temperatures and increases in certain weather extremes associated with climate change may increase water and food contamination with chemical contaminants (such as Methyl-Hg or persistent organic pollutants [POPs]), and this may result in increased human exposure to chemical contaminants (depending on the risk management and risk communication systems in place) and hence an increased risk of associated diseases and conditions.

In addition, the increased use of pesticides may result in the increased presence of pesticide residues in foods, which may increase the chances of human exposure to pesticides and

hence result in an increased risk of associated diseases and conditions. In the case of animal production and aquaculture systems, there might be also an increased use of veterinary drugs and other chemo-therapeutants (FAO, 2008).

> *Key Finding 3: Rising Carbon Dioxide Lowers Nutritional Value of Food*
>
> Rising atmospheric carbon dioxide will continue to lower the nutritional value of most food crops, including wheat and rice, and can also reduce the concentration of essential minerals in a number of crop species. [*Very Likely, High Confidence*]

The Committee suggests that it would be helpful, especially for readers that are unfamiliar with this research, to put more emphasis on this important Key Finding and to further explain that rising atmospheric carbon dioxide lowers the nutritional value of most food crops and the concentration of essential minerals in a number of crops. This may continue as atmospheric carbon dioxide continues rising, and could have significant implications for human nutrition.

Content Areas Missing

There is a critical body of evidence on climate change and associated foodborne and waterborne illness risks, including models developed recently by the European Food Safety Authority and the European Centers for Disease Control, that should be mentioned in this chapter. Examples include: (1) The European Food Safety Authority study of the potential increase in aflatoxins in cereals in the EU as a result of climate change which includes modeling, predicting, and mapping the emergence of aflatoxins in cereals in the 27 EU countries due to climate change (Battilani et al., 2012); (2) the European Centre for Disease Prevention and Control technical report on Assessing the potential impacts of climate change on food- and waterborne diseases in Europe (ECDC, 2012); and (3) the Decision Support Tool developed by the European Centre for Disease Prevention and Control to Compare Waterborne and Foodborne Infection and/or Illness Risks Associated with Climate Change (Schijven et al., 2013).

Chemical contamination is covered in both the water and food chapters, but these chapters do not fully represent the existing body of literature. For example, the section on chemical contaminants may need more work to cover issues related to:

- Contamination with chemicals related to recurrent river floods in the United States (for reference, the EU-wide study of the impacts on food/water contamination with POPs, dioxins of recurrent floods of the Danube river; see also Umlauf et al., 2005);
- Chemicals' concentration and consequent dispersion related to droughts followed by floods in the United States (see Rotkin-Ellman et al., 2010);
- Limited activity of pesticides in dry conditions (Muriel et al., 2001) and faster pesticide degradation related to higher temperatures and higher dose levels or more frequent applications needed to protect crops (Bailey, 2004);
- Increased use of veterinary drugs and other chemo-therapeutants associated with animal production and aquaculture systems (FAO, 2008); and

- Chemical transport systems in the Arctic (perhaps including any new findings since the previous Arctic Climate Impact Assessment [ACIA, 2004]).

Emerging Issues and Research Needs

The section on "Research Needs" would benefit from being more thorough and specific. Areas related to food chemical contamination highlighted above need to be studied in different regional contexts and geographical areas in the United States (e.g., the Arctic).

There are many research needs on climate change and food safety that have been already addressed in European countries and Canada but have not been studied in the United States yet. For example, there are no studies on the impact of climate change on food and waterborne diseases in the United States and it would be helpful to develop tools that can be used in climate change adaptation strategies for foodborne and waterborne diseases (Schijven et al., 2013). Another key research need is the development of predictive models of the emergence of aflatoxins in cereals due to climate change in the United States. Scenarios and maps could also be created to focus on potential future contamination of cereal crops. The Committee agrees that all the emerging issues highlighted in the chapter deserve further research.

The section on populations of concern needs to address the potential health risks of chemical food contamination to tribal communities in the Pacific North West and Alaska. Particular risks related to traditional diets of these tribal communities have been covered in Chapter 5, but these dietary issues are perhaps more relevant for Chapter 6.

The Chapter would benefit from including a section or table on adaptation needs and strategies for food safety including, for example, good agriculture and veterinary practices. Potential trade issues related to food contamination by aflatoxins could be mentioned in the section on food access to reflect the potential additional efforts by USDA to monitor food imports. Food prices could be mentioned in relation to the impact on food access (e.g., California). Issues related to risk benefit analysis and consequent risk communication could be included, for example, about fish contamination and consumption during pregnancy.

The section on nutrition does not refer to the "*opportunities to achieve* co-benefits from actions that reduce emissions and at the same time improve health by shifting consumption away from animal products, especially from ruminant sources, in high-meat consumption societies, toward less emission intensive healthy diets" (Field et al., 2014). If these issues are not addressed, perhaps the section of nutrition should be named differently, e.g., Nutritional Value of Foods.

Graphics

The chapter covers two very different issues: the impacts of climate change on food safety and the impacts of rising carbon dioxide in the nutritional value of food. The title of Figure 1 should reflect this difference (i.e., rising Carbon Dioxide affects nutrient content but does not necessarily affect Food Safety). It would be useful to include a table on potential chemical contaminants related to climate change in the United States.

CHAPTER 7
EXTREME WEATHER

General Comments and Key Findings

Chapter 7 explores some of the health effects associated with extreme weather events. The authors have done a laudable job tackling a difficult task: to write about climate change extremes while avoiding some of the most obvious components of the topic—e.g., heat waves, infectious and waterborne disease outbreaks, and mental health—which are dealt with in their own devoted chapters. Given this mandate, the scope and completeness of the chapter is appropriate, and the authors have captured relevant literature in a balanced manner.

That said, the Committee feels that the chapter could be improved in three ways: more specific Key Findings, greater emphasis of the regional character of impacts, and consideration of adaptation. These points are expanded below.

Key Finding 1: Changes in Exposure Risk

> Climate change may increase exposure to health hazards associated with projected increases in the frequency and/or intensity of extreme precipitation, hurricanes, coastal inundation, drought, and wildfires in some regions of the United States [*Medium Confidence*]. Adverse health outcomes associated with exposure to extreme events include death, injury, or illness; exacerbation of underlying medical conditions; and adverse effects on mental health.

A general suggestion of the Committee is that all Key Findings should start from health and follow with relevant physical, ecological, or social mediators. Following that model, we suggest that Key Finding 1 begin with the second sentence "Adverse health outcomes . . ." and include a confidence statement specific to that statement. This could be followed by a statement on how climate change affects these outcomes, similar to the current first sentence of the Key Finding.

However, we also suggest that the statement on climate change affects be phrased in more specific terms. This includes replacing the word "may" with "will," since a confidence statement on "may" has no clear meaning. Regarding the "medium confidence" assessment, the Traceable Accounts support a more specific set of confidence statements that could be separated out by type of extreme event. As the authors note in Traceable Accounts, few quantitative studies draw the full connection from climate change to health impact. But the extent to which this connection has been made varies by type of extreme. For wildfires, for example, the authors cite studies that address climate trends in both frequency and exposure. For floods and droughts, however, the Traceable Accounts indicate that there is published evidence of climate trend but trends in exposure are less certain (though coastal floods might be an exception). For winter storms there is a lack of consensus on the climate trend itself.

These are meaningful differences that are important enough to be represented in the Key Finding. This could be done by providing different confidence statements for each type of event,

by separating events into categories of different confidence level, by dividing the Key Finding 1 statement into a sentence on climate trend and a sentence on exposure trend, or some other formulation that the authors feel is more appropriate.

> *Key Finding 2: Other Factors Influence Health Impacts*
>
> The character and severity of health impacts from extreme events depend not only on the frequency or intensity of the extremes themselves but also on a population's exposure, sensitivity, and adaptive capacity. Many types of extreme events can cause loss of essential infrastructure, such as water, transportation, and power systems that are required to safeguard human health. [*High Confidence*]

As written, Key Finding 2 combines two concepts: impacts depend on vulnerability, and some extreme events affect health via impacts on infrastructure. The first concept would seem to fit into Key Finding 3, and the Committee suggests that it be moved to that Key Finding for clarity. This would leave Key Finding 2 to focus on infrastructure, which is certainly a critical point when linking extreme events to health. Following the formula suggested above for Key Finding 1 and for the report more broadly, we suggest that the existing Key Finding 2 statement ("Many types of extreme events . . .") be followed by a statement on how climate trends are affecting this relationship. In the context of infrastructure it would also be valuable to add a sentence on how changes in infrastructure can reduce health impacts, supported by the natural disaster literature.

As with Key Finding 1, it might be useful to separate out different types of extremes in Key Finding 2 since the depth of available literature differs by event.

> *Key Finding 3: Certain Populations Are More Vulnerable*
>
> Key risk factors that individually and collectively shape a population's vulnerability to health impacts from extreme events include age, health status, socioeconomic status, race/ethnicity, and occupation. [*High Confidence*]

This is an important Key Finding that ties closely to Chapter 9 and to the general theme of vulnerable populations throughout the report. As noted above, the Committee suggests moving the vulnerability finding from Key Finding 2 to Key Finding 3, as it seems more closely related to this point on vulnerability. More importantly, report authors should coordinate to ensure that vulnerable population findings are presented in a consistent manner across all chapters.

Regional Specification

The Committee suggests two updates to Table 1. First, confidence statements similar to the 2014 NCA report should be added to the climate projections in column three. Second, it would be useful to insert an additional column that identifies the most affected regions for each

type of event. Including regional information in this table would also require that the phrasing in column three be formalized in some cases, which would also improve the table. Some of the statements are unclear—e.g., droughts have increased in the past "couple of decades" (which decades?); winter storms have increased and shifted northward (what is the relative confidence in intensity, frequency, and location?). Alternatively or additionally, a map could be included alongside Table 1 that draws on findings on extremes from the 2014 NCA report.

Another possible way to clarify regional impacts would be to lead off each subsection with a subheading on the "Most Affected Regions." While most subsections cover this matter effectively in the text, a subheading that lists regions might be useful for the reader.

Adaptation

Currently the chapter addresses adaptive capacity only in the context of uncertainty. Given the importance of adaptation in this context, some consideration of how adaptation mediates health impacts is within the scope and important to include. While literature that specifically addresses the health impacts of adaptation to extremes under climate change might be limited, there is a wealth of relevant analyses on the health benefits of preparedness in the natural disaster literature, including studies on the siting and construction of health infrastructure (e.g., location of generators in flood-prone hospitals), the use of early warning systems, insurance incentives, and zoning in areas at risk of wildfire.

This is, admittedly, a diffuse literature, much of which is contained in analyses of infrastructure or behavior rather than of health in an explicit sense. One possible starting point on the health-specific literature is the recent book *Disasters and Vulnerable Populations: Evidence-Based Practice for the Helping Professions* (Baker and Cormier, 2014). Authors may also wish to consider another recent report on "Disaster Resilience: A National Imperative" (NRC, 2012). It might be just as useful, however, to build a short "adaptation" section or case study Box drawing on recent Federal Emergency Management Agency (FEMA), U.S. Army Corps of Engineers (USACE), or other analysis of a major disaster like Superstorm Sandy or Hurricane Katrina, from the numerous analyses of flood relocation programs in the United States (e.g., Kick et al., 2011), or from the literature on behavioral response to disaster warnings and evacuation orders (e.g., Tinsley et al. [2012] and references therein).

CHAPTER 8

MENTAL HEALTH AND WELL-BEING

General Comments and Key Findings

The Chapter examines a range of mental health consequences of climate change as well as specific groups of people that may be at higher risk. This is an extremely important chapter that reviews a fairly new literature and attempts to cover a wide range of topics. While the authors have done an excellent job of covering a lot of material in a limited space, and the scope and completeness of the chapter is largely appropriate, the chapter should address the following problems: alteration of the format of the Key Findings, the insufficient representation of the

literature in Key Finding 3, addressing specific gaps in the chapter, and several other literature gaps in other parts of the chapter.

> *Key finding 1: Mental Health Consequences of Exposure to Disasters*
>
> Many people exposed to climate-related disasters experience stress and serious mental health consequences. Depending on the type of the disaster, these serious mental health consequences include significant symptoms of post-traumatic stress disorder (PTSD), depression, and general anxiety, which often occur at the same time. The majority of affected people recover over time on their own, although a significant proportion of exposed individuals develop chronic levels of psychological dysfunction. [*Very High Confidence*]

A general suggestion of the Committee is that all Key Findings should start from health and follow with relevant physical, ecological, or social mediators. Following that model, we suggest that Key Finding 1 be re-ordered to be rephrased with more specificity, "Experiences from climate-related disasters cause stress and serious mental health consequences…"

> *Key finding 3: The Threat of Climate Change*
>
> The threat of climate change, the perceived direct experience of climate change, and changes to one's local environment can result in substantial adverse mental health outcomes and social impacts for the American public. Virtually all Americans are exposed to the threat of climate change and to events attributed to the impacts of climate change through frequent multimedia coverage. [*High Confidence*]

This Key Finding claims that media portrayals of climate risks increase stress and mental health impacts of climate change. Report authors may wish to consider any available literature that demonstrates how people may temporally or spatially distance themselves from climate risks. The Key Finding as currently worded gives the overall impression that media portrayals of climate change are more detrimental than they may actually be, considering the distancing that at-risk communities tend to engage in. In addition, the second part of this Key Finding that states "virtually all Americans are exposed to the threat of climate change and to events attributed to the impacts of climate change through frequent multimedia coverage" needs to be better supported by existing literature or perhaps removed entirely from Key Finding 3.

Overall Representation of the Evidence

Possibly due to the page limitations, the chapter often simplifies very complex phenomena that might be better understood with a slightly more detailed treatment, so that they can possibly be addressed in applied settings. If this report is meant to speak to a wide audience, such as mental health professionals and others who might be in a position to deal with these issues, then more detailed discussion is important. For example, on page 298, lines 10-11, the assertion is that sea level rise affects mental health, but there is not an exploration of why.

Another example is the discussion of increased violence on page 297, line 32. Another phrase or paragraph explaining why interpersonal violence increases or for whom would help. This issue is very briefly addressed in different terms on page 300, lines 4-6, and could be moved and explained in more detail.

This general portrayal raises the larger issue of adaptation within the review of mental health and well-being. There is literature that shows that specific approaches to preparing for or responding to extreme events can mitigate the mental health impacts of extreme events. This literature should be represented in the chapter where appropriate. This is particularly true in the section on "Resilience and Recovery." It would be ideal to expand the scope of the chapter a bit in the section on climate mitigation in order to include well-being and climate change, not just mental health impacts.

Content Areas Missing

There is a lack of discussion on access to health care and health resources necessary to deal with the mental health burden introduced by climate change. While this Assessment is not policy prescriptive and is not meant to offer policy recommendations, the lack of resources to deal with mental health impacts of extreme weather events has already played a critical role in the exacerbation of these impacts, making this issue important to raise. There is literature to refer to in this area (e.g., Blashki et al., 2009 and Shukla, 2013).

While the chapter details many specific relationships between types of weather events and illnesses that promise to exacerbate mental health impacts, there is no mention of how cumulative increases in mental health outcomes may have ramifications we have not anticipated. It is worth mentioning because most of the review is of past events, and there is an abundance of literature demonstrating that climate change will alter events in ways we have not anticipated (e.g., the past does not predict the future).

Overall, the mental health findings are very well represented in this chapter, but the findings regarding well-being specifically would benefit from additional consideration. In order to make the chapter relevant to broad audiences outside of academics, it is important to not only represent the problems presented by climate change, but also the potential solutions, which can be equally important for well-being. This might merit the addition of one specific section dedicated to this topic or the integration of such findings throughout all sections in this chapter.

CHAPTER 9

CLIMATE-HEALTH RISK FACTORS AND POPULATIONS OF CONCERN

General Comments and Key Findings

The stated goal of this Chapter is to identify factors that may create or exacerbate the vulnerability of certain groups to the health impacts of climate change. The Chapter also aims to integrate information from the other report chapters to identify specific groups of people that may face greater health risks due to climate change.

Key Finding 1: Vulnerability Varies Across Individual, Time Scales, and Places

Across the United States, people and communities differ in their exposures, their inherent sensitivity, and their adaptive capacity that enables them to respond to and cope with climate change related health threats. Vulnerability to climate change varies across time and geographic areas, across communities, and among individuals within communities. [*Very High Confidence*]

Overall the authors present substantial evidence that there are differences in exposures, inherent sensitivity, and adaptive capacity across the United States. Extensive discussion is provided on the concept of vulnerability. Given that vulnerability is woven into the preceding chapters of the document, the discussion of the definitions and concept should be provided in the introductory chapter, as previously noted. Because much of the content on vulnerability, sensitivity, and adaptive capacity is discussed in previous chapters, the authors should note more extensive discussions elsewhere in the document.

A large issue is how to describe the vulnerability of individuals according to race and ethnicity absent socioeconomic factors. There are specific examples of vulnerability related to race and ethnicity, but they are not covered in this chapter. Neither race nor ethnicity automatically imply vulnerability, but they could point to inherent sensitivity.

Key Finding 2: Climate Factors Interact with Non-Climate Factors to Increase Health Risk

Climate change related health risks interact with some of the same non-climate factors that increase the risk of poor health generally. Non-climate factors, such as those related to demographic changes, socioeconomic factors, and pre-existing or chronic illnesses, may amplify, moderate, or otherwise influence climate related health effects, particularly when they occur simultaneously or close in time or space. [*High Confidence*]

This component of the chapter appears to be comprehensive, particularly the discussion of compromised mobility, cognitive function, and other mental factors. The discussion of compromised literacy could be expanded to describe the challenges that non-English-speaking populations face when they cannot comprehend warnings or health threats. The section on psychological stress has considerable overlap with Chapter 8, but does not include sufficient discussion on how fear of authority and deportation among undocumented immigrant workers could affect their susceptibility during climate events.

The statement of qualitative vulnerability assessment involving conducting surveys on the resilience of health infrastructure needs an example. It is not clear why the focus is on surveying health infrastructure if the aim is to assess pockets of vulnerability to climate change.

In general, the measurement of the extent to which non-climate factors affect vulnerability is complex and is limited by data availability, particularly at the national level. These factors are, in one sense, the essence of much of the unpredictable vulnerability that is observed after climate events.

Key Finding 3: Increased Vulnerability to Climate-Related Health Impacts is Widespread Across Ages and Stages of Life

People experience different vulnerabilities at different ages and life stages. For example, the very young and the very old are particularly sensitive to climate related health impacts. [*High Confidence*]

The confidence in this finding is limited due to the lack of data on the extent to which this vulnerability affects populations, particularly at the national level. The concept that youth may present increased vulnerability but also enhanced adaptability and resiliency is an important one; the authors should either cite data that is available on this question or identify in the "Research Needs" section key needs for additional evidence. Also there is redundancy in the chapter by first focusing under Key Finding 1 on children and then focusing in this Key Finding on life stages and repeating much of the previous discussion on children.

Key Finding 4: Mapping Tools and Vulnerability Indices Help to Identify Where and for Whom Climate Health Risks Are Greatest

The use of geographic data is allowing more sophisticated mapping of risk factors and social vulnerabilities, to identify and protect specific locations and groups of people. [*Medium Confidence*]

The authors only conclude medium confidence in this Key Finding. The figures provided in the text illustrate the capacity that is currently available to map vulnerability, but significant limitations remain. Mapping of the elderly and heat wave exposure is the most commonly cited example of identifying pockets of vulnerability. However, there are few examples of mapping other pockets of vulnerability, such as where vulnerable populations are located in coastal communities or communities threatened by wildfires. In general the first paragraph under application of vulnerability indices should include some of the more challenging examples, clearly illustrating the lack of confidence in this Key Finding.

Rather than having a Key Finding that results in only medium confidence, the authors could consider approaching it as an emerging trend (as mapping is handled in Chapter 8). If this section was relabeled "Emerging Trends," a more inclusive discussion could address the challenges of investing in the infrastructure and resources to do mapping prospectively. It is helpful to know not only where the vulnerable pockets are, but also the challenges of investing in these pockets in order to be better prepared in emergencies. The example of mapping after Hurricane Katrina is helpful, but there is little discussion of how to obtain the resources to do this type of work prospectively in order to predict pockets of vulnerability. Ultimately the goal would be not just to develop mapping of pockets of vulnerability, but also to be able to predict (given a certain geographic site) the probability of a human health impact (e.g., if the temperature at a location exceeds 100° F, what is the probability of that exceedance lasting for 3 or more days in the current and future time periods?; or if ozone exceeds 70 ppb, what is the probability of the

exceedance continuing for the following 2-3 days?; or if a wildfire erupts in a geographic area, what is the probability that it can be controlled within a 48 hour time period?).

The section on mapping could be more inclusive. Heat is a good illustration, but it would be helpful to discuss mapping of some other vulnerability factors, such as workers' exposure to heat and better warning systems for persons who do not have access to information or alerts in emergencies. For example, outdoor workers need some type of monitoring system, but at this time, we do not know how many workers are exposed to heat waves per year, and it is unclear which communities are stepping forward to address this challenge.

The inadequate discussion in this section is exemplified in the Traceable Accounts section on page 362. It is only here that the authors note that not all geocoded health data are available in all locations and that, in fact, vulnerable populations such as immigrant populations are more likely to be in the health databases even if they are coded. Mental health outcome data is particularly challenging to obtain and geocode, partly because the majority of cases are underdiagnosed. These uncertainties need to be addressed, not only in the Traceable Accounts section, but in the section describing mapping potential.

References

ACIA. 2004. Arctic Climate Impact Assessment. Fairbanks, AK: ACIA Secretariat.

Bailey, S. W. 2004. Climate change and decreasing herbicide persistence. Pest Management Science 60(2):158-162. DOI: 10.1002/Ps.785.

Baker, L. R. and L. A. Cormier. 2014. Disasters and Vulnerable Populations: Evidence-Based Practice for the Helping Professions. New York: Springer.

Battilani, P., V. Rossi, P. Giorni, A. Pietri, A. Gualla, H. J. van der Fels-Klerx, C. J. H. Booij, A. Moretti, A. Logrieco, F. Miglietta, P. Toscano, M. Miraglia, B. De Santis and C. Brera. 2012. Modelling, predicting and mapping the emergence of aflatoxins in cereals in the EU due to climate change. Question No EFSA-Q-2009-00812. Parma, Italy: European Food Safety Authority.

Blashki, G. A., H. L. Berry and M. R. Kidd. 2009. Primary Health Care Responses to Climate Change. In Climate Change and Social Justice. J. Moss, eds. Carlton, Victoria, Australia: Melbourne University Press.

Bradshaw, W. E. and C. M. Holzapfel. 2001. Genetic shift in photoperiodic response correlated with global warming. Proceedings of the National Academy of Sciences of the United States of America 98(25):14509-14511. DOI: 10.1073/pnas.241391498.

Budescu, D. V., S. Broomell and H. H. Por. 2009. Improving Communication of Uncertainty in the Reports of the Intergovernmental Panel on Climate Change. Psychological Science 20(3):299-308. DOI: 10.1111/j.1467-9280.2009.02284.x.

ECDC (European Centre for Disease Prevention and Control). 2012. Assessing the potential impacts of climate change on food- and waterborne diseases in Europe. Stockholm: ECDC.

Ellis, A. M., A. J. Garcia, D. A. Focks, A. C. Morrison and T. W. Scott. 2011. Parameterization and Sensitivity Analysis of a Complex Simulation Model for Mosquito Population Dynamics, Dengue Transmission, and Their Control. American Journal of Tropical Medicine and Hygiene 85(2):257-264. DOI: 10.4269/ajtmh.2011.10-0516.

Fann, N., C. G. Nolte, P. Dolwick, T. L. Spero, A. C. Brown, S. Phillips and S. Anenberg. 2015. The geographic distribution and economic value of climate change-related ozone health impacts in the United States in 2030. Journal of the Air and Waste Management Association 65(5):570-580. DOI: 10.1080/10962247.2014.996270.

FAO. 2008. Expert Meeting on Climate-Related Transboundary Pests and Diseases Including Relevant Aquatic Species, 25-27 February 2008. Options for Decision Makers. Rome, Italy: Food and Agriculture Organization of the United Nations.

Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L.L.White. 2014. Human health: impacts, adaptation, and co-benefits. In Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Smith, K. R., A.Woodward, D. Campbell-Lendrum, D. D. Chadee, Y. Honda, Q. Liu, J. M. Olwoch, B. Revich and R. Sauerborn, eds. Cambridge, United Kingdom and New York, NY: Cambridge University Press.

Fischer, E. M. and R. Knutti. 2015. Anthropogenic contribution to global occurrence of heavy-precipitation and high-temperature extremes. Nature Climate Change 5:560-564. DOI: 10.1038/nclimate2617.

Glunt, K. D., K. P. Paaijmans, A. F. Read and M. B. Thomas. 2014. Environmental temperatures significantly change the impact of insecticides measured using WHOPES protocols. Malaria Journal 13. DOI: 10.1186/1475-2875-13-350.

Ilacqua, V., J. Dawson, M. Breen, S. Singer and A. Berg. 2015. Effects of climate change on residential infiltration and air pollution exposure. Journal Of Exposure Science And Environmental Epidemiology(in press). DOI.

Kick, E. L., J. C. Fraser, G. M. Fulkerson, L. A. McKinney and D. H. De Vries. 2011. Repetitive flood victims and acceptance of FEMA mitigation offers: an analysis with community-system policy implications. Disasters 35(3):510-539. DOI: 10.1111/j.1467-7717.2011.01226.x.

Leibensperger, E. M., L. J. Mickley and D. J. Jacob. 2008. Sensitivity of US air quality to mid-latitude cyclone frequency and implications of 1980-2006 climate change. Atmospheric Chemistry and Physics 8(23):7075-7086. DOI: 10.5194/acp-8-7075-2008.

Melillo, J. M., T. C. Richmond and G. W. Yohe, Eds. 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. Washington, DC: U.S. Global Change Research Program.

Monaghan, A. J., S. M. Moore, K. M. Sampson, C. B. Beard and R. J. Eisen. 2015. Climate change influences on the annual onset of Lyme disease in the United States. Ticks and Tick-Borne Diseases(in press). DOI: 10.1016/j.ttbdis.2015.05.005.

Muriel, P., T. Downing, M. Hulme, R. Harrington, D. Lawlor, D. Wurr, C. J. Atkinson, K. E. Cockshull, D. R. Taylor, A. J. Richards, D. J. Parsons, J. E. Hillerton, M. L. Parry, S. C. Jarvis, K. Weatherhead and G. Jenkins. 2001. Climate Change and Agriculture in the United Kingdom. London, UK: Ministry of Agriuclture, Fisheries and Forestry.

NRC (National Research Council). 2012. Disaster Resilience: A National Imperative. Washington, DC: National Academies Press.

Ogden, N. H., R. Milka, C. Caminade and P. Gachon. 2014. Recent and projected future climatic suitability of North America for the Asian tiger mosquito *Aedes albopictus*. Parasites & Vectors 7(532). DOI: 10.1186/s13071-014-0532-4.

Paaijmans, K. P., R. L. Heinig, R. A. Seliga, J. I. Blanford, S. Blanford, C. C. Murdock and M. B. Thomas. 2013. Temperature variation makes ectotherms more sensitive to climate change. Global Change Biology 19(8):2373-2380. DOI: 10.1111/Gcb.12240.

Reisen, W. K., D. Cayan, M. Tyree, C. A. Barker, B. Eldridge and M. Dettinger. 2008. Impact of climate variation on mosquito abundance in California. Journal of Vector Ecology 33(1):89-98. DOI: 10.3376/1081-1710(2008)33[89:Iocvom]2.0.Co;2.

Reiter, P., S. Lathrop, M. Bunning, B. Biggerstaff, D. Singer, T. Tiwari, L. Baber, M. Amador, J. Thirion, J. Hayes, C. Seca, J. Mendez, B. Ramirez, J. Robinson, J. Rawlings, V. Vorndam, S. Waterman, D. Gubler, G. Clark and E. Hayes. 2003. Texas lifestyle limits transmission of dengue virus. Emerging Infectious Diseases 9(1):86-89. DOI: 10.3201/eid0901.020220.

Rotkin-Ellman, M., G. Solomon, C. R. Gonzales, L. Agwaramgbo and H. W. Mielke. 2010. Arsenic contamination in New Orleans soil: Temporal changes associated with flooding. Environmental Research 110(1):19-25. DOI: 10.1016/j.envres.2009.09.004.

Ruiz-Moreno, D., I. S. Vargas, K. E. Olson and L. C. Harrington. 2012. Modeling Dynamic Introduction of Chikungunya Virus in the United States. Plos Neglected Tropical Diseases 6(11). DOI: 10.1371/Journal.Pntd.0001918.

Schijven, J., M. Bouwknegt, A. M. d. R. Husman, S. Rutjes, B. Sudre, J. E. Suk and J. C. Semenza. 2013. A Decision Support Tool to Compare Waterborne and Foodborne Infection and/or Illness Risks Associated with Climate Change. Risk Analysis 33(12). DOI: 10.1111/risa.12077.

Schwartz, J. D., M. Lee, P. L. Kinney, S. Yang, D. Mills, M. Sarofim, R. Jones, R. Streeter, A. S. Juliana, J. Peers and R. M. Horton. 2014. Projections of temperature-attributable deaths in 209 U.S. cities using a cluster-based Poisson approach. Environmental Health(submitted). DOI.

Shukla, J. 2013. Extreme Weather Events and Mental Health: Tackling the Psychosocial Challenge. ISRN Public Health. DOI: 10.1155/2013/127365.

Tinsley, C. H., R. L. Dillon and M. A. Cronin. 2012. How Near-Miss Events Amplify or Attenuate Risky Decision Making. Management Science 58(9):1596-1613. DOI: 10.1287/mnsc.1120.1517.

Umlauf, G., G. Bidoglio, E. H. Christoph, J. Kampheus, F. Kruger, D. Landmann, A. J. Schulz, R. Schwartz, K. Severin, B. Stachel and D. Stehr. 2005. The situation of PCDD/Fs and dioxin-like PCBs after the flooding of river Elbe and Mulde in 2002. Acta Hydrochimica Et Hydrobiologica 33(5):543-554. DOI: 10.1002/aheh.200400597.

USGCRP (US Global Change Research Program). 2008. Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems (SAP 4.6). Washington, DC: US Environmental Protection Agency.

WHO (World Health Organization). 2007. WHO Initiative to Estimate the Global Burden of Foodborne Diseases: First formal meeting of the Foodborne Disease Burden Epidemiology Reference Group (FERG). Implementing Strategy, Setting Priorities and Assigning the Tasks. 26-28 November 2007. Geneva: WHO.

Appendix A
Compilation of Committee Member Comments

GENERAL COMMENTS

Comment #	Page/line	Comment
1		Standardize spelling across all chapters: • Vectorborne not vector born or vector-borne • Mosquitoes not mosquitos
2		Punctuation following [likelihood, confidence statement]. This is neither consistent within the Executive Summary (see Extreme weather versus Waterborne chapters) nor within sections within the Executive Summary (see Food safety).
3		Understandably, the report emphasizes increases in health risks. While reductions are addressed in some passages (e.g., cold extremes), the report does not attempt an overall estimate of harm versus benefit of climate change and does not make an explicit effort to explore all potential health benefits of climate change. This is not necessarily a problem, but some statement of scope on this matter would be useful.
4		It would be helpful to readers if the new quantitative modeling efforts were featured more prominently in the preface.

CHAPTER 1: CLIMATE CHANGE AND HUMAN HEALTH

Comment #	Page/line	Comment
5	P2/L13	Do you want "increases" before "diseases" and "stresses" (the prior clause starts with "degraded", which does not fit here)?
6	P3/L9	Comment states that "research needs" are included at the end of each chapter. These are not in every chapter, and depending on response to other review comments, this sentence should be revised.
7	P23/L28	May need to edit "2007-2014" as the range for the literature search.
8	P26/L20	Authors should consider the possibility that heat waves could become more humid, with subsequent greater impacts on human health.
9	P26/L20-22	It may be helpful to mention dust storms or dust events due to climate change.
10	P27/L24	Suggest adding "behavior" as in "… affect the survival and behavior of mosquitoes, ticks… " Movement sounds like migration, but with mosquito-borne and tick-borne this is also, and more critically, talking about changes in biting frequency, rates, times, hosts, etc. So not movement but behavior.
11	P28/L1	Needs a "." at the end of this sentence.
12	P28/L7	Use degraded coastal ecosystems rather than altered.
13	P28/L16	"This means areas that already experience…" *that* areas *that* reads funny
14	P28/L26-34	It is not clear how the concepts in these few sentences fit together and this needs clarification as to the point being made.
15	P29/L18	How hard would it be to include numbers? For example, "The US

		population has grown by approximately 103% since 1950 (from ### in 1950 to ### in 2015)."
16	P30	In section 1.3.2, consider adding e-cigarette smoking rates, which is an increasingly important health risk among youth.
17	P30/L37	Change presence to "prevalence".
18	P31/L1	What does "disease risks have been getting worse" mean here? Increasing prevalence, incidence, poorer health care, etc? This is too vague.
19	P34/L1	Does "related" in this sentence mean "associated with"?
20	P36/L25-31	What about changes in medical care and treatment?
21	P37-38	This may be a standard way in climate change literature, but it is really a qualitative estimate of uncertainty to be associated with a quantitative statement . . . or vice versa as even though there is a scale, there are not actual probabilities associated with these categories. That i.e., even though the authors are told "very likely" corresponds to ">9 in 10," they are still making a qualitative estimate of that probability.

CHAPTER 2: TEMPERATURE-RELATED DEATH AND ILLNESS

Comment #	Page/line	Comment
22	P51/L21	Will human health projections really "reduce but not eliminate the increase in future deaths from heat"? Consider using "predicted increase" instead.
23	P51/L25	When talking about "working age adults", does it really mean that age group, or does it mean workers in various job categories that put that them at increased risk?

24	P51/L25	Try "the socially isolated, economically disadvantaged, and those with chronic illnesses, as well as some communities of color…" The first part of the list refers to individuals, and the latter to communities as a whole.
25	P84	Figure 3: cities or counties? Those look like counties. This needs to be fixed in the text too.

CHAPTER 3: AIR QUALITY IMPACTS

Comment #	Page/line	Comment
26	P89	Include PM in the discussion of the harmful effects of poor air quality.
27	P89/L28	Unbold "." after "…2009)"
28	P91/L11	NOx should be NO_x
29	P91/L26	Consider adding "in some areas" after "decrease", and add citations.
30	P93/L4	The number of premature deaths changes between "perhaps hundreds to thousands" (Page 102, line 32) to "tens to thousands" (page 93, line 4). The latter is probably more appropriate in this case.
31	P94/L15	Would not start this paragraph with "However".
32	P97/L14	Not sure the term "enter buildings at lower rates" is quite what was intended. Those species are also removed faster after entering. While the former may often be true, the more reactive species and larger particles are also removed faster in the building leading to lower levels. Potentially add "and are removed faster". There is also an issue with ultrafines, which can be removed quickly.

CHAPTER 4: VECTORBORNE DISEASES

Comment #	Page/line	Comment
33	P121	Table of Contents: capitalize "Disease" in "Lyme Disease"
34	P122	Contributing Authors: Suggest changing Mary Hayden and Andrew Monaghan affiliations to their primary affiliations.
35	P123	Key Finding 2: With respect to the text about northward expansion in habitat, is it only expansion, or is the southern limit likely to be bounded in some cases?
36	P123	Key Finding 4: Is this new? That may be ok. What is the difference between "vulnerability to VBD" and "risk for disease"? Should the "influence risk for disease occurrence" be "influence disease occurrence"?
37	P123/L14	What does "infection rate" mean/refer to? Is it the prevalence of infection in the vector?
38	P123/L20	What do "vulnerability to vectorborne disease" and "influence risk for disease occurrence" mean?
39	P124/L4	"carrier"
40	P124	Table: could mortality be included? LD is high on morbidity, but low on mortality. WNV is moderate on Morbidity but, compared with LD high on mortality.
41	P124	Caption: consistency of terms elsewhere "disease agents" is "infective pathogens"
42	P125/L10	Suggest adding "(especially when considering non-human hosts)" after "… relative abundance of disease carrying hosts"

43	P125/L18	Replace "carriers" with "hosts"
44	P125/L26	Missing citation that specifically addresses introduction & establishment Kilpatrick, A.M. and S. E. Randolph, 2012: Drivers, dynamics, and control of emerging vector-borne zoonotic diseases. *Lancet*, **380**(9857):1946-55, doi: 10.1016/S0140-6736(12)61151-9.
45	P126/L5	Standardize VB D vs V-B D vs V B D
46	P128/L7-11	Moore et al 2014 is not the most relevant citation. Replace Moore with: Falco, R. C. D. F. McKenna, T. J. Daniels, R. B. Nadelman, J. Nowakowski, D. Fish, and G. P. Wormser, 1999: Temporal relation between *Ixodes scapularis* abundance and risk for Lyme disease associated with erythema migrans. *American Journal of Epidemiology*, **149**(8):771-6. (See figure 1: http://aje.oxfordjournals.org/content/149/8/771.full.pdf)
47	P128/L15	Replace "transmitted" with "maintained"
48	P131	For consistency with other chapters, the "Research Highlights: Lyme Disease" should be a box.
49	P131/l28	Edit to clarify that Moore (2014) is not the source of the projections. That is, Moore et al. is not driven with downscaled simulations.
50	P133/L1-2	Clarify why the discrepancy.
51	P134/L4	Spelling inconsistency: change "mosquitos" to "mosquitoes"
52	P134/L38	Remove "," after United States

53	P135/L29	Replace "discovered" with "identified"
54	P135/L30	Insert "primarily" as in "… both viruses are primarily transmitted by…"
55	P136/L5-7	Nicely said
56	P136	Section 4.4.3: This section is a bit hard to read and could be clearer. The authors are trying to make a distinction between changes in the vectors and changes in disease. This is a critical distinction and addressed well in most places in this document. - "…range of projections over the next century.." given the context of just this chapter, this is not clear.
57	P137/L6	Question about citations: "…secondary to existing socioeconomic vulnerabilities…" As written this sentence implies that the citations refer to climate change influencing SES. - The Reiter and Gubler are DEN references talking about SES influencing DEN risk, not climate change influencing existing socioeconomic vulnerabilities. - Ramos should not be included here. They only speculate about possible SES associations "The only factor found to be associated with recent dengue infection in Brownsville was smaller lot size. This finding *could* [emphasis added] reflect denser concentration of people or could be related to socioeconomic factors.18,26"
58	P137	Add Yuma/San Luis to update DEN outbreaks in US
59	P139	"… reservoirs; however, the influence of climate change on the timing, prevalence, …" remove "however," it is grammatically redundant of the ";" and diminishes the significance of the second clause.
60	P140	Description of evidence missing additional earlier literature. For example Moore et al., 2014 is not the most relevant citation. Replace Moore with:

		Falco, R. C. D. F. McKenna, T. J. Daniels, R. B. Nadelman, J. Nowakowski, D. Fish, and G. P. Wormser, 1999: Temporal relation between *Ixodes scapularis* abundance and risk for Lyme disease associated with erythema migrans. *American Journal of Epidemiology*, **149**(8):771-6. (See figure 1: http://aje.oxfordjournals.org/content/149/8/771.full.pdf)
61	P140/L28	"There is low confidence that climate change will influence human incidence of LD." Is it low confidence that it *will* influence or it is low confidence on *how it will* influence?
62	P141/L5	"landscape" use a clearer term for the audience?
63	P141/L33	"There is low confidence that climate change will influence human cases of WNV." As with LD, is it low confidence that it *will* influence or it is low confidence on *how it will* influence? This is an important distinction. As written, the CDC is saying that climate change will not influence these diseases. One could argue that this is more a lack of evidence of how it may.
64	P142/L15	Remove "will"
65	P142/L19-20	"… which may disproportionately affect certain populations." This feels a little out of the blue.
66	Figure 2	Remove the empty circle "insignificant"?

CHAPTER 5: WATER-RELATED ILLNESS

Comment #	Page/line	Comment
67		Possible omissions from the discussion of water-related illness include: (1) the importance of regional variability associated with climate driven hydrological impacts and, in turn water-related illness, and (2) impacts associated with alterations to annual snowpack and snowmelt (e.g. water availability/quantity and quality). Highly

		regionalized variations in water-related illness should be discussed (or at least mentioned) in Section(s) 5.2 and/or 5.3, and a discussion of climate change-induced shifting patterns in snowpack/snowmelt (and possibly glacial mass balance) should be addressed. The Committee notes, however, that the primary category of disease for which this issue is relevant may be vectorborne diseases, especially arbovirus encephalitis (e.g., West Nile, Western equine, St Louis, etc.) and Lyme disease. See, for example, Reisen et al., 2008 and references therein. Thus, report authors may wish to include information about this in Chapter 4 instead.
68	P163/L4	Will warming expand seasons for all species?
69	P164	Table 1, Vibrio species: "blood poisoning" is not typically used by the medical profession; better might be "bloodstream infections."
70	P165	Table 1, Chemical Contaminants: it is not clear that inclusion of mercury and other chemicals in this table makes sense, despite the fact that ingestion of food containing such metals and compounds is a cause of "foodborne" illness.
71	P166/L1-4	"Our understanding…is complicated by limited case data": is vague. Given what follows, one can assume it is meant to refer to underreporting or incomplete reporting of reportable (and even more so non-reportable) conditions; if so, this should be re-written. In addition, the sentence that begins "All other reporting is voluntary…" is misleading-data concerning many legally reportable conditions are incomplete because the reporting, while legally mandated, depends on both correct diagnosis and willingness of providers and labs to report to passive surveillance systems. Data concerning conditions that are not "reportable" by law typically must and do come from special studies and surveys, not from "voluntary reporting."
72	P168/L8-10	The sentence that begins "The majority of drinking water outbreaks…" may imply that Legionella infections/Legionnaires' disease cases are the result of ingestion of contaminated drinking water. While there is disagreement about the relative importance of inhalation of contaminated aerosols versus aspiration of contaminated water in the causation of Legionella pneumonia, few experts in the field would refer to outbreaks of legionellosis as "drinking water outbreaks."

73	P170/L27	While the Committee does not dispute the statement that ". . . contamination of marine waters is a significant risk for illness," a statement that is more specific with regard to what types(s) of illness this statement refers to should be included.
74	P171/L4	Wrong degree symbol
75	P172/L1-7	The first part of the first two sentences clearly refers to the effects of higher sea surface temperatures on "seasonal window" and "geographic range," while the second sentence is clearly referring to "higher levels" of Vibrios; these are *not* equivalent, and one does not, necessarily, imply the other.
76	P172/L5	Note that Urquhart et al. (2014) found that projections of *Vibrio* increase at high SSTs are highly sensitive to the structure of the statistical model (Urquhart, E. A., B. F. Zaitchik, D. W. Waugh, S. D. Guikema, and C. E. Del Castillo, 2014: Uncertainty in Model Predictions of *Vibrio vulnificus* Response to Climate Variability and Change: A Chesapeake Bay Case Study. *PLoS ONE* **9**(5):e98256, doi: 10.1371/journal.pone.0098256).
77	P172/L25, 27	It is not clear that "intestinal" is the correct word in either of the lines; "enteric" might be closer to what is intended.
78	P178	Section 5.6 (Emerging Issues): much of the concern about ingestion of mercury, pesticides, etc. relates to the risk of "chronic" health outcomes, such as endocrine disorders, autism, cancer, etc. rather than acute illnesses, such as gastroenteritis, hepatitis A, shellfish toxin-related illness, etc. Some explanation/discussion of the differences between acute illnesses caused by a single exposure and with an incubation period of minutes/hours to days and weeks versus chronic diseases in which repeated exposure can/may lead to an increased risk of a "chronic condition" years or decades later might be helpful to include here.
79	P181/L20	Is the word "actual" really helpful here?
80	P181/L25	The word "issues" is vague and unhelpful.

81	P184/L2	Missing a period after "…(Zamyadi et al 2012)"

CHAPTER 6: FOOD SAFETY, NUTRITION, AND DISTRIBUTION

Comment #	Page/line	Comment
82	P215/L23	Move "." to end of sentence.
83	P224/L2	Remove "a" from "lead" so that it says "… rain led…"

CHAPTER 7: EXTREME EVENTS

Comment #	Page/line	Comment
84	P261/L36	Johnson and Fonseca 2014's study on the effect on reproductive success under conditions of forced egg retention (by removing water sources in the lab) is an inappropriate citation. Suggest looking at the literature they cite in the introduction, including, at a minimum, the Shaman article that everyone cites for WNV and drought: Shaman, J., J.F. Day, and M. Stieglitz, 2005: Drought-induced amplification and epidemic transmission of West Nile virus in southern Florida. Journal of Medical Entomology, **42** 134–141.
85	P263	Is C. gatti an example of impacts of climate extremes?
86	P266/L33	Remove everything after "..increase infectious disease risk." This is inaccurate and not supported by the citation "Patz & Uejio."
87	P290	Figure 2—Pregnant women and newborns are not additional risk factors.

CHAPTER 8: MENTAL HEALTH AND WELL-BEING

Comment #	Page/line	Comment
88		Key Finding—punctuation not consistent with other chapters "…[]." not "… .[]"
89	P299/L16	Can "most" be quantified?
90	P299/L31-38	It also seems that the prior paragraph could largely be included in the heat chapter rather than here, since it is largely about issues other than mental health. If the authors would like to expand the scope of the chapter to well-being more generally, which is reflected in this paragraph, there are many other issues that might be included throughout the chapter.
91	P300/L1-6	The characterization of increased crime and violence due to heat is a bit lopsided. The literature is more nuanced than this. In addition, there is literature that addresses the relationship between heat, stress and interpersonal conflict that would helpful to mention in that section and also in the overall chapter.
92	P300/L20	Replace West Nile virus with WNV
93	P300/L27-30	Move to previous paragraph on WNV
94	P301/L9	Remove "." after "…future."
95	P301	Third paragraph: describe hybrid risk in more detail.
96	P302	Under populations of concern, farmers are called out, but no detail is given. Since farmers are not discussed in Chapter 9 as a vulnerable population, a few sentences regarding occupational groups who will be most economically affected by climate change (fishermen, farmers) would be helpful.
97	P303	The section on Children should include the research out of the Colorado Center on Disasters regarding the creation of resilience and

		post-disaster recovery that improves childhood outcomes. There may also be other research in this arena to include. Again, it is important to make sure that research showing answers, not just the impacts and problems, is included in order to address the interests of broad audiences who might be reading this report.
98	P305	In the first paragraph on economically disadvantaged, need to discuss that this population may lack access to care for mental health issues.
99	P305	In the second paragraph, any discussion of emergency workers and first responders should be expanded to include health care workers and public safety workers who often become first responders in acute climatic events.
100	P305	The issue of access is particularly important to include in the section on Low Income populations, as it is a problem that generally affects this group more than others.
101	P306/L12-14	Remove line "Those who sleep outdoors at night…" or find appropriate citation. Ramos and Svoboda are citing a non-peer-reviewed source and the link is no longer valid—could not be verified.
102	P308/L26	"With regards to…" remove "s"
103	P309	Research needs. In reading this section, there is a much more realistic discussion of the limitations of current data systems and monitoring. Much better than the discussion in Chapter 9 that has a specific section on monitoring vulnerable populations. The chapters need to cross reference each other on this important topic.

CHAPTER 9: CLIMATE-HEALTH RISK FACTORS AND POPULATIONS OF CONCERN

Comment #	Page/line	Comment
104		The structure of this chapter is fairly redundant. It is not always clear why a section is a section and how it repeats a previous section.
105		The treatment of VBD is not consistent and seems to be trying to make distinctions where there may not be evidence to support a distinction.
106		Suggest replacing the term Hispanic with the word Latino (as we are largely referring to persons from North, Central, and South America and the Caribbean, rather than from Spain).
107	P338/L36	Fix font of comma after hazard.
108	P339/L6	Figure 2 does not explain what the text says it is supposed to explain (it does not appear to be related to the description of the framework given in the text).
109	P339/L30	Add “and other air pollutants” after aeroallergens.
110	P340/L6	Condition of Infrastructure should include reference to “access” to infrastructure. For example, access to communication infrastructure can influence a person’s vulnerability.
111	P341/L6	Should read “see Section 9.3.2.” There is no section 9.2.2.
112	P342/L11	Insert “inadequate” before “access to health care.”
113	P342/L18	Insert “lack of access to emergency communications” after “poor quality housing.”
114	P342/L21	Insert “such as” after “adaptation measures” and give an example.

115 P343/L8-10 "Because of poor housing conditions and other SE factors, some populations of color and low-income populations may be at risk for exposures to disease carried by vectors such as fleas, ticks and mosquitoes Ramos et al 2008 (See also Chapter 4 VBD)."

(1) Not a valid interpretation of Ramos (DEN on the TX-MX border). From Ramos: "The only factor found to be associated with recent dengue infection in Brownsville was smaller lot size. This finding could reflect denser concentration of people or could be related to socioeconomic factors.18,26"

(2) Not sure a DEN paper can be extrapolated to all vectors

(3) Doubt Chapter 4 would support this statement

(4) Making statements like this without support leads to spurious conclusions, and an assumption that we know more than we actually do about VBD in the United States

116 P343/L11 The first sentence (on nutritional content) is unclear and it would be helpful to the reader to include a short explanation. Consider adding information to connect the remainder of the paragraph to climate change.

117 P343/L18 Stress-related mental health impacts are also due to greater vulnerability, not just access to mental health care.

118 P344/L15 The sentence on mercury exposure should be strengthened. Mercury also affects all life stages as it is a potent neurotoxin. Perhaps add a reference to salmon in the western and northwestern U.S.

119 P346/L29 Add space between "Impacts). Children"

120 P347/L7-10 "Climate change is potentially driving the increasing prevalence and exposure to diseases spread by ticks and mosquitoes [note: add an "e" here], as the length of warm seasons and the habitat suitability … "

- This is consistent with Chapter 4 VBD

- Given the paucity of data on children and pregnant women, perhaps this piece needs to pull international studies/data? Usually think of a lot of the mosquito borne disease effecting children (usually because of first exposure).

- In this section of "Children and Pregnant Women" should pregnant women at least be addressed in so much as a statement that

we do not know? Rather than an omission, explicitly stating that this is a gap in the literature may be important especially since part of this document's goal is to inform policy and research priorities.

121	P347/L16	Insert "increasing costs" after "affecting supplies."
122	P347/L23	"Pregnancy, the developing fetus, and newborns are considered.. vectorborne diseases…" Unfortunately, given the literature cited in the preceding section, there is little to no evidence to support this. Suggest that VBD be pulled out of this sentence and given its own sentence, for example: "Given the paucity of U.S. based literature regarding VBD and these risk populations, we cannot estimate the effect, however, it is known that these populations tend to be more severely affected and, until there is literature to support it, we can assume that they will disproportionality experience negative impacts."
123	P349/L31-37	This paragraph is well written and could be duplicated in other sections for better clarity.
124	P350/L9-15	Older Adults "VBD pose a greater …" Citation?
125	P350/L25	Is urban heat island a 'Non-Climate Stressor"?
126	P350/L28	Housing stocks? What is that?
127	P351/L23	This section speaks only about outdoor workers, who may be at great and most obvious risk, but warehouse workers, for example, with no air conditioning and demanding workloads are also at high risk for heat related illness, especially in cases where employers manage from air conditioned offices. Management's awareness of changes in conditions in the workplace as a result of climate change will influence the level of exposure of employees to extreme conditions, both indoors and outdoors.
128	P352/L27-29	This is more consistent with the language in Chapter 4
129	P352/L34-36	U.S. vs United States

130	P353/L4	Military and VBD—the literature shows that military are currently at risk for VBD in a very different way than most U.S. citizens, but Chapter 4 does not say anything about Military. The reference to Chapter 4 is inappropriate. - Similarly, L 14 Lyme disease and military? That does not seem like the best example of VBD risks to military ppns. LD is Northeast and Upper Mid-west, most military bases are South. Spotted fevers may be a better example, or even leishmaniasis (Old World Leishmaniasis: An Emerging Infection among Deployed U.S. Military and Civilian Workers, Weina, ClinID, 2004: 39(11)) or, if it needs to be U.S. acquired, WNV. - LD gets reported at bases all over the United States—this disconnect between where the vector is (Chapter 4) and where the reports are coming from seems like something the CDC should look into in a DOD-CDC collaboration. - Question whether valley fever might not need to be included here. Historically in the United States this has been a problem and it somewhat continues to be. - Try "Coccidioidomycosis in the U.S. military—A review" Crum-Cianflone, Ann NY Acad Sci 2007 - Suggest a little bit of a literature review to support these statements about military and VBD.
131	P354/L27	Change "introduction chapter" to "chapter on Climate Change and Human Health" here and in line 30.
132	P355/L8	Change punctuation as follows "… Nordone t al 2009; See also Ch.8: Mental Health and Well-Being). In…"
133	P357	Emerging Issues?
134	P387	Figure 3. "Young children are particularly sensitive to … death," suggest removing "and death" so that it reads "Young children are particularly sensitive to … heat-related illness, "

APPENDIX: TECHNICAL SUPPORT DOCUMENT

Comment #	Page/line	Comment
135		SPAs are listed but never explained or referenced.
136		Exposure Response modeling: The form of the relationship (e.g., linear or non-linear) is another major source of uncertainty that is not mentioned here.
137	P404	Figure 3 is not that useful. Also the panels do not show "model output."

Appendix B
Statement of Task

An ad hoc committee will conduct an independent review of the report The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. The review will provide an overall critique of the draft report and address the following questions:

- Does the report meet its stated goals?
- Is the report responsive to the nation's needs for information on the health impacts of climate change and their potential implications?
- Does the report accurately reflect the scientific literature? Are there any critical content areas missing from the report?
- Are the approaches to quantitative modeling reasonable and adequately supported by existing literature?
- Are the findings documented in a consistent, transparent, and credible way?
- Are the report's key messages and graphics clear and appropriate? Specifically, do they reflect supporting evidence, include an assessment of likelihood, and communicate effectively?
- Are the research needs identified in the report appropriate?

This study was sponsored by the United States Global Change Research Program, administered by the National Aeronautics and Space Administration.

Appendix C
Committee Biographies

Daniel S. Greenbaum *(Chair)* joined the Health Effects Institute as its President and Chief Executive Officer on March 1, 1994. In that role, Mr. Greenbaum leads HEI's efforts, supported jointly by US EPA and industry, with additional funding from US DOE, Federal Highway Administration, US AID, the Asian Development Bank, and foundations, to provide public and private decision makers—in the United States, Asia, Europe, and Latin America—with high quality, impartial, relevant and credible science about the health effects of air pollution to inform air quality decisions in the developed and developing world. Mr. Greenbaum has been a member of the U.S. National Research Council Board of Environmental Studies and Toxicology and vice chair of its Committee for Air Quality Management in the United States. He served on the NRC Committee on The Hidden Costs of Energy and on their Committee on Science for EPA's Future. Mr. Greenbaum also chaired the EPA Blue Ribbon Panel on Oxygenates in Gasoline which issued the report Achieving Clean Air and Clean Water and EPA's Clean Diesel Independent Review Panel, which reviewed technology progress in implementing the 2007 Highway Diesel Rule. In May 2010, Mr. Greenbaum received the Thomas W. Zosel Outstanding Individual Achievement Award from the U.S. EPA for his contributions to advancing clean air. Mr. Greenbaum has over three decades of governmental and non-governmental experience in environmental health. Just prior to coming to HEI, he served as Commissioner of the Massachusetts Department of Environmental Protection from 1988 to 1994, where he was responsible for the Commonwealth's response to the Clean Air Act, as well as its award-winning efforts on pollution prevention, water pollution and solid and hazardous waste. Mr. Greenbaum holds Bachelor's and Master's degrees from MIT in City Planning.

Heidi Brown has worked on a variety of human (e.g., valley fever, *Helicobacter pylori*), animal (e.g., rabies, canine heartworm) and vector-borne diseases (e.g., West Nile virus, dengue, chikungunya, Chagas, bluetongue, plague, tularemia) using tools ranging from math modelling to remote sensing to epidemiology to ecological niche modeling. Many of these diseases are endemic to the United States and many of the diseases will feel the effects of climate change. Moreover, her recent work spearheading the chapter, Human Health, in the Assessment of Climate Change in the Southwest United States (part of the U.S. National Climate Assessment process) attests to both her commitment to the science and the communication of the impacts of climate change on health. She is adept at cross-discipline discussions as highlighted by her affiliation with multiple departments across the University of Arizona campus, for example, while her home department is in the College of Public Health, she is affiliate faculty at the Center for Insect Science and the School of Geography and Development, as well as multiple institutions on campus. She is also very active in the NOAA Regional Integrated Science and Assessment (RISA) Climate Assessment for the Southwest (CLIMAS) program. She received a Ph.D. in 2007 from Yale University.

Peter Daszak is President of EcoHealth Alliance, a U.S.-based organization which conducts research and outreach programs on global health, conservation and international development. Dr. Daszak's research has been instrumental in identifying and predicting the impact of emerging diseases across the globe. His achievements include identifying the bat origin of SARS, identifying the underlying drivers of Nipah and Hendra virus emergence, producing the first ever global emerging disease 'hotspots' map, identifying the first case of a species extinction due to disease, coining the term 'pathogen pollution', and discovering the disease chytridiomycosis as the cause global amphibian declines. Dr. Daszak is a member of the IOM's Forum on Microbial Threats, the NRC Advisory Committee to the USGCRP, the Supervisory Board of the One Health Platform, the One Health Commission Council of Advisors, the CEEZAD External Advisory Board; has served on the IOM Committee on global surveillance for emerging zoonoses, the NRC committee on the future of veterinary research, the International Standing Advisory Board of the Australian Biosecurity CRC; and has advised the Director for Medical Preparedness Policy on the White House National Security Staff on global health issues. Dr. Daszak won the 2000 CSIRO medal for collaborative research on the discovery of amphibian chytridiomycosis, is the EHA institutional lead for USAID-EPT-PREDICT and PREDICT-2, is on the Editorial Board of One Health, Conservation Biology, and Transactions Roy. Soc. Trop. Med. Hygiene, and is Editor-in-Chief of the journal EcoHealth. He received a Ph.D. in Parasitology from the University of East London.

Linda McCauley began her tenure as Dean of the Nell Hodgson Woodruff School of Nursing at Emory University in May 2009. Dr. McCauley is a national leader in the area of research on environmental exposures and conducts interdisciplinary research using participatory research models to study pesticide exposures among minority communities. Her work aims to identify culturally appropriate interventions to decrease the impact of environmental and occupational health hazards in vulnerable populations, including workers and young children. Dr. McCauley has been awarded research funding from the National Institutes of Health, the Centers for Disease Control and Prevention, the Department of Defense, and the Department of Veterans' Affairs. Her research has resulted in more than 100 publications, ongoing consultations, leadership on occupational and environmental advisory panels, and testimony to governmental oversight bodies. Prior to coming to Emory, Dr. McCauley held academic appointments at the University of Cincinnati, Oregon Health & Science University, and the University of Pennsylvania. She received her BSN from the University of North Carolina-Chapel Hill and her master's in nursing from Emory University. She completed her doctorate in Environmental Health at the University of Cincinnati.

Sabrina McCormick is a sociologist and filmmaker. Dr. McCormick takes an in-depth, mechanistic approach to understanding how climate change gets under the skin. She works on extreme impacts of climate-related phenomena like heat waves, emergent vector-borne disease, and climate-related disasters. She recently served as a Lead Author on the Special Assessment of the Nobel Prize-winning Intergovernmental Panel on Climate Change entitled Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Dr. McCormick's award-winning documentary film work aims to transform science into stories that compel social action. She was an Associate Producer on The Years of Living Dangerously, an eight-part Showtime series that earned the Emmy Award for Best Documentary in 2014. Dr.

McCormick was a Science & Technology Policy Fellow of the American Association for the Advancement of Science working in the Global Change Research Program at the Environmental Protection Agency from 2009 to 2011, during which time she advised Congress, the State Department, and the White House on climate change issues. She is currently Associate Professor in the Environmental and Occupational Health Department in the School of Public Health and Health Services at George Washington University, and Senior Fellow at the Wharton Risk Management and Decision Processes Center at the University of Pennsylvania. She completed her Ph.D. in Sociology at Brown University in 2005.

Christopher J. Portier is an expert in the design, analysis, and interpretation of environmental health data. His research efforts and interests include such diverse topics as molecular biology, risk assessment, biostatistics, bioinformatics, epidemiology, carcinogenesis, development, genetically modified foods, genomics, climate change, EMF, and health economics. Dr. Portier has contributed to the development of risk assessment guidelines for national and international governments and agencies and has directed or contributed significantly to numerous scientific reviews and risk assessments, most notably those for dioxins, aflatoxins, electromagnetic fields, diesel particle emissions and climate change. Dr. Portier has served on U.S. National Academy of Sciences committees, has served on USEPA's Science Advisory Board and USEPA's Science Advisory Panel, has served as an advisor to the Finnish Academy of Sciences, has been a member of numerous WHO/IARC scientific committees, and as a reviewer for grants in the United States, the European Union, and many other sponsoring organizations. He has received numerous awards including the Spiegelman Award from the American Public Health Association and the Outstanding Practitioner of the Year Award from the International Society for Risk Analysis. He is an elected Fellow of the International Statistics Institute, the World Innovation Foundation, and the American Statistical Association. Until 2013, Dr. Portier was the Director of the National Center for Environmental Health at the Centers for Disease Control and Prevention in Atlanta and the Director of the Agency for Toxic Substances and Disease Registry. Prior to CDC, Dr. Portier was with the National Institute of Environmental Health Sciences where he served as the NIEHS Associate Director, Director of the Environmental Toxicology Program, and Associate Director of the National Toxicology Program, and Senior Scientific Advisor to the Director. During his 32 years at NIEHS, Dr. Portier maintained his own research laboratory focused on the impact of the environment on human health. Dr. Portier received a B.Sc. degree (1977) in mathematics and M.S. (1979) and Ph.D. (1981) degrees in biostatistics.

Arthur Reingold is Professor and Head of the Division of Epidemiology at the School of Public Health at the University of California, Berkeley, and holds concurrent faculty positions at UCSF. Board-certified in internal medicine, Dr. Reingold has devoted the past 30+ years to the study and the prevention and control of various infectious diseases in the United States and in countries in Africa, Asia, and Latin America, including epidemic meningitis in West Africa and Nepal; pneumonia in Indonesia; influenza, Lyme Disease, and other infectious diseases in the United States; and numerous vaccine preventable diseases in multiple settings. He has served as a member and Vice Chair of WHO's Strategic Advisory Group of Experts (SAGE) on immunizations, the Advisory Committee on Immunizations Practices (ACIP) of the U.S. Department of Health and Human Services, and the External Advisory Committee of NIH's Fogarty International Center, among many other advisory committees, as well as on numerous

IOM committees, including a committee examining the U.S. Quarantine system and committees on vaccines and vaccine preventable diseases. He has published almost 300 original research papers on a wide variety of infectious disease topics and has numerous research and training grants from NIH and CDC, including a cooperative agreement from CDC for the California Emerging Infections Program, which he has directed or co-directed since its inception in 1994. He was elected to membership in the IOM in 2003, as well as to Fellowship in the Infectious Diseases Society of America, the AAAS, and various other honorary and scientific societies, as well as having served as President of the Society for Epidemiologic Research and of the American Epidemiological Society. He received his M.D. from the University of Chicago.

Armistead (Ted) G. Russell is the Howard T. Tellepsen Chair and Regents' Professor at the Georgia Institute of Technology. Professor Russell arrived at Georgia Tech in 1996, from Carnegie Mellon University, and has expertise in air quality engineering, with particular emphasis in air quality modeling, air quality monitoring and analysis. He has been a member of a number of the National Academies Committees, including chairing the Committee to Review EPA's Mobile Model and the Committee on Carbon Monoxide Episodes in Meteorological and Topographical Problem Areas, and serving on the committee on Tropospheric Ozone Formation and Measurement, the committee on ozone forming potential of reformulated fuels and the committee on Risk Assessment of Hazardous Air Pollutants. Dr. Russell was a member of the EPA's Clean Air Scientific Advisory Committee and the subcommittee on Air Quality Modelling Subcommittee of the Advisory Council on Clean Air Compliance Analysis. He was a member of the EPA FACA Subcommittee on Ozone, Particulate Matter and Regional Haze, the North American Research Strategy for Tropospheric Ozone and California's Reactivity Science Advisory Committee. Dr. Russell earned his MS and PhD degrees in Mechanical Engineering at the California Institute of Technology in 1980 and 1985, conducting his research at Caltech's Environmental Quality Laboratory. His BS is from Washington State University (1979).

Cristina Tirado has been working on climate and environmental change, sustainable development, food and health issues with WHO, FAO, governmental and nongovernmental organizations and universities worldwide for 20 years. Currently she serves as adviser for the Pan American Health Organization and is adjunct professor at the School of Public Health of the University of California at Los Angeles. Her policy research focuses on the co-benefits to health of climate change of adaptation and mitigation in the food & agriculture systems (sustainable production, consumption and waste reduction), and the co-benefits of green urban development. Cristina is moderator of the U.N. Standing Committee on Nutrition's Working Group on Climate Change and Nutrition, contributing author of the Intergovernmental Panel on Climate Change's (IPCC) last assessment report and she is a health advocate at the UN Framework Convention on Climate Change Conferences of the Parties. As director of the Center for Public Health and Climate Change at PHI she has been mainstreaming Climate Change and Health at the UN Conference on Non Communicable Diseases at the UN General Assembly, she has contributed to UNFCCC work and she has been a partnerships driver at the UN Conference Rio+20. Cristina has co-authored numerous research and policy publications and books. She is a DVM and has M.S. and Ph.D. degrees in environmental sciences from Cornell University.

Benjamin Zaitchik is an assistant professor within the Earth and Planetary Sciences Department at Johns Hopkins University. His research is directed at understanding, managing, and building resilience to climatic and hydrologic variability and change. He looks for new approaches to controlling human influences on climate and water resources at local, regional and global scales, and explores improved forecast systems and methods of risk assessment. His work has received funding from NASA, the National Institutes of Health and the National Science Foundation, and appeared in the Journal of Climate and Water Resources Research, among others. Dr. Zaitchik is interested in helping provide new insights in such crucial areas as transboundary water management, climate-informed disease early warning systems, and adaptation strategies in subsistence agricultural communities. He received his Ph.D. in climate science from Yale University.