The Future of Research on Climate Change Impacts on Water

A Workshop Focusing on Adaptation Strategies and Information Needs

Subject Area: Water Resources and Environmental Sustainability

WERF6C10

The Future of Research on Climate Change Impacts on Water

A Workshop Focusing on Adaptation Strategies and Information Needs

WATER RESEARCH FOUNDATION℠

ADVANCING THE SCIENCE OF WATER®

About the Water Research Foundation

The Water Research Foundation (formerly Awwa Research Foundation or AwwaRF) is a member-supported, international, 501(c)3 nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.

The Foundation's mission is to advance the science of water to improve the quality of life. To achieve this mission, the Foundation sponsors studies on all aspects of drinking water, including resources, treatment, distribution, and health effects. Funding for research is provided primarily by subscription payments from close to 1,000 water utilities, consulting firms, and manufacturers in North America and abroad. Additional funding comes from collaborative partnerships with other national and international organizations and the U.S. federal government, allowing for resources to be leveraged, expertise to be shared, and broad-based knowledge to be developed and disseminated.

From its headquarters in Denver, Colorado, the Foundation's staff directs and supports the efforts of more than 800 volunteers who serve on the board of trustees and various committees. These volunteers represent many facets of the water industry, and contribute their expertise to select and monitor research studies that benefit the entire drinking water community.

The results of research are disseminated through a number of channels, including reports, the Web site, Webcasts, conferences, and periodicals.

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More information about the Foundation and how to become a subscriber is available on the Web at www.WaterResearchFoundation.org.

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A Workshop Focusing on Adaptation Strategies and Information Needs

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National Oceanic and Atmospheric Administration
Washington, DC 20230

U.S. Environmental Protection Agency
Washington, D.C., 20460

National Aeronautics and Space Administration
Washington, DC 20546

Water Environment Research Foundation
Alexandria, VA 22314

and

University Corporation for Atmospheric Research (UCAR)
Boulder, CO 80307

Published by:

WATER RESEARCH FOUNDATION℠

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This workshop was funded by the University Corporation for Atmospheric Research (UCAR) under cooperative agreement No. NA06OAR4310119 with the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Commerce (DOC). UCAR assumes no responsibility for the content of the research study reported in this publication or for the opinions or statements of fact expressed in this report. The mention of trade names for commercial products does not represent or imply the approval or endorsement of UCAR. This report is presented solely for informational purposes. Preparation of the workshop final report was funded separately by the U.S. Environmental Protection Agency (EPA) under contract GS-10F-0299K to Stratus Consulting. The views expressed in this report represent those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

ISBN 978-1-60573-131-5

Printed in the U.S.A.

Printed on recycled paper

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FOREWORD

The Water Research Foundation (Foundation) is a nonprofit corporation that is dedicated to the implementation of a research effort to help utilities respond to regulatory requirements and traditional high-priority concerns of the industry. The research agenda is developed through a process of consultation with subscribers and drinking water professionals. Under the umbrella of a Strategic Research Plan, the Research Advisory Council prioritizes the suggested projects based upon current and future needs, applicability, and past work; the recommendations are forwarded to the Board of Trustees for final selection. The Foundation also sponsors research projects through the unsolicited proposal process; the Collaborative Research, Research Applications, and Tailored Collaboration programs; and various joint research efforts with organizations such as the U.S. Environmental Protection Agency, the U.S. Bureau of Reclamation, and the Association of California Water Agencies.

This publication is a result of one of these sponsored studies, and it is hoped that its findings will be applied in communities throughout the world. The following report serves not only as a means of communicating the results of the water industry's centralized research program, but also as a tool to enlist the further support of the nonmember utilities and individuals.

Projects are managed closely from their inception to the final report by the Foundation's staff and large cadre of volunteers who willingly contribute their time and expertise. The Foundation serves a planning and management function and awards contracts to other institutions, such as water utilities, universities, and engineering firms. The funding for this research effort comes primarily from the Subscription Program, through which water utilities subscribe to the research program and make an annual payment proportionate to the volume of water they deliver and consultants and manufacturers subscribe based on their annual billings. The program offers a cost-effective and fair method for funding research in the public interest.

A broad spectrum of water supply issues is addressed by the Foundation's research agenda: resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide the highest possible quality of water economically and reliably. The true benefits are realized when the results are implemented at the utility level. The Foundation's trustees are pleased to offer this publication as a contribution toward that end.

Roy L. Wolfe, Ph.D.
Chair, Board of Trustees
Water Research Foundation

Robert C. Renner, P.E.
Executive Director
Water Research Foundation

ACKNOWLEDGMENTS

The authors wish to thank the National Oceanic and Atmospheric Administration (NOAA), University Corporation for Atmospheric Research (UCAR), and the U.S. Environmental Protection Agency (EPA) for collaborating on this project. In addition, the authors thank the National Aeronautics and Space Administration (NASA), the Water Research Foundation (WaterRF), and the Water Environment Research Foundation (WERF) for supporting and helping execute this project. Many individuals contributed information, insights and assistance to this effort. In particular, the authors would like to thank the following individuals who dedicated many hours making the workshop a success: Nancy Beller-Simms and Anne Waple from NOAA; Tom Johnson, Karen Metchis and Rachael Novak from EPA; David Toll from NASA; Kenan Ozekin from WaterRF; Claudio Ternieden and Lauren Fillmore from WERF; and Kathy Jacobs from the White House Office of Science and Technology Policy.

A special thank you goes to the workshop workgroup chairs, co-chairs and participants for their hard work before, during, and after the workshop. Workgroups chairs and co-chairs were: Art Umble and Dionne Driscoll for Flooding and Wet Weather Implications, Peter Ruffier and Lorraine Janus for Water Quality, Douglas Yoder and Peter Schultz for Coastal Zone, Gregg Garfin and Paul Fleming for Water Supply and Drought Implications, and Harold Reed and Cheryl Stewart for Water and Energy Nexus.

EXECUTIVE SUMMARY

This report summarizes insights from a workshop to identify research needs – and related decision support tools – to help practitioners develop climate change adaptation strategies for water supply, wastewater, and stormwater management. The workshop also reflects an outreach effort by the federal agencies to communicate with, and learn from, the community of water professionals who are the intended end users of federal research efforts in this area. The collaborators on this workshop were the National Oceanographic and Atmospheric Administration and University Corporation for Atmospheric Research, U.S. Environmental Protection Agency, and the National Aeronautics and Space Administration. The water industry partners were the Water Research Foundation and the Water Environmental Research Foundation.

The workshop, held in Denver, Colorado, on August 31 and September 1, 2010, included over 80 researchers and practitioners. The participants included water and wastewater utility professionals, other water and wastewater management practitioners and researchers, staff members from sponsoring and participating federal agencies and water industry foundations. On September 2, 2010, the Office of Science and Technology Policy led a listening session with these same practitioners regarding input for the National Climate Assessment.

The majority of the workshop activities revolved around facilitated workgroups defined by five topic areas: Flooding and Wet Weather, Water Quality, Coastal Zone Management, Water Supply and Drought, and the Water-Energy Nexus. The primary objective, for the workgroups, was to identify research needs to support water, wastewater, and related planning within each of the five topic areas. The participants were guided to focus on *key decisions* that utilities and other water resource managers need to make – that may be *climate-sensitive* – on infrastructure, water resources, and other *long-lived and costly investments.* The workgroups identified research needs, and developed outlines for those research projects identified as most important by each group. Approximately 50 research needs projects of high value for decision support were identified and described.

There were several key themes that ran across the workgroups; these include the following:

Theme A: Developing a fundamental decision-making process for adaptation in the context of uncertainty. Several project ideas were developed across workgroups that recognize the inevitable high degree of uncertainty that will exist in developing region-specific, climate change impact projections. Given that climate change-related projections (such as seasonal precipitation, storm intensity, flood severity and frequency, and so forth) can only be developed with relatively high degrees of uncertainty, it will be necessary for utilities and other water resource managers to have tools and approaches that provide practical and sound ways for assessing their vulnerabilities and making sound adaptation and related planning decisions under conditions of high uncertainty.

Theme B: Evolving engineering and planning paradigms to increase flexibility. Related to Theme A's recognition of the need to support suitable decision-making in the face of uncertainty, several workgroups identified research needs associated with increasing flexibility in both training/education, as well as in process and engineering design. Flexibility and adaptive management are hallmarks of sound adaptation planning and decision-making under high degrees of uncertainty regarding future conditions.

Theme C: Improving communication. Multiple workgroups identified the need for better ways to communicate issues related to climate change and associated adaptation planning. Some of the communication-related ideas reflect a need to effectively convey the value and rationale of appropriate adaptation actions to various audiences (e.g., governing boards, city councils, rate regulators, customers, voters), regardless of the uncertainties about future climate. The communication projects generally recognize that while uncertainties are inevitable, they do not eliminate the need for suitable climate change-related planning and decision-making (but they do make explaining and justifying adaptation programs more difficult).

Theme D: Coordinating development of consistent regional data/information for planning scenarios that are useful for water utilities/downscaling models.[1] This theme is represented by several workgroups with research project ideas related to providing better and more useful spatially-relevant climate change data to utilities and other water resource managers. In particular, downscaled climate model data would be provided in a format that can be used by utilities. Several projects tie into the previously-described themes related to uncertainty, and to conveying to decision-making practitioners the meaning and limitations of downscaled or other available data regarding regionally-scaled climate change impacts. A key recognition expressed across these projects is the need to assist practitioners to understand and properly interpret region-specific data, given the complexities and the uncertainties inherent in regional climate change projections.

Theme E: Compiling and using observed data. Projects were identified across workgroups reflecting the value of doing more research related to collecting and/or interpreting climate-related data, especially as they relate to improving the ability to observe important current trends and forecast extreme events. These data would be useful for a wide range of adaptation planning activities, and would be vital to adaptive management approaches, whereby entities adjust their actions based on new climate information as it becomes available.

Theme F: Integrating adaptation and mitigation approaches. Several research ideas were identified that reflect the fact that there are instances in the water and wastewater sector where mitigation and adaptation may be two sides of the same coin. Hence, research could assist in identifying and improving ways in which energy use and carbon footprints may be reduced in the water and wastewater sectors, while concurrently assessing how these mitigation-related activities may assist (or hamper) utilities with their adaptation planning.

Theme G: Promoting institutional changes. Multiple workgroups identified research topics that touched on the need to examine how key institutional arrangements may need to be modified in order to enhance the ability of utilities to better plan for and adapt to climate change. The

[1]. The meaning of “regional” needs to be defined, and may vary by application. Suitable “regional” scales may include the following: watershed, water management district, water basin, municipality, and climate zones.

institutional activities mentioned include development of regulatory regimes, design standards, and training and education.

Theme H: Examining the potential role of decentralized and hybrid systems. Several research ideas touched on the issues of decentralization in wastewater management or water supply, and the suitable role of decentralized approaches and technologies as part of adaptation planning. Key questions to explore include examining the manner in which decentralized or hybrid systems may make communities more (or less) flexible, redundant, and resilient with respect to climate change impacts.

In addition to the cross-cutting themes mentioned above, each workgroup recognized that there are a wide variety of ways in which climate change can significantly impact water supply, water quality, wastewater management, and related planning efforts. The commonalities across topic areas reflect a recognized need for better science and related technical information, and also for the tools to facilitate prudent and appropriate use of that information by utility managers to make sound adaptation decisions.

INTRODUCTION

This report summarizes insights from a workshop to identify research needs – and related decision support tools – to help practitioners develop climate change adaptation strategies for water supply, wastewater, and stormwater management. The workshop also reflects an outreach effort by the federal agencies to communicate with, and learn from, the community of water professionals who are the intended end users of federal research efforts in this area. The leaders of the workshop were the National Oceanographic and Atmospheric Administration (NOAA) and University Corporation for Atmospheric Research (UCAR), U.S. Environmental Protection Agency, and the National Aeronautics and Space Administration. The water industry partners were the Water Research Foundation and the Water Environmental Research Foundation.

The workshop was held in Denver, Colorado, on August 31 and September 1, 2010. The insights reported here were derived by a set of over 80 researchers and practitioners. The participants included water and wastewater utility professionals, other water and wastewater management practitioners and researchers, staff members from sponsoring and participating federal agencies, and staff from the Water Research Foundation (WaterRF) and Water Environment Research Foundation (WERF). On September 2, 2010, the Office of Science and Technology Policy led a listening session with these same practitioners regarding input for the National Climate Assessment. A full list of attendees is provided in Appendix A.

WORKSHOP SPONSORS AND OBJECTIVES

The workshop was funded and sponsored by UCAR, through a contract with WaterRF. The USEPA and NASA also contributed to the effort. The Bureau of Reclamation was also represented at the workshop. Stratus Consulting, with support from MWH Global and Oxenford Consulting, provided facilitation services and follow-up reporting.

The workshop reflects an effort by the participating agencies to elicit insights from water and wastewater utility practitioners, and others, regarding their perceived needs for research in the realm of climate change adaptation decision support. The workgroup activities and identified research needs, as summarized later in this report, were in no manner an effort to establish research priorities for, or by, the agencies. Rather, the workshop efforts and its outputs reflect an outreach effort by the agencies to communicate with, and learn from, the community of water professionals who are the intended end users of research efforts in this area.

WORKSHOP AGENDA AND APPROACH

The agenda for the meeting is provided in Appendix B. The workshop opened with introductory remarks and presentations by the host Foundations and NOAA, with welcoming remarks from Nancy Beller-Simms of NOAA, Robert Renner of WaterRF, and Claudio Ternieden of WERF.

Representatives from sponsoring agencies then provided an overview of the tools and missions of each agency with respect to climate change research and its relation to water resources in general, and to water supply planning and wastewater/stormwater management in specific. Presentations on agency-specific climate research were provided by Chet Koblinsky (Director of the Climate Program Office at NOAA), Jim Goodrich (Chief of the Adaptation Branch of the Office of Research and Development, USEPA), David Toll (Water Resources Program and Hydrological Sciences Branch, NASA), Radley Horton (Center for Climate Systems Research at Columbia University), and Kathy Jacobs (Office of Science and Technology Policy, White House). Copies of these presentations are provided in Appendix E.

Following the introductory presentations, the majority of the workshop activities then revolved around facilitated workgroups defined by five topic areas:

1. Flooding and Wet Weather
2. Water Quality
3. Coastal Zone
4. Water Supply and Drought
5. Water Energy Nexus.

The "charge" for the workgroups was presented by Joel Smith (Stratus Consulting). He explained that the main objective of the workgroups was to identify research needs to "support water, wastewater, and related planning on *key decisions* that utilities and other water resource managers need to make, that may be *climate-sensitive,* on infrastructure, water resources, and other *long-lived and costly investments.*"

The workgroups were directed to determine which of the research needs they identified were the most important, and to focus their efforts on those needs. The workgroup members were further guided to focus on practitioners' perspectives regarding what research would be useful for supporting decision-making related to climate change by providing better:

- Information on climate change *impacts* affecting utility operating environments
- Information on adaptation options and strategies
- Decision-making processes for coping with the inevitable uncertainties.

The charge also directed the groups to provide details on the research items identified in the workgroups and identify those that would be most important and valuable, from a utility practitioner's perspective. The research projects identified in each group were defined, prescribing a general format to:

- Describe the main research objectives
- Specify the climate-sensitive water supply or wastewater management decisions the research would support
- Suggest specific research approaches or techniques to be considered or applied
- Define key outputs.

The breakout group activities then revolved around a series of questions circulated to participants prior to the workshop. These questions were:

1. What are the most important climate-sensitive operational and/or infrastructure decisions facing water and wastewater agencies now, and over the next 10–20 years?

2. What is critical to know about the impacts of climate change on the future operating environment of utilities in order to support these decisions?
3. Where does the understanding of climate change impacts on the future operating environment most need improvement in order to improve decision-making?
4. What is critical to know about the range of adaptation/mitigation options, and about their efficacy, in order to support good decisions? (Including hard and soft – i.e., institutional – options.)
5. What is most needed to improve the understanding of the available range and efficacy of adaptation/mitigation options?
6. What decision analysis methods and institutional capacity building efforts are needed to enhance the ability to cope with the inevitable uncertainties – with or without better information?
7. What specific research projects or related clusters of research projects could be conceived and conducted in the near-term to meet or address these needs?
8. What should these specific research projects or areas of research be like?:
   - Specific research objectives
   - Specific research approaches or techniques to be studied or tried
   - Functionality, complexity, and accessibility of specific tools that might be useful.

The workgroups met in breakout sessions for the balance of Day 1, and most of Day 2. The main objective for each workgroup was to develop a list of important and pragmatic research needs related to decision support for climate change adaptation in their respective topic areas, and to create the basic outlines for those research projects deemed most important by the intended user group. Details regarding the workgroup structure and the activities within the breakout sessions are provided in Appendix C, which describes the objectives and procedures used within the facilitated process.

Representatives from agencies funding research and from water research foundations were considered “observers” at the workshop. As observers, the agency and Foundation participants did not necessarily identify potential research topics in workgroups (as these were developed primarily by the invited utility representatives and related practitioners); however, these individuals participated actively in the related workgroup discussions.

WORKGROUP ACTIVITIES

On the workshop’s first day, each workgroup was asked to identify the most important climate-sensitive decisions that will face water and wastewater utilities in the next 10 to 20 years, within the workgroup’s topic area. Following identification of those decisions, the breakout group participants were asked to identify research topics that would provide information which could help inform and improve the decision-making process on the identified key utility decisions. The workgroups then discussed the research topics, and consolidated similar ideas and needs as applicable.

Workgroup participants then voted on the 10 or so topics they thought would be best to recommend to the plenary sessions. The first day ended with the participants returning to the plenary session, where each workgroup chair reported on the recommended research topics developed by their workgroups.

On the second day, each work group provided more specifics to their list of most important research needs and ideas. For each recommended research topic, they identified key objectives and the decisions the research would support. They also described research approaches and methods likely to be most suitable and useful, and articulated key outputs anticipated or recommended from the research.

Details of what each workgroup developed are provided below. Each workgroup report is somewhat unique, reflecting the individual nature of each group and of their respective topics. Note that the materials provided below are in the form of notes and outlines, as captured by the facilitators with support from several helpful workgroup chairs and participants. These materials are not intended to be consistently formatted written reports; instead, they are intended to capture the core ideas that emerged from the discussions and deliberations, and they reflect the individuality that emerged within each of the workgroups as they grappled with their set of topic-specific issues.

OUTCOME FROM EACH WORKGROUP

OBSERVATIONS FROM THE WET WEATHER AND FLOODING WORKGROUP

Attendees

Art Umble (Greeley and Hansen) *Chair*
Dionne Driscoll (CONTECH Stormwater Solutions) *Co-Chair*
Joel Smith (Stratus Consulting) Facilitator
Bob Bastian (U.S. Environmental Protection Agency)
Casey Brown (University of Massachusetts)
Claudio Ternieden (Water Environment Research Foundation)
Curt Baronowski (U.S. Environmental Protection Agency)
Geoff Bonnin (National Oceanic and Atmospheric Administration)
Jade Soddell (U.S. Bureau of Reclamation)
Jeanine Jones (California Department of Water Resources)
Ken Potter (University of Wisconsin)
Latham Stack (Syntectic International)
Nolan Doeskin (Colorado State University)
Paul Fesko (City of Calgary)
Phil Mote (Oregon Climate Change Research Institute)
Soroosh Sorooshian (University of California, Irvine)

Overview

The breakout group on flooding and wet weather was composed of scientists, hydrologists, engineers, water managers, and consultants. The group represented municipalities, states, government, academia, and consulting.

The wet weather breakout group identified a variety of decisions that could benefit by better information on changes in the intensity, frequency, and duration of wet weather events. These decisions include building of infrastructure, but also non-infrastructure options such as low impact development (LID) and regulatory and management decisions.

The recommended research projects are as follows. The projects are not listed in terms of order of priority nor based on how many votes they received. Rather they are organized to put similar projects in the first, second, and final thirds of the list. The recommended research covers both improved decision-making and improved science to support decision-making.

Key Observations

A number of key themes emerged in the discussions by the flooding and wet weather breakout group. The group recognized that water policy, science, and hydrologic communities are not adequately keeping up with changes in climate, hydrology, and society as they are happening. Data sets and estimation of extreme events are out of date, as are standards. Meanwhile, monitoring networks are degrading. Maintaining up-to-date and reliable data sets, updating estimation of extreme events, and projecting potential future extremes will require substantial resources and a sustained effort.

In addition, more needs to be done on how decision-makers should use the information in light of uncertainties about changing climate conditions (presently and in the future) and how to promote adaptations to changing climate. The outputs of climate modeling are still difficult to apply at a local scale and guidance is needed on how to use climate model projections to support decision-making. For example, the climate change science community has tended to focus on changes in average conditions, whereas changes in extremes such as high precipitation events are very important and needs more attention. Action needs to happen at the federal level (e.g., in supplying more up-to-date information and updating design standards) and at the state and local levels (e.g., in better understanding vulnerability and taking appropriate safety measures to account for risks from climate change).

Most Important Climate Sensitive Decisions on Flooding and Wet Weather

The workgroup identified a number of climate sensitive decisions where information is needed on how climate change would affect flooding and wet weather. The group did not rank these decisions in order of importance. The list below is in the order decisions were identified. There was limited discussion on how these decisions would be affected by climate change or what modifications might be necessary.

- Storm water design
- New design standards for flood control planning
- Improve models such as quantitative precipitation forecast (QPF)
- Redundancy and safety factors
  - E.g., to what storm design standard should flood protection measures in New Orleans or Columbia, Missouri be built?
  - What is appropriate to project economic development
- Highway design
- Soft designs such as LID
- Hydropower and water supply scheduling decisions
- Balance storage needs with flood control
- Balance economic development and flood protection
- Restoration of natural flows
- What climate observation network is needed (to monitor climate change and provide useful information to support decision-making)?
- CSO storage decisions (green or grey)
- Designation of ordinary high water mark (OHWM)
- Long term asset management (e.g., sewers, pumps, dams, bridges, levees, highways)
- Pathogen management in the event of extreme storms
- Low flows (e.g., 7Q10)
- Water quality compliance
- Non point sources
- System redundancy requirements

- Maintenance methods and frequencies
- Energy inputs [greenhouse gas (GHG) emissions]
- New flow and load (development)
- Biosolids management
- Treatment technology standards
- Operability margins.

Research Needs Identified

- Project 1: Research on decision processes
- Project 2: Assess vulnerability of existing infrastructure to increased flooding and wet weather conditions
- Project 3: Examine how to build public support for funding of adaptations
- Project 4: Predict frequency and magnitude of extreme events
- Project 5: Update extreme precipitation and hydrologic data
- Project 6: Testing and evaluation of climate models using real data
- Project 7: Develop a process for creating new federally supported hydrologic design standards
- Project 8: More research on extreme hydrologic events (atmospheric rivers,[2] hurricanes, cyclones) and their impacts
- Project 9: What is the appropriate level of redundancy and necessary safety factors (should there be an increase due to climate change)?

A number of key themes emerged in the discussions. One is that much work needs to be done to be able to incorporate climate change into decision-making on flood and wet weather measures. Better information (see below) will help. But, more needs to be done on how decision-makers should use the information in light of uncertainties about changing climate conditions (presently and in the future) and how to promote adaptations to changing climate. Action needs to happen at the federal level (e.g., in supplying more up to date information and updating design standards). Action also has to happen at the state and local levels (e.g., in better understanding vulnerability and taking appropriate safety measures to account for risks from climate change). The group also recognized that water policy, science, and hydrologic communities are not adequately keeping up with changes as they are happening. Data sets and estimation of extreme events are out of date, as are standards. Monitoring networks are degrading. Maintaining up to date and reliable data sets, updating estimation of extreme events, and projection of potential future extremes will require substantial resources and a sustained effort. In addition, many users feel that outputs of climate modeling are still difficult to apply at a local scale. More work needs to be done in figuring how to use climate model projections to support decision-making. Finally, there was a recognition that the climate change science community has tended to focus on changes in average conditions or aspects of climate variability that may not be of greatest concern to wet weather event managers,[3] whereas changes in extremes such as high precipitation events are very important and needs more attention.

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[2]. Atmospheric rivers are narrow regions of the atmosphere containing large flows of moisture. Their location is important for heavy precipitation events in many regions such as the western United States.

[3]. One reason for this is that far more storage space is needed to save daily data rather than just save monthly data. Daily data (and even higher temporal resolution) are typically needed to examine many extreme events.

Outlines for Identified Research Projects

Project 1: Research on decision processes

Main objectives

The research would address the decision processes that incorporate science, political considerations, education and other considerations relevant to making long-term investments or programs that address the uncertain climate conditions and climate variability.
The research should develop a definitive decision-making process that is applicable to the lesser capacity utilities (in terms of size and managerial/financial/technical capacity). The research should address spatial scales that affect the "scope of authority" of the decisions made (e.g., watershed influences and land uses).

Decisions supported

The research would support decision processes such as design of a "water operation plan" that results in an implementable plan addressing service needs influenced by climate change and variability. It would support addressing uncertainty in such decisions.

Research approach

The research will characterize the uncertainties of climate change and variability relative to other uncertainties that water utilities and other decision-making bodies already deal with. The research will also provide clarity in use of criteria for Triple Bottom Line (TBL) approaches. California is developing guidance for local agencies on how to use climate information. New York City's process can also be examined.

Key outputs

The research should:

- Create a tool box of decision processes and methodologies appropriate for incorporating climate information
- Conduct case studies (e.g., WUCA) of the use of such process or methodologies, or other decision-making processes that involve science and uncertainty
- Develop processes that bring consistency for TBL approaches and conduct case studies of successful application of TBL criteria.

Project 2: Assess vulnerability of existing infrastructure to increased flooding and wet weather conditions

Main objectives

Local and regional water resource agencies (and utilities) need a means to assess their existing infrastructure within the context of climate science. Specifically, they would like to know what infrastructure is vulnerable to increased flooding or wet weather conditions and also the agencies would like to know relative vulnerabilities of their infrastructure so they can set priorities for adaptation. The method for conducting such risks assessments should be “user-friendly.” The research and tools it applies or develops should educate local and regional agencies on the uncertainties about climate change and variability and in particular, the scope of information on climate variability and change that is available.

Decisions supported

This project will help local and regional water agencies make adaptation decisions on infrastructure upgrades, replacements, modifications to accommodate climate science data and information. It will help the agencies to set priorities on adaptation of infrastructure to ensure provision of intended services and protection of public health.

Research approach

The research will evaluate existing models and tools that can be customized for incorporating climate science data (refinement of data inputs) and correctly using the data. (This is a role that the federal agencies can play.) The research will develop new, innovative model approaches and define risks in terms of probabilities.

Key outputs

The research will create vulnerability assessment tools (e.g., CREAT) that are customized with climate science data to make vulnerability assessment. There is no need to develop new approaches or models if existing ones can be used. This research objective is not a call for a national assessment of infrastructure carried out by one organization or the federal government. The emphasis is on use of tools and methods that the agencies and utilities can use to assess the vulnerabilities of their infrastructure. Case studies will be used to illustrate use of the tools.

Project 3: Examine how to build public support for funding of adaptations

Main objectives

Understand public’s willingness to pay for adaptation. Improve understanding by the public (and other groups) of risks, feasibility, benefits, etc. The discussion on this proposed project indicated that municipalities and regional water managers would be a primary user for the project’s outputs.

Develop a set of tools that promote effective communications with uncertainties, costs, benefits, and consequences that results from decisions made from climate science inputs. Develop communication tools that can be used to communicate this information to public officials, managers, and general public. In addition, provide tools that enhance effective communication to the technical community.

Decisions supported

This can support any decisions involving additional funding to adapt to climate change. Successful research will help public officials and staff determine how to reach out to the public on climate change in spite of the uncertainties. Finally, the research can provide direction on what should be communicated and how communications can be carried out to effectively get the message out about the need for adaptation.

Research approach

Research should examine use of “No Regrets/Low Regrets” approach to effectively making the case for adaptations. It should also examine use of a multi-benefits approach to maximize the benefits and the arguments for adaptation. The analysis could conduct case studies by collecting information from communities that have been successful in communications on related matters. The research could also involve focus groups with key stakeholders and examine lessons taken from communications protocols developed for emergency response planning (where such protocols addressed how to communicate across communities).

Key outputs

Research would identify specific and proven communication mechanisms that help the public understand similar decisions. It would provide a tool box and could include guidance to agencies on methods for communicating to the public. The technical content is critical. The outputs should include case studies to test and verify tools and programs that promote development of ordinances or legislation.

Project 4: Predict frequency and magnitude of extreme events

Main objectives

The objective of this research is to project the frequency, magnitude, and duration of future flood events. This should include a better understand of long-term variability superimposed on climate change. The research will involve understand of meteorological and hydrologic mechanisms and will address extreme tails of hydrology.

This project requires updating of precipitation data (see Project 5) and is related to Project 8 on projection of extreme events. It will also support Project 7.

Decisions supported

Users want projections which include climate change and climate variability. They want to know precipitation frequency for the lifecycle of project. This will require projections of decades to century or longer time scales.

Research approach

Because of the breadth and challenge of this research area, the group did not attempt to identify specific research projects. Instead, this topic should be viewed as a serious program of research, not just a few projects, as it will address many aspects of the climate system (including rivers of precipitation). A committee of experts may be needed to develop recommendations. The research should put more focus on hydrologic extremes in climate science rather than on projections of more frequent hydrologic conditions.

Key outputs

The project should produce a strategic plan with milestones and priorities. Ultimately, the research could be used to update intensity duration frequency (IDF) curves.
It was noted that expectations should not be raised about what the research will accomplish.

Project 5: Update extreme precipitation and flood estimation techniques; and update hydrologic data

Main objectives

The research project focuses on updating estimates of extreme precipitation and flooding. Estimation of probable maximum precipitation (PMP) relies on data that goes only up to the 1970s (the catalogue of extreme storms done by the U.S. Army Corps of Engineers was mentioned) and uses meteorological science that predates the understanding of meso-scale convective complexes and other rainfall producing mechanisms associated with PMP. The research would apply new science and techniques on up to date extreme precipitation data. The project would also update techniques for and estimates of probable maximum floods (PMF). New analytic techniques would be applied to data up to the present day as well as historic floods. The estimation of the flow in such floods may change considerably. The analysis should include paleo-climate (pre-observation) floods. The work should be regularly updated with new data.

Decisions supported

- Vulnerability analyses
- Design of flood control infrastructure
- Flood plain designation
- Nuclear Regulatory Commission requirements on flood protection of nuclear facilities.

Research approach

The research would draw on a number of data sources including the rainfall network, remote sensing, bucket surveys, and radar. New tools and statistics would be used to estimate PMPs and PMFs. The adequacy of hydrologic models should be examined. The needs of the hydrologic community should be used to determine meteorological data that are saved and provided.

Key outputs

The PMPs and PMFs should be provided at a spatial resolution needed to be able to understand mesoscale processes and support flood hazard analysis and management. This may require estimation at a spatial scale of as low as 4 km and at a 30 minute time step. This would produce output that useful for hydrologic needs, not just meteorological needs.

There was discussion on whether this project is research and how it supports adaptation. Some participants felt it would be a research project. One mode of adaptation is to ensure that systems are at least adapted to the latest observed conditions, not conditions of the past. This project would not address how the newly estimated PMP or PMFs would be used in estimation of change in future conditions.

Project 6: Testing and evaluation of climate models using real data

Main objectives

The research objective is spurred by the perception in the water community that it is difficult to evaluate validity of model projections. Some degree of verification of the climate models is needed for different climates including short-term, mid-term, and long-term effects. Note: don’t have decadal projections. Need probability distributions. Note: different needs of user regarding spatial and time scales.

Decisions supported

Use of models in decision-making. The research would better enable analysts to select models which best simulate regional climate.

Research approach

Consistent standard model testing and validation techniques would be applied to test the models. The research would provide information on validity of models at regional scale, e.g., northern California or the Front Range of the Rockies.

Key outputs

Skill scores or some other metric of model accuracy.

In subsequent discussion, it was noted that climate models have been compared to observed data and evaluated. The comparison should be done at the scale of climate model output. One issue is which metric or metrics to use. The relative performance of models changes depending on which metrics are used (which may also mean that the relative reliability of models may vary depending on decisions being considered). The use of appropriate metrics and tests could be part of the research in this project.

Project 7: Develop a process for creating new federally supported hydrologic design standards

Main objectives

Replace existing agency documents and guidance that use old data (which serve as defacto standards) with new standards that incorporate updated data and improved science and allow for continued updates and improvements. The standards should be updated every 5 years.

Decisions supported

- Design of stormwater facilities and new flood control structures (dams, levees, etc.)
- Analysis of capacity of existing infrastructure (with ties to vulnerability assessment Project 2).

For all of these and other related decisions, this research will help determine the redundancy and safety factors that should be used (see Project 6).

Research approach

Update existing hydrologic data (rainfall runoff relationships), evaluate utility of climate model runs and their uncertainty, evaluate methodological approaches (statistical, deterministic), and evaluate risk management techniques (weighting factors, hybrid approaches).

Key outputs

Develop a set of federally supported NEW guidance documents to replace existing outdated federal resources (such as U.S. Bulletin 17B, NOAA Atlas 14, FEMA 100-year Flood maps).[4] Develop standards that provide an opportunity for re-evaluation and modification of standards based on new data and science.

Project 8: More research on extreme hydrologic events (atmospheric rivers,[5] hurricanes, cyclones) and their impacts

Main objectives

Improve ability to forecast lead times and magnitude of extreme hydrologic events by improving QPF and understanding the causes of extreme hydrologic events. (Note this research project is closely tied to Projects 4 and 5 on updating data and estimates of extreme hydrologic events.)

Decisions supported

- Flood forecasting

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[4]. Note this output may come from projects 4 and 5 and would be used to support this project.

[5]. Atmospheric rivers are narrow regions of the atmosphere containing large flows of moisture. Their location is important for heavy precipitation events in many regions such as the western United States.

- Water, wastewater and stormwater facility operations
- Emergency response operations.

Research approach

- Further review of historic data and identification of event triggers
- Research current and emerging trends
- Reanalysis of General Circulation Model (GCM) runs (use appropriate terminology and explicitly define extreme events). (There was disagreement within the breakout group as to whether reanalysis of GCM runs would provide information useful for this research project.)

Key outputs

- Improved QPF and forecasts with associated measures of reliability at different time scales
- New models
- Identify events relevant to the engineering community.

Project 9: What is the appropriate level of redundancy and necessary safety factors (should there be an increase due to climate change)?

Main objectives

Understand and incorporate the uncertainties related to climate change projections in establishing design and operational criteria for water facilities and infrastructure.
This research project complements Research Project 7 that involves setting of standards which would serve as minimum requirements. This research project would help water agencies go beyond minimum standards as appropriate.

Decisions supported

- Infrastructure design needs
- Flood planning
- Risk based decision-making due to uncertainty
- Emergency management.

Participants noted that when Hurricane Rita hit Dallas in 2005 decisions makers were faced with a choice of breeching levees protecting the industrial area, downtown, or a low-income residential area. Better information on extreme weather events would have helped in designing a more robust levee system.

Research approach

The research should update existing hydrologic data (e.g., on rainfall runoff relationships), evaluate utility of climate model runs and their uncertainties, evaluate methodological approaches, evaluate risk management techniques (e.g., weighting factors, hybrid approaches),

conduct further review of historic data and identification of event triggers, examine current and emerging trends in observations (e.g., recent extreme events and infrastructure impacts).
Note: the research on updating hydrologic data overlaps with Project 8.

Key outputs

Training and decision support for water management agencies in dealing with uncertainties. This would include risk based cost benefit concepts, deciding on approaches which use prevention or response or both, use of methods to examine risks and costs tied to safety margin. The research could also identify triggers for decisions.

There was discussion on whether the engineering community only needs information on uncertainty or guidance on what safety factors to apply. Some felt that only information on uncertainty information is needed.

OBSERVATIONS FROM THE WATER QUALITY WORKGROUP

Attendees

Peter Ruffier (Clean Water Services) *Chair*
Lorraine Janus (New York City Department of Environmental Protection) *Co-Chair*
Jeff Oxenford (Oxenford Consulting, LLC) *Facilitator*
Carol Russell (U.S. Environmental Protection Agency)
Christine Kirchhoff (University of Colorado)
Cynthia Finley (National Association of Clean Water Agencies)
Djanette Khiari (Water Research Foundation)
Jim Goodrich (U.S. Environmental Protection Agency)
Kathy Jacobs (Office of Science and Technology Policy)
Lauren Fillmore (Water Environment Research Foundation)
Laurna Kaatz (Denver Water)
Melissa Kenney (National Oceanic and Atmospheric Administration)
Olivia Thorne (South Australian Water Corporation)
Rick Holmes (Southern Nevada Water Authority)
Robert Webb (National Oceanic and Atmospheric Administration)
Stephanie Granger (National Aeronautics and Space Administration)
Tom Johnson (U.S. Environmental Protection Agency)

Overview

The Water Quality Workgroup was evenly split between practitioners, academics and representatives of sponsoring agencies. While the group focused on practitioner input for the key issues and decisions being faced, each participant was encouraged to freely share their ideas throughout the process. There was excellent exchange of ideas between practitioners, academics, and representatives of the sponsoring agencies throughout the workshop.

The workgroup focused on addressing the impacts of climate change on water quality. Under different climate change scenarios climate change impacts can include drought, flooding, salt water intrusion, higher temperatures, pH changes, and rapid short-term volume and quality changes due to storm events. These impacts can result in water quality issues due to changes to the ecosystem and aquatic biology, public health drinking such as algal growth (taste and odors, algal toxins), salinity changes, disinfection by-products formation, and turbidity. Considerations were given to the water quality related impacts of climate change on drinking water, wastewater, and stormwater utilities, as well as impacts on the environment.

Key Observations

The water quality workgroup discussed how to make water quality decisions under uncertainty associated with climate change. Under different climate change scenarios, climate change impacts can cover a broad range, including drought, flooding, salt water intrusion, higher temperatures, and rapid changes in water quantity and water quality due to storm events. These impacts can result in water quality issues due to changes to the ecosystem and aquatic biology, as well as public health-related drinking water quality issues such as algal growth (taste and odors, algal toxins), salinity changes, disinfection by-products formation, turbidity, and increased pollutant loads to source waters.

Potential changes to water quality can have a range of impacts for utility operation and management, including changing source water management practices, considering the need for additional or more flexible treatment processes, and modifying the assumptions applied to asset management planning. To support decision making in light of uncertainties, the workgroup discussed the need for guidance on using current models, defining trigger points for taking action, and evaluating monitoring plans to identify what additional data is needed to support future decisions. Recognizing that decisions will need to be made without such data being complete, the workgroup identified the need for guidance on the effectiveness of best management practices (BMPs) under climate change scenarios and recommended studies to evaluate the potential impact of today's decisions with respect to future climate scenarios.

Most Important Climate Sensitive Decisions on Water Quality

The workgroup first identified a comprehensive list of climate-sensitive decisions. Votes were then cast to identify the most important decisions. The top decisions identified were:

1. How will water and wastewater treatment need to be modified to address climate change, with questions such as:
   - What technologies are needed? What are cost and energy effective alternatives?
   - How should utilities address water quality changes due to droughts and floods (taste and odor, salinity, turbidity, algae, nutrients)?
   - How do utilities and planners improve storm water quality and address sewer overflows?
   - When and how should water managers consider and/or balance watershed protection and green infrastructure versus traditional water and wastewater treatment?
   - What are options for modular treatment, i.e., additional capacity on standby for extreme events, to add flexibility to the treatment process?
2. How should utilities and planners account for the uncertainty associated with climate change in developing asset management strategies?
3. How should utilities, regulators and planners address water quality in circumstances of diminishing quantity?
4. How does climate change impact designated uses?
5. How should utilities, regulators and planners manage water supply with constraints from regulations and conflicts between regulations (such as the Endangered Species Act, Ground Water Rules, CWA, and SDWA), and water rights, flow management and in-stream flows? For example, how do water managers address restrictions from permits that constrain alternatives and/or use an outdated baseline?
6. How should agencies improve monitoring to obtain baseline information needed for future decision making in regards to climate change? What water quality information (spatially and temporally) should we begin collecting today?

7. How do we change management of and approach to watersheds to account for climate change? For example, decreasing capacity and quality changes from forest fires.
8. What are the impacts of today's decisions on future water quality?

Research Needs Identified

Working from the decisions identified in session 1, the workgroup identified over 20 research needs. Participants were given an opportunity to vote on what they felt were the highest priorities. Nine project areas emerged as high priorities.

The workgroup was further divided into three small teams to flesh out the project ideas by defining project objectives, decisions supported, research approach, products or desired outcomes, and related research. During this process, two areas were so large that they clearly justified splitting into additional projects. As the result, the workgroup developed the 11 project descriptions listed below. There was no attempt to further prioritize these projects. Once descriptions were completed, the small teams presented their approaches to the full workgroup and the descriptions were refined. Descriptions of the final 11 projects are provided below. The ordering of projects is arbitrary; no order of importance is implied.

Outlines for Identified Research Projects

Descriptions of the 11 projects developed by the workgroup are provided below. As noted above, the ordering of projects in this section is arbitrary, and no order of importance is implied.

Project 1: Climate-Ready Regulation

Main objectives

- Identify current regulations that support or provide impediments to responding to climate change
- Identify opportunities to modify or develop new regulations to improve response to climate change.

Decisions supported

- Obtaining permits
- NEPA, TMDL, NPDES, MCL compliance
- Investments, grants
- Training, staffing.

Research approach

- Analysis of current legislation for impacts on climate change adaption
- Identify barriers and motivators
- Identify trade-offs and conflicts between regulations
- Identify opportunities for trading programs and other shared compliance approaches

- Conduct case studies of utilities that are addressing climate change and addressing regulatory issues.

Key Outputs

- Recipes for utilities that include opportunities for credits and trading
- Guidance for addressing and removing regulatory barriers in responding to climate change
- Recommendations for changes to the regulatory environment (i.e., legislation, policy, guidance, interagency cooperation) to improve the ability to respond to climate change.

Related research

- USEPA, Office of Water Climate Change Strategy
- WaterRF 4239, Regulatory Landscape for climate change.

Project 2: Trigger Points (e.g., thresholds) for Water Quality Planning to Address Climate Change Scenarios

Main objectives

- Identify triggers (i.e., parameters) for responding to climate change
- Use these triggers in a planning framework to make optimal decisions for managing water quality decisions under climate change.

Decisions supported

- When should a utility resize and/or upgrade infrastructure; increase disinfection or other treatment modifications; are new types of treatment needed? What is the planning horizon?
- When are additional water sources needed (e.g., new groundwater sources)? What uses or level of quality need to be sustained? What ecosystem functions need to be protected?
- What policy decisions are needed to meet water quality requirements?

Research approach

- Identify and quantify climate related trigger points for construction or management; quantify the probability that changes will occur and what action should be taken
- Use scenario analysis to evaluate combinations of management options
- Conduct asset management case studies to explore using these trigger points in making climate related decisions.

Key outputs

- A matrix that shows how climate change will affect a variety of water quality parameters under various scenarios
- Probability of future climate scenarios

- Decision tree to guide infrastructure and management decisions on how to use the trigger points
- Guidance on how to integrate climate change into asset management planning.

Project 3: Methodology to Quantify the Value of Ecosystem Functions

Main objectives

- Enable a more holistic approach to water quality management that balances ecological, water quality, and water supply factors
- Identify ecosystem parameters that can be used as metrics for defining suitable offsets (e.g., actions to compensate ecologic losses by providing comparable services elsewhere).

Decisions supported

- What are appropriate strategies to address water quality and ecological impacts of climate change?
- What is the right regulatory pathway to improve physical, chemical and biological aspects of watersheds?
- What is the appropriate regulatory framework to enable trading and offsets?

Research approach

- Identify ecosystem functions and how they relate to climate change impacts
- Develop a methodology to quantify the value of ecosystem functions in the climate change context
- Evaluate ways to improve and balance the physical, chemical and biological aspects of watersheds used for water supply under climate change
- Evaluate regulatory options such as trading and offset programs.

Key outputs

- Method to quantify and balance ecosystem functions and water supply in the climate change context
- Recommendations for changes to the regulatory framework.

Project 4: Monitoring Plans to Track Long-Term Change in Environmental Drivers and Water Quality

Main objectives

- Design a monitoring program to generate long-term trend data to guide adaptation to climate change.

Decisions supported

- Meeting seasonal limits on permit requirements

- Protection of designated uses
- Refinement of the choice of scenarios going forward
- Budgeting for treatment and other adaptation strategies.

Research approach

- Identify climate related questions that monitoring data needs to address including both short- and long-term needs.
- Define the parameters (frequency, sites, and technology) to define seasonal and other changes that affect important water quality issues.
- Review existing monitoring programs. Evaluate how they can be coordinated and sustained over the long term.
- Identify the need for additional monitoring and monitoring programs to capture long-term trends.

Key outputs

- Recommendations for monitoring approaches that support long-term trend analysis of seasonal and other water quality changes due to climate change
- Documentation necessary to support permit requirements and protect designated uses.

Related research

- Global Lake Ecological Observatory Network (GLEON)
- Stream Ecological Observatory Network (STREON)
- National Ecological Observatory Network (NEON).

Project 5: Methods to Evaluate Effectiveness of Best Management Practices under Climate Change

Main objectives

- Provide methods for evaluating the effectiveness of mitigation actions taken to address water quality impacts of climate change.

Decisions supported

- Whether to modify or enhance infrastructure to meet water quality standards in the future.
- What adaptive management is needed for all drivers of water quality?

Research approach

- Define objectives of actions taken in response to climate change
- Define metrics needed to evaluate the effectiveness of these actions
- Define the baseline (environmental and regulatory) against which you would evaluate the effectiveness of actions taken

- Develop recommendations that include:
  - How can success or failure be defined?
  - Define baseline conditions of regulatory structure; is it working?
  - What needs to be changed?

Key outputs

- Guidance and recommendations for decision making with regards to best management practices for addressing climate change.

Project 6: Methods to Project Water Quality Changes under Future Climates

Main objectives

- Develop a method to project water quality changes under future climate conditions and how these may impact utility operations and management.

Decisions supported

- Long-term water resource planning.

Research approach

- Identify the parameters
  - Select critical parameters
  - Propose surrogates if needed
  - Evaluate spatial and temporal changes
- Develop a tool for water utilities to quantitatively assess changes in water quality
- Conduct case studies and evaluate potential vulnerability (i.e., system operations, capital planning, regulatory compliance).

Key outputs

- Vulnerability assessment tool for projecting water quality changes due to climate change and the associated costs and operational requirements.

Related ongoing research

- Developing simplified climate change impact assessment tools for the water utilities.

Project 7: Guidance on the Use of Models for Water Quality and Climate Change Decision Making

Main objectives

(Note: this might be phased after the project “methodology to project water quality changes under future climates”).

- Understand the appropriate use and strengths and weaknesses of climate models (use in conjunction hydrologic, land use, population models)
- Determine the sensitivity/range of uncertainties in model outputs/compounding factors within the models
- Develop methodologies for modelled data interpretation for model outcomes.

Decisions supported

- What are the appropriate models for use in responding to projections of water quality changes due to climate change at the scale of the decisions?
- What data are needed to run the model?

Research approach

- Identify the models and intended uses
- Evaluate the past use of the model and performance
- Evaluate uncertainties of sequential or compounding models
- Develop recommendations for appropriate use of the models.

Key outputs

- Recommendations of appropriate models for evaluating water quality changes due to climate change.

Project 8: When Does Climate Change Matter to Water Quality Decision Making?

Main objectives

- Discriminate the difference between the specific effects of climate change versus natural variability to support adaptation decision making
- Provide information in a form compatible with decision-maker needs.

Decision supported

- Development of adaption strategies for water quality
- Future investment or facilities.

Research approach

- Understanding the range of water quality conditions that the current facility functions within. Understand key variables that are (or should be) analyzed
- Identify when the system has shifted, a trigger point (i.e., threshold or tipping point) has been exceeded
- Conduct a sensitivity analysis of climate change impacts on both the facility functioning and natural ecosystems.

Key outputs

- Guidance manual for climate change impact analysis for utilities
  - Systems or scenario approach
  - Not a single option but a robust approach
  - Compatible with existing decision making frameworks.

Project 9: Robust Treatment Alternatives and Flexible Planning for Changing Climate

Main objectives

- Define what climate drivers would push a utility to look for new treatment processes
- Identify treatment alternatives (water, wastewater, storm water)
- Identify criteria to evaluate treatment alternatives
  - Menu of environmental and treatment criteria
  - Cost
  - Triple bottom line approaches
- Identify cooperative and flexible options.

Decisions supported

- Robust treatment options and planning
  - Asset management processes
  - Resilient
- Flexible policy approaches.

Research approach

- Conduct an international review of current pilot and demonstrations studies; conduct additional studies as necessary; include an analysis of utility components and regulatory frameworks
- Conduct an analysis of regulatory policies (incentives, mandates) that promote or hinder alternative treatment technologies
- Evaluate the robustness of treatment technologies
- Demonstrate emerging technologies
- Evaluate creative and innovative approach with considerations to:
  - Flexibility
  - Sustainability
  - How impacts other areas
  - Energy efficiency.

Key outputs

- Flexible framework to re-evaluate and evaluate treatment options and goals
- Menu of options – treatment objectives, evaluation criteria, considerations of decisions
- New technology.

Related/ongoing research

- Ongoing WERF research – Lauren Fillmore
- Ongoing USEPA ORD research – Tom Johnson.

Project 10: Quality Consequences of Current Actions: The Good, the Bad, and the Unintended

Main objectives

- Evaluate the consequences of current adaption strategies.

Decision supported

- Informing adaptation and mitigation options and decisions – across the board: for example, what are the quality consequences of aggressive conservation programs?
- Assess asset management, etc.

Research approach

- Identify consequence definitions of immediate, short-term, long-term implications and impact of current and proposed adaptation strategies including:
  - Direct and indirect effects
  - Across sectors and media
  - Adaptation and mitigation
  - Watershed scale, treatment plant scale, regional scale, global scale?
- Identify current management strategies in place
- Identify assess the quality consequences of those management decisions.

Options for the approach can include:

- Develop a systematic approach to decision impact on quality issues
- Identify, consider, and assess the impacts of the consequences
- Look at current practices, then future plans as well as cumulative effects across scales.

Key outputs

- Education and training on identified consequences
- Ability and understanding of thinking through consequences in a holistic manner.

Related/ongoing research

- NEPA implementation?

Project 11: Utility Management and Planning: Cost, Timing, Triple Bottom Line, Strategies of Infrastructure and Treatment Approaches

Main objectives

Develop a decision analysis framework for quality and treatment options that includes items such as:

- Capital focus
- Timing focus
- Across spatial and decision making scales
- What options are supported and why?
- Stranded assets?

Decisions supported

- Asset management
- Capital investment.

Research approach

- Conduct case studies (i.e., NYCDEP)
- Evaluate existing financial instruments
  - Future cost of money vs. current cost of money
  - Across decision scales – local to regional or vice versa
- Evaluate financial and temporal planning options – decision support
- ID critical decisions – where opportunity could be lost: cost, availability of option.

Key outputs

- Recommendations for new financing tools or guidance for new financial tools
- Method for assessing the timing of critical decisions to avoid lost opportunities.

OBSERVATIONS FROM THE COASTAL ZONE MANAGEMENT WORKGROUP

Attendees

Douglas Yoder (Miami-Dade Water and Sewer Department) *Chair*
Peter Schultz (ICF International) *Co-Chair*
Russell Jones (Stratus Consulting) *Facilitator*
David Major (Columbia University Earth Institute)
David Toll (National Aeronautics and Space Administration)
Erica Brown (Association of Metropolitan Water Agencies)
Karen Metchis (U.S. Environmental Protection Agency)
Mary Culver (Coastal Services Center)
Paul Kirshen (Battelle Memorial Institute)
Richard Rood (University of Michigan)

Overview

The workgroup started off with each member generating a list of their most important climate-sensitive water/wastewater operational and/or infrastructure decisions that they are facing. While the process guidelines that the group was provided indicated only "participants" (i.e., utility member and water/wastewater managers; non-federal) were to generate the list, the group decided to include all members present due to the small number participants in the group. This decision was very beneficial to the process, as it fostered additional discussion and raised questions that were important to the participants which otherwise would have been missed. The group also decided that the 10–20 year timeline presented in the guidance document was not long enough to capture many of the coastal impacts that utilities would be faced with – especially in terms of sea level rise. Consequently, no specific temporal limitation was imposed on the decision list generated.

Key Observations

The coastal workgroup detailed a variety of specific research projects to help decision-makers address the future climate change issues they will be facing, and several general topic areas emerged. These topic areas are discussed further below.

The first topic area is the need to have better information on what impacts utility managers may be facing. To this end, the group felt that research should be focused on two main areas. The first area is obtaining better baseline topographic information. This would include gathering high-resolution elevation data such as lidar as well as information on local subsidence and its causes. Second, the group felt that climate change information needs to be better coordinated and more standardized. Currently, because of the wide variety of climate change projections and little guidance on how to apply models, there is a real fear that individual water utilities in the same region may make decisions using different scenarios. If a standard or guidance were developed on the set of models, emissions scenarios, and other assumptions, then decision-makers in a region would be more likely to come up with a more unified adaptation approach.

Another topic area that emerged from the workgroup was the need for better communication between climate change scientists and the utility users of the climate change information. The workgroup focused on two groups of end-users: (1) decision-makers such as utility managers, and (2) the general population of utility users. First, the group felt that research should be conducted on how to translate the highly technical findings from climate change scientists into more practical terms such as the potential implications of the findings on utility infrastructure. Similarly, the group felt that research should be focused on how better to communicate the risks to the end users rather than in the more abstract forms that are currently used. If the end-users had a better understanding of the implications of climate change on the water utility, this would also help them to understand the potential need for adaptation and associated costs.

Lastly, there seemed to be a consensus among the group for a need for research into how to improve the resiliency and flexibility of water utility systems in light of uncertainty surrounding climate change scenarios. The group proposed a few ideas. For example, in terms of improving the ability of assets to cope with changing climate, members felt that there is a need to move away from event-based engineering design to more flexible and adaptable infrastructure. The group also felt that institutional-type changes could be used to address the uncertainty. One example was to integrate small-scale systems with more centralized systems to enhance the robustness of the overall system. This would allow for redistribution of water resources across a region based on varying need.

Most Important Climate Sensitive Decisions on Coastal Zone Management

After going around the room a couple of times, the group generated a total of 23 critical decisions that the members faced in light of climate change. The decisions listed were diverse, covering physical/engineering, institutional, operational, educational, and social topics. The decisions also ranged from quite specific to more general, but in the latter case, additional bullets or specific examples were included. Overall, the group was quite satisfied that they had covered the major decisions they face in relation to climate change.

- Decisions regarding reinforcement of levees in San Joaquin Delta – coping with sea level rise and runoff
- Decisions to cope with changes in water quality (e.g., due to upland characteristics, including land cover)
    - Non-point sources/point sources
    - Design of treatment process
    - Watershed management practices
- Decisions whether to protect or relocate existing infrastructure
    - Structured process needed for characterizing the rehabilitation cycle in utilities
- How can all relevant regulatory, land use, capacity, location, etc., issues be effectively factored into decisions?
- To what extent should climate affect decisions?
    - How can that we done?
- What no-regrets strategies exist?
- How/whether to take action to maintain viability of drainage systems?

- How can decision-makers best make the connection between science and planning/management?
  - E.g., stormwater drainage; movement of the salt front, salt water intrusion; re-routing of rivers
- How will changes in flood recurrence intervals affect infrastructure and emergency planning?
- How can the support be garnered to make/communicate the necessary changes?
  - Particularly for costly decisions?
  - Communicate climate risk relative to non-climate risks?
- What are the options for making shoreline protection resilient?
- How do adaptation actions affect both the natural and built environment?
- What decisions need to be made regarding what to protect (or not)?
  - What wetlands can retreat?
- What should be rebuilt and how in the wake of environmental catastrophes?
- What institutional (government insurance) decision-making/personal decision-making (e.g., land use decisions) need to occur?
- Do water managers need to account for decisions by other actors?
- To what extent does planning for critical infrastructure need to be coordinated across sectors?
  - Cross sector vulnerability and solutions
- How can robustness be built into the system? Cost? Benefit?
  - Including within system and across systems (e.g., via re-use)
  - As a function of water availability and extreme events
  - Other/non-climate factors (e.g., ESA, invasives management)
  - Over what timeframe?
- What kind of sewer systems should be built/rebuilt to cope with climate change?
  - Sewer lines
  - Septic tanks
- How can the carbon footprint/energy-efficiency be considered of new adaptation measures?
  - E.g., reducing water use can:
    - Increase availability
    - Reduce energy demand
- How will the extent of centralization affect vulnerability?
  - Storage capacity, catchments, treatment; reservoirs
  - What effect on robustness?
- How can decisions be made with poor topographic/lidar data?
  - Poor information on siting characteristics (e.g., elevation)
  - Poor information on subsidence/uplift
    - Effect of groundwater withdrawal?
    - What policies are exacerbating subsidence?

Research Needs Identified

Following the decision list generation, the group generated a list of 32 research needs to address the decisions. As with the decisions themselves, the research needs covered a wide range of topics and specificity. While many of the research needs listed were specific to data and technology (e.g., higher quality elevation data and model output and engineering designs), others dealt with institutional or regulatory research projects (e.g., ability to meet standards/hazards in light of climate change). The groups also felt that research into collaborative efforts between utilities would help determine if combined systems might offer greater robustness and flexibility. The group also felt that research into the risk perception in light of climate change impacts would be beneficial to stakeholders and would enhance the ability to make tough decisions in the future. Lastly, there was wide support of the need to make climate change and impacts models more useable to utility managers and the need to have either standardized models or approaches so that adjacent water districts would be working under the same set of assumptions.

Following the discussion of research topics identified, the full list was grouped (non-exclusively) into six general categories to facilitate selection of the top ten. The categories were: (1) ethical, legal, and institutional; (2) general data needs; (3) planning process/decision science; (4) models and other scientific uncertainties; (5) new technologies; and (6) toward an end-to-end approach for decision support and translation of climate change outputs to actionable information. Finally, the top-ten research needs were selected from the list, which included at least one from each of the general categories.
The top ten research needs were then linked back to the critical decisions that the water/wastewater participants are potentially facing in light of climate change. The group then expanded on the specific objectives of the research, the key decisions that would be addressed, the general approaches to be taken, and the outputs of the research. The expanded list is presented below.

Outlines for Identified Research Projects

Project 1: Integrated end-to-end adaptation planning

Main objectives

Improve the usability of climate info into utilities' practices.

Decisions supported

The aim of this project would be to help decision-makers (utility, scientists, etc.) make the connection between science and planning with regard to climate change all decisions – end-to-end.

Research approach

- Analyze available planning approaches (e.g., NPCC – NYC report, 2010; CCAWWG, 2010; UNDP, 2005)
- Analyze adaptation planning by early adopters and pilots and try to determine what has worked and what has not to study.

Key outputs

- Case studies, best practices, gaps in knowledge transfer, guidelines/approach or framework for facilitating transfer of usable knowledge between climate scientists, researchers, etc., to utility users
- Translation services –to provide process/information for utilities to translate climate models, information, and data to applied use for water utility adaptation planning. This is bi-directional – utilities need to have information translated to them and climate scientists/science/academic community needs to have the needs of utilities translated to them.

Project 2: Risk communication

Main objectives

Communication approaches of climate risks and impacts to coastal areas and opportunities of climate change to effectively inform decision-making.

Decisions supported

Climate-related decisions by managers, including operational, infrastructural, and ecosystems (e.g., flood risk, placement of protective structures).

Research approach

Determination of how to present data.

- Audience segmentation (residents vs. tourists, people groups)
- Surveys of customers, decision-makers, and focus groups
- Testing methods of data presentation
- Use of social marketing approaches
- Public dialog on risk.

Key outputs

- ID of where and what types of effective risk communication is most important
- Effective /best practices
- Training
- Customer communication guidelines.

Project 3: Integration of small-scale and integrated solutions to enhance robustness (centralized systems connecting to each other and smaller systems)

Main objectives

Determine the feasibility (obstacles and incentives) to incorporating/constructing small-scale systems or infrastructure into an integrated system to improve robustness, as well as linking large-scale/centralized systems.

Decisions supported

Infrastructure development to meet new or existing demands and to optimize flexibility/redundancy for meeting current and future demands in light of coastal climate change impacts. Examples:

- Water supply side – heavier, less frequent rainfall events that lead to different safe yield
- Wastewater side – needing decentralized places to deal with wastewater/stormwater flows.

Research approach

- Technical evaluation of current systems
- Tech. evaluation of emerging technologies
- Modeling/simulation of various system structures under various conditions
- Evaluate emergency preparedness and response for coastal communities
- Case studies.

Key outputs

- Case studies that have this type of resiliency and how they fared better
- Technologies demonstrated to be effective, gaps in knowledge.

Project 4: Costs and benefits of adaptation

Main objectives

Evaluate comprehensive cost/benefit in order to optimize and justify selection of adaptation measures for coastal utilities and others.

Decisions supported

Design and scheduling of hard and soft infrastructure investments and system operations including locations/siting. Also, looking over the life of facility that you have accounted for all the threats.

Research approach and Key outputs

- Case studies and comparative evaluation of key adaptation measures
- Attempts to estimate multi-objective costs/benefits
- Approaches for capturing indirect costs, e.g., insurance; co-benefits, modeling of avoided losses
- Cost/benefit framework development including cost scheduling agency lags, risk aversiveness, uncertainty
- Development of approaches for incorporating climate change into asset management systems
- Modeling of avoided losses
- Approaches for non-monetary characterization (contingent evaluation, etc.)

- Characterization of whole-system implications.

Project 5: Research on managing water quality and availability in the face of coastal climate change impacts

Main objectives

Maintain adequate water quality standards in the face of climate change (salt water intrusion, temperature change, sea level rise, storm surge).

Decisions supported

Deployment of treatment technologies to maintain water quality standards (e.g., salinity, mobilization of toxins, landfills, pathogens…).

Research Approach

Research on the relative effectiveness and costs of existing and emerging technologies.

Key outputs

Evaluation of the appropriateness of various technologies to cope with alternative climate change scenarios and impacts.

Project 6: Integrated adaptation and mitigation approaches in the coastal zone

Main objectives

Effectively adapt with a minimal and cost-effective reduction in GHG emissions.

Decisions supported

Utility adaptation decisions for water supply and wastewater.

Research approach

- SBIR (small business innovative research) to pilot new approaches
- Carbon footprinting estimates of all adaptation approaches
- Examine use of coastal renewables.

Key outputs

- Range of efficient and effective water and wastewater adaptation approaches
- STAR energy rated technologies
- Evaluation of tools/methods for water/carbon footprinting of treatment portfolios.

Project 7: Converting emerging science into engineering design paradigms

Main objectives

Improve the ability of assets to cope with changing climate. Move away from event based engineering design to flexible/adaptable infrastructure – new ways of approaching events.

Research approach

- Review of current standards/approaches
- Development of climate change information appropriate for informing engineering design
- Development of new approaches for translating climate change info into engineering standards
- Convene inter-disciplinary workshop w/ researchers and decision-makers
- Involve stakeholders.

Key outputs

- New ways of approaching events – expand contingency
- Changes in educational curricula
- Integration of universities' engineering and government and industry and climate change scientists and water managers
- Convene inter-disciplinary workshop w/ researchers and decision-makers
- Understanding barriers and constraints to changing the paradigm
- Review of current standards/approaches.

Project 8: Institutional management, planning, and legal frameworks in the face of climate change

Main objectives

Provide new management and planning approaches for adaptation including informing and complying with legal frameworks.

Decisions supported

Compliance with existing regulations.

Research approach

- Evaluation of planning and management approaches to aimed at their improvement
- Examine viability of compliance with existing relevant laws and regulations and professional standards at Fed, state, and local levels
- Detailed case studies of barriers to compliance

- Analyze the potential impact of climate change on regulations that exist or are under development
- Suggestions for how to improve the effectiveness of new sustainable management objectives that factor in climate change.

Project 9: Regional climate change projections with broad applicability (regional: watershed, basin, or other spatial scale of water management)

Main objectives

Development of regional projections (range) w/ broad applicability, including standards for the data and their use.

Decisions Supported

All adaptation responses.

Research approach

- Research to (evaluate) “validate” plausible climate scenarios
- Examine cases in which data have been used within and across jurisdictions
- Convene expert panels to evaluate relevant climate (including sea level rise) parameters
- Research, leading to service of appropriately translated products.

Key outputs

- Understanding of what downscaled climate models can/can’t inform and what alternatives exist
- Approaches for using regional climate information including the avoidance of misuse
- Include projections of storm surge, wave energy, etc.

Project 10: Meeting data needs

Main objectives

To provide the wide range of data needed to inform adaptation decisions in coastal zones.

Decisions supported

Vulnerability assessment and most coastal adaptation decisions.

Research approach

- Must be inter-disciplinary
- Sustained over time
- Approaches for translating the outputs for use – e.g., manager-friendly portals.

Key outputs

- Hi-resolution topographic data (e.g., lidar)
- Infrastructure location/characteristics and protection measures (location and elevation)
- Improved measurements of highest observed water level (HOWL)
- Current data on wetland distribution, dynamics, and impacts to them
- Improved data on factors affecting relative sea level rise (e.g., subsidence, groundwater withdrawals)
- Improved data on salinity front/distribution
- Sustained monitoring
- Water quality parameters (comprehensive statistical characterization)
- Current information on distribution of land use/land cover.

OBSERVATIONS FROM THE WATER SUPPLY WORKGROUP

Attendees

Gregg Garfin (University of Arizona) *Chair*
Paul Flemming (Seattle Public Utilities) *Co-Chair*
Jason Vogel (Stratus Consulting) *Facilitator*
Alison Adams (Tampa Bay Water)
Ann Waple (National Oceanic and Atmospheric Administration)
Brandon Goshi (Metropolitan Water District of Southern California)
Carol Collier (Delaware River Basin Commission)
Chris Martinez (University of Florida)
Chuck Henning (U.S. Bureau of Reclamation)
Daniel Nvule (Massachusetts Water Resource Authority)
David Toll (National Oceanic and Atmospheric Administration)
Jennifer Warner (Water Research Foundation)
Lorna Stickel (Portland Water Bureau)
Marc Waage (Denver Water)
Mike Hayes (National Drought Mitigation Center)
Nancy Beller-Simms (National Oceanic and Atmospheric Administration)
Noah Molotch (National Aeronautics and Space Administration)
Rachael Novak (U.S. Environmental Protection Agency)
Radley Horton (National Aeronautics and Space Administration)
Veva Deheza (Colorado Water Conservation Board)
Zane Marshall (Southern Nevada Water Authority)

Overview

This breakout group was tasked with developing a set of key research needs addressing the implications of climate change on water supplies, including the effects of changes in temperature, precipitation, heat waves, and drought conditions. The breakout group first identified a variety of decisions that could benefit from better information on changes in climate conditions. The main decision categories included building of infrastructure, changing of operations, communication of climate as a risk factor, and management and adaptation considerations.

Key Observations

For water supply research needs, two main themes emerged from the workgroup discussions – one focused on decision support and the other on the physical science. While the decision support research needs area generally received more support than the physical science needs, both were deemed important by all workgroup participants.

Proposed decision support research needs focused on two major issues: (1) a general research need for developing tools for planning under uncertainty, and (2) a number of specific research needs on water management alternatives such as non-structural approaches, indirect effects of climate on demand, and decentralized infrastructure.

The physical science research needs also fell into two broad categories: (1) a general research priority for improving the availability and accessibility of climate information such as a web site for downscaled climate projections, and improvements in the time and spatial resolution of temperature and precipitation projections, and (2) a number of specific research needs assessing the state of knowledge on a particular issue such as climate change impacts on aquifers, impacts on ecosystem services, and generating a better physical understanding of the El Niño Southern Oscillation.

While this workgroup divided into subgroups based on decision support and physical science, it is noteworthy that their recommendations support one another. On the physical science side, emphasis was placed on data availability and communication, presumably in the interests of supporting utility-scale decision-making. Meanwhile, the decision support research needs generally focused on developing methodologies for incorporating uncertain climate information into utility decision-making.

The discussions in this workgroup revealed significant overlap in the purposes of all research needs – namely to support informed decision-making through physical knowledge of climate – by communicating scientific information more effectively, by generating relevant and accessible scientific information, by improving decision capabilities under conditions of scientific uncertainty on multiple fronts (e.g., scientific, social, and regulatory), and by thinking outside the box to generate a broader array of water management options.

Most Important Climate Sensitive Decisions on Water Supply and Drought

The workgroup identified a number of climate-sensitive decisions that could most benefit from information on how climate change could affect water supply and drought. The group did not rank these decisions in order of importance; the list below is in the order decisions were identified.

Infrastructure

- *Siting infrastructure*, e.g., considering sediment transport near streams/rivers
- Making infrastructure investments to *manage demand* (total change and seasonal variability)
- Investing in new, replacement/*renewal of infrastructure*
- Understanding that infrastructure decisions by large utilities could be affected by climate vulnerability as well as the resulting supply *needs of neighboring municipalities*.

Operations

- Understanding operational implications of new infrastructure, e.g., to accommodate snowpack reduction
- Ascertaining operational changes due to changes in seasonal potential of water sources
- Understanding changes in operations due to other climate impacts

- Managing supplies for multiple benefits (e.g., water supply, instream flows, flood management) could change due to climate impacts
- Managing greater regulatory pressures to meet ecological functions, GHG regulations, etc.
- Determining how to apportion risk, allocate shortages
- Understanding operational changes that are needed to manage demand
- Understanding changes in demand assumptions.

Communication

- Communicating climate risks in a manner that supports rather than confuses decision-makers
- Communicating climate risks to customers in a manner that supports a common understanding/establish expectations
- Discerning/establishing credibility of scientific information to inform decision-making
- Establishing effective communications with decision-makers, public, et al. regarding the scientific uncertainty.

Management and adaptation

- Using watershed-scale approaches could enhance climate resiliency across jurisdictions
- Addressing constraints on adaptive capacity that could require review of legal and institutional frameworks
- Selecting robust/resilient supply sources could alter total supply needs
- Triggering drought responses could change due to climate impacts or adaptations
- Bringing the long-term nature of this issue into the short-term decision-making context, e.g., preserving options, maintaining flexibility
- Taking into account maladaptation (e.g., energy footprint of adaptation options)
- Needing to understand how to pursue adaptation in multiple realms, not just in the infrastructure realm
- Recognizing institutional context that could constrain decisions
- Pursuing holistic approaches across jurisdictions and multiple realms (e.g., legal, regulatory, institutional vs. classic engineering focus)
- Pursuing opportunities posed by adapting to climate change.

Research Needs Identified

The water supply and drought implications research recommendations that follow are not listed in terms of order of priority nor based on how many votes they received within the group. Rather, the first six research items are science-focused and were developed by one subgroup of the working group. The final four research items are focused on decision support (e.g., management- or policy-focused) and were developed by a second subgroup of the working group. The two subgroups reconvened and reviewed each other's work before reporting back to the plenary and being recorded in this document.

Science focused research needs

- Project 1: Closing the water balance knowledge gap
- Project 2: Assessment of the El Niño Southern Oscillation and other modes of large-scale climate variability
- Project 3: Assessment of potential improvements to the time and spatial resolution of temperature and precipitation projections
- Project 4: Ecosystem services
- Project 5: Climate change impacts on aquifers
- Project 6: DownscaledData.gov.

Decision support focused research needs

- Project 7: Indirect effects of climate on demand
- Project 8: Non-structural, socioeconomic, and institutional approaches to water supply management
- Project 9: The effects of decentralized infrastructure and hybrid supply systems on system resilience to climate change
- Project 10: Understanding how to create adaptive decision support tools for planning under uncertainty.

The discussion among breakout group members on research needs quickly centered around two main themes. The first was the need for scientific information to support decision-making and the second was decision support systems or planning tools to aid in management under uncertainty. During the voting process, the decision support and planning research needs received a large majority of the "votes" on research topics, while the scientific research needs received less support.

Of the science-focused research needs, the most supported idea was labeled "DownscaledData.gov." This idea included a web portal for work related to the access, mechanics, components, and use of downscaled information. As the group began to flesh out the research needs, however, they determined that there was significant overlap in several of the options.[6] Because of this overlap, the group felt that some consolidation of the science research needs was merited, but there was insufficient time to do so.

Of the decision support-focused research needs, a majority of the time was spent fleshing out the "Decision tools for planning under uncertainty" research need, which seemed to fall into its own category. The other three research needs were more focused on specific policy issues

[6]. Namely, all of the science options focused on one of two things – assessing the state of knowledge on a specific issue (e.g., "Climate change impacts on aquifers," "Assessment of the El Niño Southern Oscillation and other modes of large-scale climate variability," and "Ecosystem services") or improving the availability and accessibility of information (e.g., "DownscaledData.gov," "Closing the water balance knowledge gap," and "Assessment of potential improvements to the time and spatial resolution of temperature and precipitation projections").

Outlines for Identified Research Projects

Project 1: Closing the water balance knowledge gap

Main objectives

The objective of this research is to assess the availability and quality of data on all aspects of the water balance equation on a regional basis.

Decisions supported

Better knowledge of the baseline hydrology of an area would support nearly all operational and infrastructure investment decisions. It speaks to fundamental considerations that may or may not be beyond the authority of an individual water utility, such as water allocation decisions.

Research approach

This project should focus on assessing the quality and availability of individual datasets as well as the ability of modeling to fill in data gaps. The assessment should be done on a regional basis and focus on current data collection networks, datasets, and tools from site specific measurements (e.g., stream gauges) to the use of Doppler data to remote sensing applications to assess the full array of available information.

Key outputs

A report of the state-of-the-data, by region. The assessment would preferably establish priorities for which supply sources (including reservoirs, rainfall, groundwater, etc) are most in need of data improvements by region.

Project 2: Assessment of the El Niño Southern Oscillation and other modes of large-scale climate variability

Main objectives

The objective of this research is to identify significant modes of climate variability by region and establish the capacity and uncertainty of predictions.

Decisions supported

The research would support water supply system optimization based on the full range of climate variability. It could also support the development of supply sources that are more resilient to variability and, by extension, probably to climate change as well.

Research approach

This should focus more on better understanding extremes because variability is more important than overall trends on a 10–20 year timeframe. More reliable and accessible information on changes in both the frequency and intensity of impacts from climate models and improvements in short-term and long-term predictions are desirable, and this project should provide a sense of the realism and uncertainty associated with predictions of climate modes.

Key outputs

Existing information on the regional (e.g., watershed) effects (e.g., seasonal and annual precipitation and temperature) of each climate mode would be compiled into a tool or handbook that provides a quick reference guide and communication tool for water utility decision-makers.

Project 3: Assessment of potential improvements to the time and spatial resolution of temperature and precipitation projections

Main objectives

The objective of this research is to better understand potential improvements in climate projections that would support better understanding of changes in extreme events and temporal shifts in significant climate variables.

Decisions supported

This project could have significant effects on reservoir sizing decisions, dam operations, and the overall supply mix and standard operating procedures for all water utilities under a changing climate.

Research approach

It was decided that this project is actually a subset of 1.4.6 "DownscaledData.gov."

Key outputs

A white paper or compilation of information on the availability and uncertainty associated with higher resolution climate projection and the potential to develop such projections in the future.

Project 4: Ecosystem services

Main objectives

The objective of this research is to identify indicators and thresholds for transitions in key ecosystems critical to source water supplies.

Decisions supported

Changes to ecosystems may have significant impacts on water/environmental/economic value of water supply landscapes. This could change decisions about land use management, source water landscape conservation investment strategies, controlling invasive species, managing endangered species, etc.

Research approach

Use State and Transition Modeling to assess potential changes and impacts on water resources and ecosystem services. This should include both changes in ecosystems that impact water resources as well as changes in water resources that can impact ecosystems.

Key outputs

Identify critical ecosystems and their linkage to water. Identify thresholds in these ecosystems (e.g., temperature, precipitation, freezing days, fire frequency). Link Transition models to downscaled climate information if possible.

Project 5: Climate change impacts on aquifers

Main objectives

The objective of this research is to better understand the implications of climate change for aquifers at different scales, including changes in recharge/discharge, saltwater intrusion, etc.

Decisions supported

Better knowledge of aquifer hydrology changes under different climate conditions would support nearly all operational and infrastructure investment decisions for utilities that use groundwater. This project would tie closely with 1.4.1 “Closing the water balance knowledge gap.”

Research approach

Because WaterRF project #4325 “Groundwater Sustainability Under Climate Change” may already be addressing this research need already, it did not receive as much time or attention as the other research objectives identified for water supply and drought.

Key outputs

A state of knowledge white paper.

Project 6: DownscaledData.gov

Main objectives

The objective of this research is to develop the architecture for an easily accessible one-stop-shop for climate data and analysis tools.

Decisions supported

Any decision that uses or could potentially use climate data would potentially benefit from better and easier-to-use data and decision support tools.

Research approach

This project should develop a partnership with water utility users of climate data to develop an easy-to-use repository for climate information and tools. This could include traditional climate data and downscaled data, such as precipitation and temperature projections. However, it should also include other data and projection as appropriate, possibly including information on hydrology, streamflow, soil moisture, evapotranspiration, MET data, etc. Determining which models, downscaling techniques, and data sets are most accurate or useful by region, climate variable, or for other purposes. Key parameters that could support water decision-making should be identified to ensure that the variables most needed by water utilities are archived by the CMIP5 model runs. The time scales and spatial scales of all data need to be relevant to utilities.

Key outputs

Architecture for a website or web-based tool organized to provide information in a format most useful for utilities, e.g., by region, impact, and climate parameter.

Project 7: Indirect effects of climate on demand

Main objectives

The objective of this research is to analyze the effects of climate change on the indirect drivers of demand, such as socioeconomic factors and demography (e.g., how climate-related migration and changes in land use may impact demand). This means going beyond the relationship between temperature and water use to examine climate-driven changes in migration, water use type, industrial uses, etc.

Decisions supported

New supply source development, demand management programs, and revenue stability would all be affected by indirect climate driven changes to demand.

Research approach

This is a complicated project and may need to be developed incrementally or in partnership with other entities with an interest in and potentially some expertise in these issues. It should be integrated with a social science assessment in an attempt to identify the factors that drive water demand that may be climate-sensitive.

Key outputs

Development of a demand analysis methodology with identification of key uncertainties and indicators or signposts of demand shifts.

Project 8: Non-structural, socioeconomic, and institutional approaches to water supply management

Main objectives

The objective of this research is to identify how unconventional approaches to water management could increase adaptive capacity.

Decisions supported

This project could identify options that could offer significant advantages in terms of climate adaptation, including options that should be preserved for potential future use. It could determine if and how to deploy time and resources to capitalize on the potential of identified strategies. It could also describe barriers and limitations in these approaches.

Research approach

Conduct a survey, focus groups, and a literature review to identify and describe non-structural, institutional, regulatory, policy, and other options to enhance the adaptive capacity of a water supply portfolio (for example, stormwater infiltration, utility involvement in land use protection, regional collaborations, and applied research). Identify and describe opportunities, barriers, and limitations to pursuing unconventional approaches.

Key outputs

An inventory of different non-structural options, including pros and cons would be a major contribution in this area. It should identify different models for collaboration, new skill sets needed by utility personnel, and different organizational models that might be necessary to engage these unconventional management strategies.

Project 9: The effects of decentralized infrastructure and hybrid supply systems on system resilience to climate change

Main objectives

The objective of this research is to identify the long-term implications of decentralized systems on centralized water systems, within the realm of a changing climate, especially along these dimensions: public health, operations and maintenance, finance, emergency backup, equity, legal issues, and water rights.

Decisions supported

This project could inform how centralized water utilities engage with and manage decentralized water systems in their service area given expectations of a changing climate (e.g., What are the implications for those opting off the grid if a severe drought occurs?).

Research approach

Evaluate existing examples of decentralized systems in major utility service areas as case studies in the effectiveness of such systems, their vulnerability to climate change, and life cycle cost. In addition to analyzing existing examples, develop demonstration projects that are carefully planned to have a through evaluative element, in order to answer questions regarding vulnerabilities, trade-offs, and costs.

Conduct a literature review and a water system operational analysis. Focus on how to address the implications of de-centralized systems under changing climate conditions and ways to overcome existing barriers to develop synergistic hybrid systems. Determine how to analyze the resilience of different de-centralized and hybrid systems to climate change or whether such issues were considered in project design. Develop methods to analyze such systems that utilities can use.

Key outputs

Develop methods for assessing decentralized system resiliency and life cycle cost. Development of hybrid system concepts that could synergistically increase the resilience of the centralized and decentralized systems. Identification of barriers, how to overcome them, and the benefits of hybrid systems to both centralized and decentralized systems.

Project 10: Understanding how to create adaptive decision support tools for planning under uncertainty

Main objectives

The objective of this research is to better understand how to produce decision tools and methodologies that will enable informed adaptive decision-making under heightened climate uncertainty, such that the tools are useful for water utilities as well as policy makers.

Decisions supported

All major decisions by water utilities on infrastructure investments and operational decisions entrain significant uncertainty. This project should support all such projects, but especially the integration of climate change uncertainty as another layer onto already multi-variate decisions (e.g., increased energy costs associated with movement of water) and drivers (e.g., land use and socioeconomic changes). The decision-makers must be cautions to avoid potential maladaptation activities.

Research approach

Develop case studies from the water sector and other industries, showing both successes and failures, on how to approach planning decisions (e.g., operations, infrastructure) in the face of heightened uncertainty. Note that the purpose of performing these case studies is to better understand how decisions were made with uncertain data inputs; therefore, it would not be necessary that all of these case studies address only climate examples. As a result, it would be interesting to examine the assessment approaches of different industries or sectors, such as reinsurance and financial risk management. The post-assessment phase of each method examined should articulate climate uncertainties to the lay decision-maker within the context of all other issues they have to deal with. Communication and visualization tools should be a significant part of this post-assessment phase.

Key outputs

A "cookbook" for such decision-making processes with applied examples. This cookbook could be used for training, process simulation, and understanding the pros and cons of different methods. It could include an assessment of approaches used by other industries. It should include effective communication and visualization tools. The project should produce a product that is accessible and usable by multiple levels of decision-makers.

OBSERVATIONS FROM THE ENERGY-WATER NEXUS WORKGROUP

Attendees

Harold Reed (American Water) *Chair*
Cheryl Stewart (San Diego County Water Authority) *Co-Chair*
Robyn McGuckin (Montgomery Watson Harza) *Facilitator*
Cynthia Lane (American Water Works Association)
David Yates (National Center for Atmospheric Research)
Dennis Rule (Central Arizona Project)
Kristen Averyt (University of Colorado - Western Water Assessment)
Linda Reekie (Water Research Foundation)
Mark Knudson (Tulatin Valley Water District)
Shonnie Cline (Water Research Foundation)
Veronica Blette (U.S. Environmental Protection Agency)

Overview

The breakout group was possibly one of the smaller of the workshop, and as such we made a decision that everyone should participate in the brainstorming and discussion. Most of the ideas raised led to a short discussion, often with the participants comparing notes or asking questions about the idea or the situation described by the person speaking. Most individuals caveated each of their ideas with a short description of why or how the idea was relevant to their utilities' situation, or to the situation they had been exposed to. This often led to an exchange of related ideas. Though engaged in lively discussion, the group remained quite focused on the task at hand and was easy to guide forward. They all grasped the significance of their work, and understood the specific task they were being requested to accomplish at each phase of the breakout. The group was well selected for the focus topic of energy-water. They were educated and informed about the issue, and had engaging stories about the relevance of the topic to their utility, research focus, or work. Further context is given in each of the below sections, as relevant to the brainstorming issue described.

Key Observations

The principal topics of this workgroup's discussion focused around three key themes:
(1) problems faced with understanding energy availability, pricing and incentives; (2) challenges of getting good, up-to-date data on the energy implications/use of different equipment or processes; and (3) the need to plan for energy and water needs jointly across sectors.

The first theme "understanding energy availability, pricing and incentives" focused on two key elements: uncertainty around energy sourcing and cost, and the general lack of expertise at water utilities for planning robust energy scenarios in the face of uncertainty. This topic could generally include the understanding of various incentives for alternative and renewable energy, and how that impacts a water utility. In addition, with the shift in many areas away from coal, many water utilities are struggling to understand how this will impact their price of energy.

Finally, few water utilities have staff that can do the forward modeling of complex future energy pricing that would reflect the real energy market; instead, most utilities perceive and plan for energy as a static price factor with a slow but steady escalation rate (although there are notable exceptions to this). Additionally, some water utilities are taking advantage of energy procurement strategies where they buy power in advance in bulk to meet their base load and buy spot or day ahead for peaks; but most do not understand how to do this.

The second theme “data on the energy implications/use of different equipment or processes” centered on the need for up-to-date and possibly live and readily accessible tools that would enable live updates of the latest and greatest information on key energy stats. This might include a wiki or other accessible and free information targeted at water and wastewater utility engineering divisions. This would enable better decision-making during the design and throughout the life of a facility. At present, the latest data is in a 1996 Electric Power Research Institute (EPRI) report, which is felt to be significantly out of date.

Finally, a large amount of time was spent discussing the need for cross-sector planning, and understanding what types of cross-sector planning models can work. Cross-sector goes beyond just water and energy utility joint planning, and also includes all major end users within a watershed or service territory. Additionally, the cross-sector planning should take into consideration the climate shifts likely to occur in the area, and the resulting and additional stresses this would place on both energy and water use. It was noted that other major stresses will include demographic shifts. These combined demographic and climatological shifts will likely necessitate joint planning based on extremely limited and therefore quite expensive energy and water resources. Understanding both areas of stress and the models for successful cross-sector planning would be extremely beneficial.

Most Important Climate Sensitive Decisions on Energy-Water Nexus

The group listed and discussed key climate-sensitive decisions facing water and wastewater agencies, with respect to the energy water nexus. These were as follows:

- Synergy between water conservation measures and ability to postpone or reduce need for energy intensive new supplies.
- The relationship between having a water supply source portfolio that is robust – e.g., with a range of options you may or may not need – and how that might interface with having more energy intensity supply options in the supply portfolio.
- Making investment in existing but ageing conventional energy supply vs. making investments in new sources energy supply – considering new regulatory impacts of e.g., mercury and carbon the conventional sources might become too expensive to maintain or may be shut down; however, new sources of energy supply such as renewable are very cost intensive and often not feasible (w/o a base load compliment).
- Integrate energy price forecasts into master plans and rate structures; the impression is that water planners do not understand the energy price escalations that are likely, nor the options for alternative strategies for procuring energy, and therefore this cost factor is not adequately integrated into the rate cases

- How do water and wastewater utility directors "sell" the expenditures needed to decision-making bodies and ratepayers in order to adapt our water and energy systems to climate change
- Integrated water sector and energy resources planning in a climate constrained world – transmission and citing of new facilities based on water availability and quality
- How can water and wastewater agencies be a source of energy
- How do energy extraction (e.g., fracking for natural gas and oil) and GHG mitigation (e.g., carbon sequestration) decisions impact subsurface water quality and availability both in the near and long term
- Decision to invest in a dialogue between energy and water utilities
- Opportunity for energy storage in the face of increased renewable energy on the electrical grid, and the associated need for base load and grid stability
  - Co-benefits of energy water nexus
- Decision for a water utility to invest in energy generation within their water systems given the regulatory disincentives – both in the often onerous permitting requirements, the operating needs, and the potential penalties in regard to water rights
- Availability of water for new energy supplies – balancing existing and competing needs.

Research Needs Identified

In the summary below, all the ideas for research that were generated by the workgroup are listed. Each participant in the workgroup was instructed to "vote" on the top priority research needs. Based on the voting, there were several that had the same number of votes, or relative rank of importance. We did not attempt to prioritize among those that were at the same level, but simply stopped at the tenth idea. There was actually a natural break in the number of votes received, with the top ten emerging as the clear priorities of the group.

After brainstorming the research needs the workgroup did a review and categorized the ideas. After the categorization, one of the comments was that the category "policy and regulation" had not emerged. As such, we did a review of the research needs identified and decided to asterisk all of the items that had a policy element. As such the symbol "*" in any of the below denotes that the research is related to a policy or regulatory issue.

Category A: Energy intensity

- Redo the 1996 EPRI Study around water and waste water for energy intensity.
- Identify cost intensity by region in the United States? for energy consumption of water treatment options
- Develop a tool water utilities to calculate energy intensity to treat different sources of water to required standards of quality; allow for calculation of data inputs with links or references to information that is up-to-date, local and consolidated
- Develop a tool for water utilities to evaluate energy savings of different conservation methods.

Category B: Optimize at the facility level

- Tool to optimize water and wastewater energy use at the facility level – plant operations.

Category C: Water intensity OR water for energy

- Water footprint – differentiated by water quality and quantity – for different types of energy generation and mitigation (e.g., in mg/kWh).

Category D: Planning within the water sector

- Realistic energy price projection applicable to a local utility
- How do we make energy management planning decisions in the face of uncertainties of climate change?
- Implications and opportunities of carbon pricing (long and short term) in water planning.

Category E: Integrated planning – between the energy and water sectors

- Investigate opportunities for integrated basin wide planning (all water use) multi-sector
- Develop planning tool (appropriately scaled) for energy-water balance planning (e.g., integrate water-energy demand forecasting models)
- Future scenarios for energy and water in the face of climate change impacts
  - This idea was around how climate change impact would actually affect energy and water planning, with the concept being to develop case scenarios somewhat similar to what the DOE/EIA does only incorporating the water implications as well as the energy
- Demographic shifts resulting from climate change and the resulting energy cost and planning implications, as they affect water sector planning
- Case study how water energy nexus has been addressed for integrated water energy utilities
- Best practices for how to harness power utility incentives that are energy conservation based for water agencies
- Smart meters for water, integrated with energy smart meters
- How water rights impact water energy policy
- Understanding structure of water and power utilities – region to region.

Category F: Energy generation

- Opportunities for energy generation (both water and wastewater) and barriers to implement at federal/state and local levels (and approaches to overcome the barriers)
- Energy requirements and opportunities for aquifer storage and retrieval (ASR).

Category G: Communication/social science

- How do we communicate to stakeholders the need to invest in future reliability of water and energy supply (due to climate change)
- How to change end user thinking around water and energy consumption

- How to use popular media to communicate energy water nexus.

Outlines for Identified Research Projects

Project 1: Update the 1996 EPRI energy intensity of water and wastewater processes and equipment [Category A: Energy intensity]

(Based on EPRI report "Water and Wastewater Industries: Characteristics and Energy Management Opportunities.")

Main objectives

- Quantify energy intensity by unit process (extraction, treatment, distribution) at 20 water and wastewater facilities
- Consolidate existing data and update the data from previous studies
- Identify and discuss regional differences that we might see in the data
- Identify new technologies that have emerged since 1996 and quantify
- Identify and discuss emerging technologies
- Identify dependencies on source water quality
- Enable utilities to install and understand a state of the art energy management system.

Decisions supported

- Enable better decision-making on technology selection
- Enable regulators to set standards for equipment based on energy consumption, and enable regulators to understand incremental water quality tradeoffs based on increases in energy intensity
- Selecting sources of supply
- Anticipate energy impacts of climate driven water quality changes
- Anticipate regulatory exposure of increased GHGs associated with different treatment technologies
- Identifying and targeting energy efficiency opportunities and additional needs for research
- Assist utilities in understanding how a utility can implement an energy management system.

Research approaches

1. Identify criteria for selection of unit processes that 80% of the water and wastewater utilities use in the country
2. Identify a representative sample of water and wastewater utilities that meet the criteria
3. Install meters on all equipment and collect data for one year to reflect seasonal changes
4. Review research on emerging technologies and compare with existing technologies
5. Project for environmental/technological impacts of regulatory and climate change
6. Identify the time period recommended for keeping the data up-to-date

7. Identify the (media of) the deliverable that will be relevant for utilities to use and for outreach and education.

Key outputs

Tool that is easily used by decision-makers.

Project 2: Opportunities for integrating multi-sector basin-wide planning across all water users [Category E: Integrated energy-water planning]

Main objectives

- Improve basin-wide water (including wastewater and stormwater) and energy resource planning to improve basin-wide resource management
- Understand the barriers to interdisciplinary planning
- Identify elements of successful interdisciplinary planning.

Decisions supported

- Improve water and energy planning by integrating plans of water and energy utilities
- Improve long-term supply reliability for water and energy.

Research approach

1. Develop case studies of regions that have implemented this approach, to include successes and failures
2. Focus on the United States but also consider international examples
3. Identify important stakeholders and their roles
4. Identify barriers and successful outcomes
5. Identify incentives and drivers that have led to the integrated planning.

Key outputs

Summarize case studies and identify best practices for implementing integrated planning. Identify the economic, social and environmental value of integrated planning.

Project 3: How to communicate to stakeholders the need to invest in the future reliability of energy and water supply in the face of climate change

Note: this was combined with Research Project: How to Change End User Thinking About Energy and Water Consumption" [Category G: Communication/social science].

Main objectives

- Change end-user/stakeholder opinions/thinking and actions about energy and water consumption
- Stakeholder support for investments

- Increase stakeholder satisfaction and trust
- To gain acceptance of potential rate increases to enable investments in reliability
- Identify appropriate communication vehicles and strategies
- Effectively communicate what is and is not known about climate.

Decisions supported

- The timing and scope of investments in infrastructure that are necessary
- What types of communication strategies and programs are appropriate at the utility level
- Timing and scope of investments in outreach and public information programs and when they are necessary
- Who to reach out to, and how to reach out to them (e.g., what media and outlets).

Research approach

1. Identification of where the messaging and has been successful (case study approach; U.S. and International)
2. Developing best practices and process framework
3. Identification and characterization of the stakeholders who will be targeted
4. Identify where message is and is not being effectively communicated and why
5. What are the differences between stakeholders definition of reliability versus water management definition of reliability
    - Will help identify means to convey the message to be conveyed through education and public information
6. Identify opportunities, strategies and metrics for changing stakeholder opinions and actions about energy and water consumption
7. Educational campaign on the connections between energy and water
8. Review successful approaches for raising rates in related scenarios; develop recommendations on how to do so.

Key outputs

- Best practices and process framework
- Recommendations on how to raise rates.

Project 3: Develop an appropriately scaled planning tool for integrated water energy demand forecasting [Category E: Integrated energy-water planning]

Main objectives

Develop an approach or methodology at an appropriate scale to predict the water requirements of the power industry at a regional level in light of future climate change scenarios. Provide the means by which to better understand the tradeoffs of water vs. energy use when making infrastructure investment decisions.

Decisions supported

- Provide information that would assist in citing both energy generation facilities and water supply/wastewater facilities and the infrastructure associated with both
- Provide knowledge of the TBL impacts of the alternatives (e.g., large infrastructure decisions)
- Provide knowledge to support decisions pathways for energy decisions based on enterprise level analysis of energy "water footprint."

Research approach

Develop a process (description of steps to develop a methodology) and methodology (model) to coordinate and optimize water and energy utility supply and demand projections in light of various future climate change scenarios.

- Evaluate the Sandia and other water energy nexus models
- Identify the appropriate temporal and spatial scales
- Identify barriers to integrating the water and energy planning tools, methods and methodologies to creating a useful regional tool
- Identify methodologies and tools that the water and energy utilities use for predicting Future Scenarios for Energy and Water Resources in Climate Change.

Key outputs

- Case studies.
- Model: new modeling capability to coordinate the water energy nexus analyses and planning processes by water and energy utilities. This would include a descriptive process that water and energy utilities could use to develop coordinated regional models (this allows a region to optimize the TBL requirements of a region.

Project 4: Water quantity and quality requirements of energy generation, extraction, and mitigation technologies (differentiated water footprinting for energy)

Main objectives

- Identify opportunities to accommodate alternative water qualities in energy
- Understand how to overcome barriers that might exist as related to regulations, zoning, public acceptability of power plant citing and transmission
- Educate water suppliers about water quantity and quality needs of energy industry
- Understand low/lower impact and lower cost means of supplying water needed for energy industry, as well as opportunities for collaboration between the water and energy industries for this objective.

Decisions supported

- Integrated resource planning: where to invest in available water resources in order to meet needs of the community
- Where to site transmission lines and power plants
- Understand the different water demands to inform investment in new infrastructure and water transmission required by the energy industry
- Identify the typical discharge qualities and quantities and then treatment and remediation required both now and in the future.

Research approach

1. Identify regional relevance of water requirements for industrial construction of solar panels, etc.
   - If it is important on this scale, then outline/identify water requirements for different technologies
2. Outline water quantity requirements (both water withdrawals and consumptive uses) for the major water-consuming parts of the energy extraction (e.g., fracking, oil shale recovery), generation (e.g., cooling), and mitigation (e.g., CCS) life cycles
3. Identify water quality as a proportion of total water required for each energy-related technologies
   - Include TDS requirements
   - Temperature requirements
4. Evaluate how water quality and availability might change in a warming climate
5. Incorporate in modeling exercises and identify how water resources in support of energy may change
6. Identify the typical discharge qualities and quantities associated with energy extraction
   - Assess treatment and remediation strategies both now and in the future
   - Assess/identify/develop technologies allowing for the reuse of that produced water in energy extraction process
7. Develop strategies to overcome barriers to lack of reliable water sources and/or acceptable water quality for energy facilities
8. Identify needs for continued updates in this type of research in the context of emerging technologies.

Key outputs

- Data for modeling and integrated planning in both energy and water
- A tool easily used by multiple decision-makers (e.g., wiki, online interface, database, etc.).

Project 5: Opportunities and barriers for energy generation within water and wastewater systems/utilities

Main objectives

- Identify the opportunities for energy generation within water and wastewater systems
- Identify the potential benefits in terms of revenue and energy associated with energy generation
- Identify regulatory and policy limitations and challenges on federal, state, and local scales
- Outline strategies for overcoming identified challenges
- Identify potential regulatory changes.

Decisions supported

- Based on economic and policy implications, determine whether to invest in energy generation technologies
- Support for evolution of enabling policies, regulations and permitting processes.

Research approach

1. Identify energy generation sources and potential future sources
    - Quantify energy generation
    - Identify best opportunities for energy generation that are currently untapped, with a focus or emphasis on those sources which may leverage financial investment
2. Identify international regulatory frameworks that facilitate energy generation
3. Outline relevant federal, regional, state regulations, permitting and policies (for both water and energy sectors)
    - Characterize as opportunities or barriers in a regional context for both water utilities and energy utilities.

Key outputs

- Identify necessary regulatory changes on regional and federal scales that would be beneficial for both water and energy sectors
- Guidance to aid utilities in evaluating feasibility of potential energy generation projects.

Project 6: Demographic shifts resulting from climate change and resulting energy costs implications

Main objectives

- Understand if climate change affects demographics and user categories (service population)
- Understand the associated energy impact of those demographic changes
- Understand how this impacts water utility planning (demand projections, infrastructure upgrades and capital additions)

- How is climate change going to impact demographic changes?

Decisions supported

- Improve and inform the planning process, demand projections, and resulting planning (infrastructure capital expenditures)
- Reduce the risk of stranded capital or failure of infrastructure
- Improve the accuracy of associated electric grid demand projections
- Improve the integrated urban and suburban or basin/territory-wide planning process.

Research approach

1. An interdisciplinary research team (social, climate, energy, water) will be required to do this research
2. Understand current drivers for demographic changes
3. Evaluate the climate change impacts on these drivers.

Key outputs

White paper providing a qualitative assessment and identifying the potential range of climate change impacts on demographic shifts in the United States. Also identify additional research needs (i.e., models, decision support tools, and trend analysis).

Project 7: Case studies for how the water energy nexus is addressed by integrated water energy utilities [Category E: Integrated energy-water planning]

Main objectives

- Evaluate integrated water energy utilities and determine the factors that have allowed them to plan for the water energy nexus
- Identify how the success factors can be transferred to nonintegrated utilities.

Decisions supported

- Whether to and how to engage with the power industry to successfully plan for the water energy nexus
- Evaluation of relative merits and benefits of specific tactics for integrating utilities, or integrating the planning process.

Research approach

1. Identify appropriate integrated facilities in the United States
2. Evaluate the impact and role of organizational structure and governance on their ability to plan for the water energy nexus
3. Identify specific topics in which they are coordinating; identify some specific tools that they are using; identify the qualitative and quantitative benefits

4. Identify the costs and barriers
5. Identify opportunities created by integrating the planning process
6. Develop and vet a process for integrating water and energy utilities by engaging nonintegrated water and energy utilities in a facilitated session.

Key outputs

Summary of the case studies, description of a process that could be used to integrate water and energy utilities to improve planning in light of climate change.

CROSS-CUTTING THEMES AND RESEARCH TOPIC GROUPINGS

In the final plenary sessions, the attendees placed research topics in similar categories, to help identify cross-cutting issues and themes, and to provide broader context to the efforts of the individual workgroups. Key findings from the final plenary discussions are provided below, and additional details are provided in Appendix D.

Theme A: Developing a fundamental decision-making process for adaptation in the context of uncertainty. Several project ideas were developed across workgroups that recognize the inevitable high degree of uncertainty that will exist in developing region-specific, climate change impact projections. Given that climate change-related projections (such as seasonal precipitation, storm intensity, flood severity and frequency, and so forth) can only be developed with relatively high degrees of uncertainty, it will be necessary for utilities and other water resource managers to have tools and approaches that provide practical and sound ways for assessing their vulnerabilities and making sound adaptation and related planning decisions under conditions of high uncertainty.

Theme B: Evolving engineering and planning paradigms to increase flexibility. Related to Theme A's recognition of the need to support suitable decision-making in the face of uncertainty, several workgroups identified research needs associated with increasing flexibility in both training/education, as well as in process and engineering design. Flexibility and adaptive management are hallmarks of sound adaptation planning and decision-making under high degrees of uncertainty regarding future conditions.

Theme C: Improving communication. Multiple workgroups identified the need for better ways to communicate issues related to climate change and associated adaptation planning. Some of the communication-related ideas reflect a need to effectively convey the value and rationale of appropriate adaptation actions to various audiences (e.g., governing boards, city councils, rate regulators, customers, voters), regardless of the uncertainties about future climate. The communication projects generally recognize that while uncertainties are inevitable, they do not eliminate the need for suitable climate change-related planning and decision-making (but they do make explaining and justifying adaptation programs more difficult).

Theme D: Coordinating development of consistent regional data/information for planning scenarios that are useful for water utilities/downscaling models.[7] This theme is represented by several workgroups with research project ideas related to providing better and more useful spatially-relevant climate change data to utilities and other water resource managers. In particular, downscaled climate model data would be provided in a format that can be used by utilities. Several projects tie into the previously-described themes related to uncertainty, and to conveying to decision-making practitioners the meaning and limitations of downscaled or other available data regarding regionally-scaled climate change impacts. A key recognition expressed across these projects is the need to assist practitioners to understand and properly interpret

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[7]. The meaning of "regional" needs to be defined, and may vary by application. Suitable "regional" scales may include the following: watershed, water management district, water basin, municipality, and climate zones.

region-specific data, given the complexities and the uncertainties inherent in regional climate change projections.

Theme E: Compiling and using observed data. Projects were identified across workgroups reflecting the value of doing more research related to collecting and/or interpreting climate-related data, especially as they relate to improving the ability to observe important current trends and forecast extreme events. These data would be useful for a wide range of adaptation planning activities, and would be vital to adaptive management approaches, whereby entities adjust their actions based on new climate information as it becomes available.

Theme F: Integrating adaptation and mitigation approaches. Several research ideas were identified that reflect the fact that there are instances in the water and wastewater sector where mitigation and adaptation may be two sides of the same coin. Hence, research could assist in identifying and improving ways in which energy use and carbon footprints may be reduced in the water and wastewater sectors, while concurrently assessing how these mitigation-related activities may assist (or hamper) utilities with their adaptation planning.

Theme G: Promoting institutional changes. Multiple workgroups identified research topics that touched on the need to examine how key institutional arrangements may need to be modified in order to enhance the ability of utilities to better plan for and adapt to climate change. The institutional activities mentioned include development of regulatory regimes, design standards, and training and education.

Theme H: Examining the potential role of decentralized and hybrid systems. Several research ideas touched on the issues of decentralization in wastewater management or water supply, and the suitable role of decentralized approaches and technologies as part of adaptation planning. Key questions to explore include examining the manner in which decentralized or hybrid systems may make communities more (or less) flexible, redundant, and resilient with respect to climate change impacts.

WATER SECTOR NATIONAL CLIMATE ASSESSMENT SESSION

Presented by NOAA: Climate and Societal Impacts - Water Element, EPA (Office of Water and Office of Research and Development), NASA (Water Resources)

Moderators: Kathy Jacobs (National Climate Assessment); Anne Waple (NOAA Assessments Technical Support Unit)

Background

The 1990 Global Change Research Act (GCRA), Section 106, requires:
On a periodic basis (not less frequently than every four years), the Council *(the National Science and Technology Council),* through the Committee *(the Global Change Research Committee (GCRC))*, shall prepare and submit to the President and the Congress an assessment, which

1. integrates, evaluates, and interprets the findings of the Program *(the US Global Change Research Program)* and discusses the scientific uncertainties associated with such findings;
2. analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
3. analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

Assessments serve important functions in providing the scientific underpinnings of informed policy. They also serve as progress reports by identifying advances in the underlying science, providing critical analysis of issues, and highlighting key findings and key unknowns that can improve policy choices and guide decision-making related to climate change. The approach that is envisioned for this third approach to the National Climate Assessment (NCA) is a comprehensive assessment of climate change, impacts, vulnerabilities and response strategies, within a context of how communities and the nation as a whole create sustainable and environmentally sound development paths.

Approach

The strategic plan and operational activities of the Assessment to date have been in the context of an all-Federal task force of 15 agencies that has met every two weeks since April of 2010. The decisions made by the Interagency National Assessment Task Force are to:

1. Change the focus of the Assessment from production of a single report to ensuring a sustainable process; the reports that will be generated will be viewed as a "time-slice" through an ongoing effort, in addition to being an end in themselves. This will enable sectoral, regional, topical and/or national reports to be created over time as needed, allowing us to meet the requirements of the Global Change Research Act as well as to serve a number of other important policy and science objectives.

2. Create an ongoing, national-scale evaluation process to assess current and projected climate impacts and climate-related risks in the context of other stressors; the intent of this effort is to identify opportunities as well as risks associated with changes in climate conditions. An ongoing component will be to better understand the attribution of events and trends. This information will be used to prioritize federal activities that support adaptation and mitigation decisions made within the states, regions, and sectors and to constantly reassess priorities for federal science investments.
3. "Nest", within this broad ongoing assessment, more specific investigations of areas and topics that have high priority due to existing or anticipated climate stresses, generally in the context of a variety of other concerns.
4. Coordinate through a central structure. Coordination will also depend upon a distributed process to maximize engagement of partners both inside and outside of the federal government. This approach is necessary both in order to maximize the likelihood that the Assessment will continue over time, and to recognize that though it is the role of the federal government to conduct a national assessment and to provide the support needed for regional efforts, it is neither appropriate nor possible for the federal government to actually conduct all of this work itself. However, the federal government must play a leading role in coordination, as well as in cross-regional and international efforts.
5. Depend, to the extent possible, on regional networks and a variety of public and private partners to do the "ground-truthing" and engagement of regional and sectoral partners for the Assessment, and depend on federal monitoring programs for larger scale or more comprehensive assessments and evaluations. Thus, the approach is a combination of engagement of existing regional networks, selective engagement of national organizations that represent sectors and impacted populations, and use of federal science investments.
6. Create a guide for producing information that is acceptable for inclusion in the Assessment and that will be used for all Assessment products. All information that is used by the Assessment will be reviewed prior to inclusion, using agreed-upon criteria and evaluation processes. Not all information that comes from local networks will ultimately be published through classical peer review processes or come from government data. Technical reports may require different levels of clearance depending on the audience; there will need to be good documentation of the "chain of custody" of information, tracking data from origin to use. In addition, we will ensure compliance with the Information Quality Act.
7. Recognize the international context of climate trends, decisions and programs and help to support some of the U.S. inputs to the Intergovernmental Panel on Climate Change (IPCC).
8. Give a high level of attention to the first order priorities, i.e., oversight, communications and stakeholder engagement. NOAA will establish a Federal Advisory Committee (FAC) that will include a broad set of perspectives, sectors and kinds of expertise. The FAC will be responsible for approving all Assessment related documents and will establish subcommittees to develop components of the Assessment process and products. The communications strategy will be implemented starting at the beginning of the process (there is already a newsletter and a website), and the NRC (National Research Council) will provide ongoing oversight and review of the process and products.

9. Hold a series of workshops to develop alternative procedures and approaches that will be considered by the FAC in determining the methods by which the Assessment will be conducted. These process workshops will have documented outcomes that are publicly available.

Goals and Objectives

The overarching goal for the broad climate science program within the US government is to inform and enhance our ability to respond to a changing climate in a multi-stress context.

The mission of the National Climate Assessment is:

> to establish a continuing, inclusive National process that 1) synthesizes relevant science and information; 2) increases understanding of what is known and not known; 3) identifies needs for information related to preparing for climate variability and change, and reducing climate impacts and vulnerability; 4) evaluates progress of adaptation and mitigation activities; 5) informs science priorities; and 6) builds assessment capacity in regions and sectors.

National Assessment Plenary Discussion: Question and Answer Session

1. Question: Relative to cross-sectoral Impacts, as we gather information from sectors, how will the assessment team encourage sectors to work together? Is the staff doing this? It will be beneficial to bring sectors together for inter-sectoral interactions.

   Answer: Several sectors, such as the water/energy sectors, that in combination are associated with high risk or vulnerability, will be used as examples in the first report. The goal is to bring sectors together more broadly as the process itself is more robust, but the ability of the NCA staff to examine all the influences of one sector on another are limited.

2. Question: Are you dealing with both climate variability and change in this Assessment?

   Answer: Yes, we intend to talk about the impacts of both climate variability and change and we need to be clearer about that in our descriptions of the Assessment.

3. Question: For the Federal Advisory Committee (FAC): Do you have people in mind? Or is it a public nomination process?

   Answer: Approximately 36 people will be chosen representing all sectors. Names will be released for public comments. Each member will need to bring a number of different kinds of expertise and geographic perspectives to the table.

4. Question: It is impossible to cover all the topic areas with 36 people as defined. What is the role of utility people who are equally interested in this process?

Answer: The first Assessment in the late 1990's was written by 8-10 people and the information was pulled together from a community of perhaps 1,000 people. The community is now much bigger – close to 10,000 or maybe 100,000 people. Using professional societies could be a better approach to engaging groups such as the utilities rather than working with individuals as these groups can more efficiently tailor communications with the increased number of people involved.

The FAC membership will be external to the government. The FAC will establish sub-groups to cover different topics and regions.

5. Question: Is this National Climate Assessment more like the First or the Second Assessment?

   Answer: The Third Assessment is closer to the First Assessment in approach. It will connect science to society. It will synthesize information. It will not answer specific questions that are tailored to particular individuals or businesses, but it is designed to help support decision-making in regions and sectors.

6. Question: The National Assessment will focus on impacts of climate change; does it have any legal responsibility relative to adaptation and mitigation?

   Answer: The Assessment report will discuss ways to evaluate effectiveness of adaptation and mitigation and how this can be done across sectors. It does not have any legal responsibility relative to particular decisions.

7. Question: There are a number of reports such as those produced by the NRC that most water people do not read. They keep asking the same questions. How is this different than other report efforts?

   Answer: There is a communication problem that needs to be fixed. The Global Change Research Program is working on a broad communication effort that extends beyond this process. We are hoping that the networks we will use to establish the basis for the Assessment will also help with general communications efforts.

8. Question: Is the National Assessment forming the foundation for future legislation?

   Answer: There is no legislative or political agenda. The objective is to understand and facilitate decision-making.

A Summary of the Responses from the Two Breakout Sessions: Process Discussions

What are the ways that the utilities would like to be engaged in the Assessment that are of least burden and greatest benefit?

Large and Small Utilities:

- There is a difference between small and large utilities and therefore there are differences in the way that we should engage them and what they can provide, as well as ways in which they will benefit from the assessment. Large utilities serve approximately 90 percent of the U.S. population, but there are a vast number of small utilities with a high degree of vulnerability.
- One way to be strategic is to approach proactive utilities and use existing collaborations. Larger utilities have the scientific-staff to generate the data that will be critical for the Assessment. Later in the process, the NCA Staff may want to convey information to the small utilities; it may not be as valuable to invest early efforts with this group.
- A marketing strategy could be used to reach smaller utilities, as well as larger ones; however, if the smaller utilities are not interested, how much effort should the NCA staff expend to reach them?

Who/How to Contact Staff at the State/Local Level:

- State regulatory agencies and state water research centers provide one mode for approaching utilities but it is not a consistent mechanism across states.
- In many states the primary water utilities serve agriculture, e.g., irrigation districts as well as other kinds of water districts. The NCA staff will need to decide how to approach water issues for the non-municipal sectors.
- The NCA will need communication tools to bring focus to the local level. There are a number of interactive ways to do this such as through webinars and videos (as travel is expensive and time consuming).
- Targeted surveys (online are easy to respond to) could help generate some kinds of data.
- NCA staff could rely on local knowledge to identify vulnerabilities and build from local expertise on up and not national projections down. It will be important to incorporate these local assessments and reports. It is critical to include the utility perspective and engagement with them will build capacity within the sector.
- How should the NCA staff define small: small city or community level? The NCA can use a representative sample group because it cannot reach out to a number of these systems. There is a recommendation to work with the Rural Community Assistance Partnership (RCAP) and state drinking water administrators.

Other Sources of Information/Partnerships:

- The NCA staff members need to take advantage of findings from existing reports and data from water utilities and the professional societies that represent them rather than starting from scratch and ignoring previous processes and reports.
- Water and wastewater utilities need to be approached through different organizations.

- There is a need to incorporate sources other than scientific literature in the Assessment report.
- It is helpful to be sensitive to relationships with partners and make sure that information is vetted for validity/representativeness and that there are no surprises. These relationships will be critical to maintaining trust between the Assessment activity and its partners.
- There is sensitivity as to what utilities would be ready or able to share? There are some kinds of proprietary and sensitive data that they may not want others to see due to privacy or legal requirements.
- Collecting "Lessons learned" may or may not be valuable; past experience may not fit in today's regulatory or climate framework.
- Progressive utilities are already investigating their own vulnerability and many have their own monitoring programs, these early adopters could assist with monitoring on a voluntary basis.
- Tracking how the Assessment information gets used would be valuable in terms of continuing to improve the process.
- Could the Assessment start to fill gaps in observations, including the loss of the USGS Cooperative Stream Gage program?
- Is there a way for the Assessment to have a rapid deployment of findings that could influence activities in the short term?
- A case study approach could be used to identify success or failures or just to understand how a system works.

What kinds of partnerships/networks would be effective to generate and submit information to/from the Assessment, e.g. coordinated through professional organizations, states, federal agencies or regional entities?

- Professional organizations provide a built-in network to approach their members, including WaterRF, WERF (Water Environmental Research Foundation), AWWA (American Water Works Association), AMWA (Association of Metropolitan Water Agencies), ASDWA (Association of State Drinking Water Administrators), ASWIPCA (Association of State and Interstate Water Pollution Control Administrators.
- NACWA (National Association of Clean Water Agencies) is the best way to approach the wastewater treatment side; AMWA and AWWA are probably best for the drinking water side.
- There are Rural Water Associations that support smaller utilities in most states and there is a National Rural Water Association as well.
- Consultants are an important group to engage, as they are influential at critical points in decision processes. There is a small group of large consulting firms that reach most of the large water utilities; however, they are not an appropriate mechanism for approaching the smaller utilities.
- Cooperative extension services in each county/state provide one consistent mechanism to approach water users
- The EPA States and Tribes Committee provides a good way to approach multiple subgroups, including state and tribal drinking water systems. There is a steering committee for this group that conducts monthly calls.

- Local climate change taskforces have published plans and have views on the effect of climate change on water supply; these products and processes can be used as spring boards for the Assessment, i.e. New York City.
- The EPA Storet (STOrage and RETrieval) Data Warehouse is an interesting approach to data gathering; it is a way for utilities to voluntarily upload water quality data.
- Many state agencies collect information, some of which could be useful to the Assessment (though it may not be collected consistently). For example, in Florida it is the Water Management Districts that collect information; in California, it is regional boards; in Arizona, it is the Department of Water Resources; and in Colorado, there are watershed-based resource districts
- Professional associations like WERF generate their own data and maintain their own databases, e.g., “Clean Water Central”.
- Some major utilities have long-term commitments to environmental monitoring for a variety of reasons, e.g., the Southern Nevada Water Authority monitors groundwater levels in multiple basins in the context of stipulated agreements with the Department of Interior.
- The NCA staff could design a giant venn diagram that would overlap with regions and sectors to identify direct relationships with larger utilities that can cover issues. One suggestion was to work with RCAP (Rural Community Assistance Program).
- The National Science Foundation has historically developed the Environmental Indicators Network report that identified all the monitoring systems across the country; although this network is outdated this is a valuable resource.
- The NCA should look at efforts like NEON (National Ecological Observatory Network), GLEON (Global Lake Environment Observation Network), and the reports of the Water Science and Technology Board of the NRC.
- State field supervisors for the Fish and Wildlife Service would know about the monitoring efforts that are taking place within their state, related to the ESA (Ecological Society of America).
- The USGS Water Census, now run by Eric Everson, works through states, divided into three priority groups, to collect data; it is just now being implemented.
- The Environmental Council of States (Steve Brown is the director) and the American Society of Water Pollution Control Associations are networks that could be useful.
- The CUAHSI Hydrologic test beds and the Hydrologic Information System (David Maidment, Texas) may have information that is useful.
- The Clean Water Act Section 208 planning process is being conducted regionally in Colorado; they are collecting a lot of information and could be a good test case.
- The Basin Commissions, e.g., the Delaware Basin Commission, could also be used as a model.
- There are new grant proposals coming out of the EPA Office of Compliance (Cary Johnston, David Hinden) that could result in good data sources in regards to ICIS (the Integrated Compliance Information System) and NPDES (National Pollutant Discharge Elimination System).
- THE NCA should consider bringing in states as they work closely with the small and medium utilities (ASWIPCA).
- The NCA should contact other smaller rural water organizations such as RCAP. Their biggest influence is at the state level.

- The NCA should explore the RISA model through a water lens. Part of RISA's job is to do outreach.
- There are some existing networks that are connected by the watershed management authority, e.g., the U.S. Bureau of Reclamation is a logical coordinator for Colorado River communities.
- EPA's Climate Ready Utilities report will be out soon and be useful for the Assessment.

A Summary of findings from the two Breakout Sessions: Substance Discussions

What is the science outcome that you most want from the Assessments?

Models/Projections/Scenarios/Downscaling:

- NCA can help to provide guidance on how to use information (such as which model outputs to use). Some data should come with warning labels, i.e., caveats about appropriate use.
- The NCA can help to verify projections and scenarios so that decision makers can understand what path we are on and help to understand how to respond, essentially using this updated information for adaptive management. NCA should help to provide clear-cut evaluations of trends and changes, and some analysis of appropriate monitoring systems.
- Two scientific outcomes that would be valuable would be investigating downscaling to serve different needs and identifying the scales that are most useful for specific decisions. One goal could be to establish a consistent national baseline of data from downscaled models and a clear way to get outputs into formats that utilities need/can use. Currently there is limited time to apply existing information before new GCMs are ready.
- Another idea would be to have workshops on climate models with public input.
- It is currently not possible to produce nationally downscaled assessments to the watershed scale. The Assessment may be able to produce baseline inputs that are used by others (i.e., private sector, local governments) in more specific applications.
- There is a need to identify the trends and boundaries of uncertainty. The ultimate goal is to move toward increased certainty.
- Decision makers need guidance on how to use downscaled information. What are the caveats/conditions for use of outputs?
- It would be important to show how models have been validated based on historic records.

Timescales:

- NCA could look at timescales where weather and climate intersect, for example, the three-five year timescale. What is the predictive capacity and how should estimates be given of probabilistic change for shorter-term water infrastructure investments? For example, in regards to decisions related to the recharge of surplus water for future recovery in Arizona, when will they need to implement recovery wells to deal with shortage without stranding assets? A decision now needs to pay off in five years.
- Another timescale to consider would be the ten-year predictive timeframe as most projections are much longer-term, but decisions are on much shorter time horizons.

Adaptation/Mitigation:

- It would be good to document where utilities stand in terms of actively documenting adaptation activities; case studies could be useful as examples of adaptation like the Joint Front Range Climate Change Vulnerability Study.
- Documenting the social and institutional components of adaptation and how some institutions facilitate or hinder adaptation would be useful (e.g., what are the constraints on effective adaptation).
- One of the most important outcomes will be the interface between the Assessment and current and future adaptation and mitigation actions, e.g., policy implications of the interface and the interface between science and assessment data and use of this data (translational capacity).
- Climate change paralyzes infrastructure investment decisions. The NCS should look at: adaptation by incremental changes or other non-structural approaches and ways to leverage across sectors. A financial, institutional, regulatory tool set for adaptation actions would be critical as well as an identification of needed policy changes.

Other Outcomes:

- The NCA cross-sectoral focus is going to be extremely valuable in providing information on how decisions or impacts in other sectors are going to impact water and associated water decisions.
- Attribution of events such as droughts to specific climate drivers may help to clarify decision options and in particular, an analysis of likely changes in return periods for extremes would be beneficial. This would be very valuable.
- NCA could help to support alternative solutions (i.e., nonstructural) in water adaptation. NCA could help examine the influence of financial, institutional, conservation measures, etc.
- Part of the assessment process can be to invest in evaluations of how people like to receive information (e.g., in what format, etc.).
- A key contribution will be the selection of indicators. One example of an indicator is the number of sewer overflow events.
- The Assessment should recognize and describe significant regional differences, identify what are the important issues and how utilities are moving towards a more adaptive approach.
- Building a permanent regional and sectoral network that supports ongoing assessment activities should be an important outcome for the Assessment.
- Telling compelling stories about how climate drivers affect the water sector, and how much is at stake, would be helpful. It will be important for the Assessment to include consistent, validated impacts, i.e. sea level rise.
- Cross-sectoral impacts are very important. As a result, forecasts that relate to the quantity and quality for the water sector, in the context of impacts in other sectors, In addition, it would be important to identify the collateral effect.
- A Climate Services should be multi-dimensional including information on a suite of models.
- The utilities need guidance for doing vulnerability assessments.

- There should be more effective monitoring of trends; one approach would be to improve statistical analysis in trend detection. The NCS needs an expert group to look at statistical trend analysis and help with interpretation.
- Attention should be paid to the engineering paradigm and non-structural alternatives. How do utilities figure out how to get currents assets to function 50 years out? Designs should be looked at for "just in time" infrastructure that do not strand assets and increased resilience. One potential would be to pursue paths that are less based on the 'uncertainty question'.
- The NCA should consider quantifying the value of ecosystem functions (i.e. ways to justify preserving flood plain capacity).
- Flexibility and adaptive management promotes adaptability and resilience.
- Identify lead times to make certain investments. Seasonal predictions could be used to make management decisions. The NCA could assess the reliability of predictions. Currently, confusion about the reliability of models/predictions is hampering the sector in their use of climate information.
- The NCA should assess the risk of failures of predictive capacity as some failure has greater risk. This ability would create the basis for a decision point, as it is a critical need to include the extent of risk.
- Revised and updated intensity-duration-frequency of precipitation curves would be useful, as well as a philosophy for using design information in a changing climate.
- A discussion on how to handle growth in the context of climate change and water (and possibly on land use) information would be helpful.

What kinds of information would the water industry like to bring to the table for consideration?

- WERF is willing to help bring people together to help identify the indicators to be used by the Assessment and monitor them over time. The dialogue on selecting the indicators is important, especially if a partnership emerges and if there is an ongoing commitment to supporting the development of information, it must be connected to observations that utilities are already making.
- The Assessment team was complimented for their interest in identifying the stakeholder drivers for information.
- There is a need for an assessment for the Assessment; this would include marketing and segmenting by audience.
- Investments in infrastructure can be an indicator; for example, to what degree is new infrastructure taking climate change into account? WERF is willing to document these things, as well as provide a gap analysis. They have a vested interest in this process. They are already involved in road mapping the wastewater treatment plants of the future, especially in understanding what are the new technologies that are needed? This could help with the indicator discussion.
- If there is movement towards reduced energy in the water sector, an ongoing evaluation of energy use by the sector to measure progress towards a goal would be useful; one possibility is that it could be self-reported.
- One proposed idea would be to produce a decision support system where one could produce maps, choose time frame, and find locations (city) into the future (as warmer

climates migrate north). For example, one could ask - in New York, what is the predicted climate 100 years in future? How would that differ from Miami? Ideally this system would be able to apply some factors and gives expectation under a new climate regime.
- There is a need to work on the appropriate roles for the public and private sectors relative to information produced by the Assessment.

There has been significant discussion on developing a common climate information source to serve the water industry. What are the necessary ingredients?

- A key contribution would be providing the compelling science arguments that help utilities articulate the need for adaptation. Billions of dollars are going into infrastructure right now and decision makers do not have actionable information. There is a need to argue for proactive rather than reactive adaptation.
- It would be useful to have more public accessibility of local reports on industry websites such as those run by WERF and WaterRF. One site with links would be most useful, especially if it included a suite of information resources.
- Another useful ingredient would be documentation of the changing baselines that affect regulatory programs such as TMDL (Total Maximum Daily Load) and ESA (Endangered Species Act). Most of these programs assume a stationary climate; there needs to be documentation of why this no longer works.
- The Assessment can help inform what a national Climate Service needs to be.
- The website/portal can start with a design that focuses on key clients/translators such as the Cooperative Extension Service.
- A roadmap to where to find what information across the federal agencies would be useful.
- The Assessment needs to be more than a copy of a written report, it needs to be a dynamic and extensive source of information, perhaps even a clearinghouse. (Though there is one maintained by NASA called the Global Change Master Directory (http://gcmd.nasa.gov/); however, not many people know about it.)
- An ideal portal would include menu options that help utilities make the link between adaptation strategies and the kinds of information needed to support those options.
- A "latest news in the climate world" component would be helpful. Suggested topics could include: what have we learned, and new ways of thinking about uncertainty in real time. Subscribers could receive a notice when there are important new findings which they could then find on the front page of the website.
- There should be obvious links on the website to connect to other sources of information, websites, experts on specific topics, etc.
- The website could include briefings for decision-makers, e.g., one-pagers on topics of interest to boards of directors and other decision makers.
- The website could provide a place for more detailed information and case studies for water sector information that does not fit in the Assessment report but can be a resource for those who want more detailed information.
- There is a need for a central repository for climate change plans and available vulnerability studies, etc. for water and utilities.

What information needs are there at the adaptation-mitigation interface?

- There is a need for more effective ways to do cross-sectoral analysis, e.g., how do we incorporate negative externalities of our energy options in the Assessment as well as other types of analyses?
- Other components to consider are projections of technology capacity versus demand as well as evaluations of what are the units we should be measuring.
- Just articulating the strong relationship between energy and water in the Assessment will be useful. We already know that the relationships are not the same across states and localities
- The energy-water interface is an appropriate place for the Assessment to focus.

Conclusions and Next Steps

The results of the workshop have been summarized in this document and will be used in the context of developing both the water sector Assessment components and to inform the approach to other sectors and regions. The draft summary report will be shared with attendees for corrections and included in the summary document for the full workshop. The attendees of the workshop have been added to the Assessment newsletter distribution list.

APPENDIX A - CLIMATE CHANGE WORKSHOP PARTICIPANTS

Name	Affiliation
Alison Adams	Tampa Bay Water
Andrew DeGraca	San Francisco Public Utilities Commission
Anne Waple	National Oceanic and Atmospheric Administration
Art Umble	Greeley and Hansen
Barbara Biggs	Metro Wastewater Reclamation District
Bob Bastian	U.S. Environmental Protection Agency
Brad Udall	University of Colorado – Western Water Assessment
Brandon Goshi	Metropolitan Water District of Southern California
Carol Collier	Delaware River Basin Commission
Carol Russell	U.S. Environmental Protection Agency
Casey Brown	University of Massachusetts
Chad McNutt	National Oceanic and Atmospheric Administration
Cheryl Stewart	San Diego County Water Authority
Chet Koblinsky	National Oceanic and Atmospheric Administration
Chris Martinez	University of Florida
Christine Jean Kirchhoff	University of Colorado
Chuck Hennig	U.S. Bureau of Reclamation
Claudio Ternieden	Water Environment Research Foundation
Curt Baranowski	U.S. Environmental Protection Agency
Cynthia Finley	National Association of Clean Water Agencies
Cynthia Lane	American Water Works Association
Daniel Nvule	Massachusetts Water Resources Authority
David Major	Columbia University Earth Institute
David Toll	National Aeronautics and Space Administration
David Yates	National Center for Atmospheric Research
Dennis Rule	Central Arizona Project
Dionne Driscoll	CONTECH Stormwater Solutions
Djanette Khiari	Water Research Foundation
Douglas Yoder	Miami-Dade Water and Sewer Department
Erica Brown	Association of Metropolitan Water Agencies
Geoff Bonnin	National Oceanic and Atmospheric Administration
Greg Garfin	University of Arizona
Harold Reed	American Water
Jade Soddell	U.S. Bureau of Reclamation
Jeanine Jones	California Department of Water Resources
Jennifer Warner	Water Research Foundation
Jim Goodrich	U.S. Environmental Protection Agency

Name	Affiliation
Joe Busto	Colorado Water Conservation Board
Karen Metchis	U.S. Environmental Protection Agency
Kathy Jacobs	Office of Science and Technology Policy
Ken Potter	University of Wisconsin
Kenan Ozekin	Water Research Foundation
Kristen Averyt	University of Colorado – Western Water Assessment
Latham Stack	Syntectic International
Lauren Fillmore	Water Environment Research Foundation
Laurna Kaatz	Denver Water
Linda Reekie	Water Research Foundation
Lorna Stickel	Portland Water Bureau
Lorraine Janus	New York City Department of Environmental Protection
Marc Waage	Denver Water
Mark Knudson	Tualatin Valley Water District
Mary Culver	Coastal Services Center
Matt Reis	Water Environment Federation
Melissa Kenney	National Oceanic and Atmospheric Administration
Mike Hayes	National Drought Mitigation Center
Nancy Beller-Simms	National Oceanic and Atmospheric Administration
Noah Molotch	National Aeronautics and Space Administration
Nolan Doesken	Colorado State University
Olivia Thorne	South Australian Water Corporation
Paul Fesko	City of Calgary
Paul Fleming	Seattle Public Utilities
Paul Kirshen	Battelle Memorial Institute
Peter Ruffier	Clean Water Services
Peter Schultz	ICF International
Phil Mote	Oregon Climate Change Research Institute
Rachael Novak	U.S. Environmental Protection Agency
Radley Horton	National Aeronautics and Space Administration
Rebecca West	Spartanburg Water
Richard B. Rood	University of Michigan
Rick Holmes	Southern Nevada Water Authority
Robert Webb	National Oceanic and Atmospheric Administration
Roger Pulwarty	National Oceanic and Atmospheric Administration
Sandra Stavnes	U.S. Environmental Protection Agency
Shonnie Cline	Water Research Foundation
Soroosh Sorooshian	University of California, Irvine
Stephanie Granger	National Aeronautics and Space Administration

Name	Affiliation
Tom Iseman	Western Governors’ Association
Tom Johnson	U.S. Environmental Protection Agency
Veronica Blette	U.S. Environmental Protection Agency
Veva Deheza	Colorado Water Conservation Board
Zane Marshall	Southern Nevada Water Authority

Facilitators

Jason Vogel	Stratus Consulting
Joel Smith	Stratus Consulting
Russell Jones	Stratus Consulting
Robyn McGuckin	Montgomery Watson Harza
Jeff Oxenford	Oxenford Consulting

APPENDIX B - MEETING AGENDA

A View of the Future for Research on Climate Change Impacts on Water:
A Workshop Focusing on Adaptation Strategies and Information Needs

August 31-September 1, 2010
(National Climate Assessment Component – September 2)
Curtis Doubletree Hotel
1405 Curtis Street
Denver, Colorado 80202

DAY 1: Tuesday, August 31

7:30 AM Continental Breakfast

PLENARY SESSION

8:00 AM Welcome Remarks & Objectives of the Workshop

Nancy Beller-Simms, Program Manager
Sector Applications Research Program
National Oceanic and Atmospheric Administration

Robert Renner, Executive Director
Water Research Foundation

Claudio Ternieden, Assistant Director of Research
Water Environment Research Foundation

The key objective of this workshop is to establish a link between the efforts being undertaken in research and information generation and the needs, current and future, of the water and wastewater community using the research and information generated. This session will also make the link between the proceedings and the National Assessment Efforts.

8:15 AM Climate Change: Water Sector Information, Data and Tools – What's Out There?

Moderator: Kenan Ozekin, Senior Project Manager
Water Research Foundation

Chet Koblinsky, Director
Climate Program Office
National Oceanic and Atmospheric Administration

Jim Goodrich, Sr. Environmental Scientist
Global Change Research Program - Water Adaptation Team
Office of Research and Development
Environmental Protection Agency

David Toll, Deputy Program Manager
Water Resources Program & Hydrological Sciences Branch
National Aeronautics and Space Administration/
Goddard Space Flight Center (GSFC)

Radley Horton, Associate Research Scientist
Center for Climate Systems Research Columbia University
(Working with the National Aeronautics and Space Administration)

Katharine L. Jacobs, National Climate Assessment Lead
White House Office of Science and Technology Policy

This session includes high level agency speakers from NOAA, NASA, and EPA providing an update on what these agencies have available in the way of information, data and tools helpful to the water/wastewater sector. This session will provide a common base of knowledge associated with water supply and wastewater management climate change adaptation issues to the audience of professionals which include academics, agencies, information generators, information users, tools developers and tools users. This session will set the tone of the workshop which is centered on the participants learning about the water and wastewater management tools and information being developed, generated and made available by other participants and sharing what they themselves have developed, generated and made available. Finally, this session will also feature an overview of the National Climate Assessment.

10:15 AM BREAK

10:30 AM WORKGROUP BREAKOUTS: Charge and Deliverables of Workgroups

Facilitator: Robert S. Raucher, Stratus Consulting, Inc.

Participants: The following climate change topics will guide the discussion in the facilitated breakout groups. These topics are centered on a specific theme, however, there is considerable overlap between topics to explore different views from infrastructure to the natural environment. Questions to help guide these discussions are also being made available (see accompanying document with detail discussion of the workgroups approach).

- **Flooding and wet weather implications**
  Many water facilities and infrastructure are located near major waterways for obvious reasons. Such proximity gives rise to a concern for increased flooding to these facilities

in the presence of a changing climate. The increased risk of flood damage arises from either sea level rise or more intense rainfall events. This group will discuss the latter (intense rainfall events) while sea level rise is part of the coastal zone issues.

- **Water quality implications**
  The implications of climate change on water quality can be expansive, diverse and are probably less understood than other groups of implications. Water quality can be affected directly by warmer temperatures and altered aquatic biology and water chemistry. However, climate change effects in the watershed can also impact water quality as can extreme wet and dry weather events.

- **Coastal zone implications**
  Coastal zone implications can affect the water sector in several ways, from increased risk of direct storm and flood damage, to salt water intrusion in to fresh groundwater, and altered biochemistry of brackish waters. At the root of all of these impacts, however, is the warmer seas and sea level rise. This group will discuss the implications of impacts resulting from sea level rise.

- **Water supply and drought implications**
  Warmer weather and drier summers can affect the water sector through extreme heat waves, dry spells and drought. Extreme heat presents operational challenges. Drought presents water supply issues as well as maintenance issues from damage to pipes from accelerated corrosion by concentrated wastewater to addition root damage. Low stream flows have water quality implications, watershed risks from fire, and risk from changing agriculture practices and altered biology and chemistry of the water bodies. This group will discuss all implications from heat wave and drought conditions.

- **Water-Energy Nexus**
  Water and energy are critical, mutually dependent resources- the production of energy requires large volumes of water and water is required to generate energy. Additionally, a large amount of energy is needed to extract, convey, treat, and deliver potable water. As water and energy demand and supply shift, two resources will need to be managed together to maintain reliable and sustainable supplies of both energy and water. This workgroup will discuss the water-energy nexus.

12:00 PM Buffet Lunch

1:00 PM Topic Workgroup Breakout – Reconvene

4:00 PM Report Out on Afternoon Workgroup Breakouts Work

5:00 PM Reception with Tools Demonstrations/Posters from NASA, NOAA and EPA

DAY 2: Wednesday, September 1

7:30 AM **Continental Breakfast**

8: AM **Welcome Speakers:**

Moderator: **Karen Metchis, Climate Advisor**
Office of Water
Environmental Protection Agency

Speaker: **Catherine R. Gerali, District Manager**
The Metro Wastewater Reclamation District
Denver, Colorado

WORKGROUP BREAKOUT

8:30 AM **Overview of DAY 1 Activities and DAY 2 Charge to the Workgroups**

Facilitator: **Robert S. Raucher,** Stratus Consulting, Inc.

8:45 AM **Groups Continue Breakout**

12:00 AM **Break/Working Lunch**

PLENARY SESSION

1:00 PM Topic Workgroup Reports and Discussions

- Flooding and wet weather implications
- Water quality implications
- Coastal zone implications
- Water supply and drought implications
- Water-energy nexus

Discussions: Clarifying questions (ALL)

3:00 PM **BREAK**

3:15 PM **Continued Discussions of Water Sector Information Needs**

4:15 PM **Follow-up to Workshop and Wrap Up**

4:30 PM **Adjourn**

DAY 3: Thursday September 2, 2010

NATIONAL CLIMATE ASSESSMENT DISCUSSIONS

7:30 AM **Continental Breakfast**

NATIONAL CLIMATE ASSESSMENT DAY

8:00 AM **Welcome**

Nancy Beller-Simms, Program Manager
Sector Applications Research Program
National Oceanic and Atmospheric Administration

Overview of National Climate Assessment
Katharine L. Jacobs, National Climate Assessment Lead
White House Office of Science and Technology Policy

Overview of Days 1 & 2 – Getting on the Same Page
Anne Waple, Program Lead
NOAA Assessment Services

9:00 AM Session 1: Listening Session on the National Climate Assessment related to Process:

1. What are the ways that the utilities would like to be engaged in the Assessment that are of least burden and greatest benefit?
2. What kinds of partnerships/networks would be effective to generate and submit information to/from the Assessment, e.g. coordinated through professional organizations, states, federal agencies or regional entities?
3. How can we measure the value of climate information in decision processes (as opposed to other factors like politics, economics, social welfare, etc?)

10:15 AM **Break**

10:30 AM Session 2: Listening Session on the National Climate Assessment related to Substance:

1. What do we need to know to do a better job of understanding the impacts of climate change on the industry (including gaps)?
2. What kinds of information would the water industry like to bring to the table for consideration?

3. What are the kinds of water-related adaptation and mitigation decisions that need climate-change related input? Are there specific types of climate information not currently available to support these decisions?

4. What are the climate change impacts and vulnerabilities of greatest concern and what are the indicators for those issues? What are the outcomes/thresholds/triggers you most want to avoid?

5. What are the information needs related to projected changes in water quality? How can this information be generated?

11:45 AM	Report out and a discussion of next steps for the utilities (if we have more than one group discussing each topic – otherwise we will have slightly longer sessions)
12:30 PM	Adjourn

APPENDIX C – WORKGROUP STRUCTURE AND ACTIVITIES WITHIN BREAKOUT SESSIONS

Breakout Group Structure

The ***facilitators*** will keep the groups motivated and on task in executing the planned exercises and managing the discourse to ensure all parties have the opportunity to offer their views. In addition, a chair and co-chair have been selected for each of the five breakout groups. The chair and co-chair will be responsible for tracking and reporting the dialogue. The ***chair*** will serve as the group's spokesperson when reporting back to the plenary and will take notes and ask clarifying questions for that purpose. The ***co-chair*** will record the flipchart notes and ask points of clarification as needed to assure accurate capture of each participant's offerings. Notes and flipcharts will be obtained by the facilitators afterwards in order to support the write up.

Agenda, Process, and Outputs for Tuesday Morning Breakout Session

Agenda for Tuesday Morning, August 31

- Prior to the breakout sessions, participants will reconvene in plenary after the mid-morning break at 10:30 AM. Bob Raucher of Stratus Consulting will present a brief "charge to the groups," outlining the process to be followed and the desired outputs. The five groups will then disperse to their assigned rooms.

- In this initial morning session, the groups will identify and briefly describe the most important climate-sensitive operational and/or infrastructure decisions facing water and wastewater agencies now, or during the next 10–20 years, within each breakout group's topic area (e.g., water quality).

Process for Identification of the "Most Important Climate-Sensitive Decisions Facing Water and Wastewater Agencies"

The process for the initial breakout group exercise is the same as applied in the January 2009 USEPA Office of Water (OW)/ORD Workshop in Washington, DC – borrowed from the Aspen Institute. With such a high level of expertise among the participants, everyone will have several ideas at the front of their minds that they see as priority needs for consideration and discussion. It is very effective to get these ideas in play right from the start to assure all participants that their most important ideas about which they feel strongly are already on the table and will not be missed. In addition, the topic is the lead-off question forwarded to participants to contemplate ahead of time. The process proceeds as follows:

- All participants are handed a sheet of paper and asked to spend the first ten minutes listing and prioritizing their top suggestions for "***the most important climate-sensitive operational and/or infrastructure decisions facing water and wastewater agencies during the next 10–20 years***" within each breakout group's topic area (e.g., water quality).

  - Note that the term "participants" here refers to utility members and other water/wastewater managers.

  - Federal agency personnel will typically be "observers" in this process, and will be provided opportunities to ask clarifying questions, make relevant points, and describe where existing federal research efforts may already be addressing a research need identified by a utility participant.

- The facilitator then invites the participants to select their #1 priority item and speak about it for 1 minute. The item is recorded on the flip chart. The next participant follows in like manner and the process continues around the table.

- If a participant's #1 item has already been mentioned, they have the option of seconding it, and moving on to their #2 item. Or, they may choose to use their turn to amend the previous speaker's articulation of the idea.

- The process continues until all the ideas from all the lists have been aired. It rarely takes more than three times around because of duplication – which is quite reinforcing and builds an early sense of points of consensus. Accordingly, at the outset, facilitators will urge participants not to worry about duplication but to undertake the task as though they alone were charged with listing and prioritizing the most important climate-sensitive decisions. The idea is to sample expert opinion; not to invent on the spot.

Outputs for Tuesday Morning Session August 31

- The desired list is a wall full of flipchart pages in each breakout room which – to the satisfaction of all – no important climate-sensitive decisions are missing.

Agenda, Process, and Outputs for Tuesday Afternoon Breakout Session

Agenda for Tuesday Afternoon, August 31

- In the afternoon session from 1 PM to 4 PM, facilitators will work the breakout groups through a process of (1) briefly reviewing and categorizing the "important climate-sensitive utility decisions" listed in the morning session, (2) developing a list of the associated research needs that would be most appropriate for supporting more informed and better decision-making for the key climate-sensitive decisions, and (3) prioritizing the research needs to arrive at a "top ten" list of research needs to support important, climate-sensitive utility decisions.

Process for Identifying, Categorizing, and Prioritizing the "Research Needs to Support Utilities in Making Important Climate-Sensitive Decisions"

- Facilitators will begin the afternoon session by *briefly* (i.e., limited to the first 30 minutes of the afternoon session) reviewing the list produced in the morning session and urging participants to engage in categorizing their list of the most important climate-sensitive operational and/or infrastructure decisions facing water and wastewater agencies in the coming years. In the course of this process, facilitators will ask the group to review and assess the resulting categories and their constituents for completeness and clarity. It is likely that several items will require additional discussion and modification.

- The afternoon session will then begin to focus on the ***research needs and tools*** that will best support more informed and better decision-making by utilities, for the key utility decision areas defined previously. "Research needs" are broadly defined here as outputs that could plausibly be produced by research efforts to improve decision-making.

- The elicitation process to identify and prioritize research needs will be the same as used in the morning session to elicit key decisions. Specifically:

  - All participants are handed a sheet of paper and asked to spend the first ten minutes listing and prioritizing their top suggestions for "the most important research needs" for supporting the key climate-sensitive operational and/or infrastructure decisions facing water and wastewater agencies, within each breakout group's topic area (e.g., water quality).

  - The facilitator then invites the participants to select their #1 priority item and speak about it for 1 minute. The item is recorded on the flip chart. The next participant follows in like manner and the process continues around the table.

  - If a participant's #1 item has already been mentioned, they have the option of seconding it, and moving on to their #2 item. Or, they may choose to use their turn to amend the previous speaker's articulation of the idea.

  - The process continues until all the ideas from all the lists have been aired. It rarely takes more than three times around because of duplication – which is quite reinforcing and builds an early sense of points of consensus. Accordingly, at the outset, facilitators will urge participants not to worry about duplication but to undertake the task as though they alone were charged with listing and prioritizing the most important climate-sensitive decisions. The idea is to sample expert opinion; not to invent on the spot.

  - It is possible that some research needs could overlap and apply to two or more categories, but the objective is to relate research needs to categories of decisions. If there is overlap, the facilitators, chairs and co-chairs must clarify and capture that aspect.

- Following the categorization and clarification step, voting to rank the research needs will be done. The facilitators will issue each participant a fixed number of colored dots (e.g., 7) with which to vote their preferences as to the "top ten" list of the most important categories of climate-sensitive decisions. Specific voting rules will be clarified at the session (e.g., the total number of votes, whether a voter can place multiple dots as votes for a single project, and if so, the maximum number of dots a person can vote for a specific project).

- Following the voting process, facilitators will lead a discussion to see if the list is truly satisfying: noting close runner-ups, allowing minority opinions to be heard, and examining the list to see if any re-categorizations (recalling the previous discussion of categories) might be entertained as a means of making the list more fully satisfying. In the end, a "top ten" list will emerge. Runner ups will be noted in the report-out session and in the project report.

- The last item of business on Wednesday afternoon will be to develop flip chart materials that the group chair can use to report in plenary on the top ten list of research needs, and the associated important utility decisions they support.

- At 4 PM, the groups will each report back to the plenary (with the chairs serving as spokespersons), describing the top ten categories of research needs and the associated climate-sensitive decisions they would support.

Outputs for Tuesday Afternoon Breakout Session on August 31

- The desired output is a "top ten" list of categories of the "most important research needs" as associated with supporting the most important climate-sensitive utility decisions in each topic area. Additional comments will be collected and considered from the other breakout groups during the report-out session by the chairs.

Agenda, Process, and Outputs for Wednesday Morning Breakout Sessions

Agenda for Wednesday Morning, September 1

- Following a brief reconvening of the plenary (wherein Day 1 will be summarized and the charge for Day 2 will be reiterated), the breakout groups reconvene and work through lunch.

- The focus of Day 2 will be to flesh out the "top ten" lists identified on the previous day within each of the five breakout groups. The intent is to produce broad outlines of specific research projects (or groups of related research projects) for each of the top ten areas that would be helpful to water and wastewater agencies in meeting their most important decision-making challenges resulting from climate change.

- After lunch, attendees will reconvene in plenary, and the chairs will report back on the findings of their respective breakout groups.

Process for Developing Broad Outlines of Research Projects or Groups of Related Projects for Each of the Top Ten Categories of Most Important Climate-Sensitive Decisions Facing Water and Wastewater Agencies

While each group will have its own topic area, there will be a common set of over-arching questions to guide the development of broad outlines of research projects or groups of related projects. These questions are those that bear on role of information in decision-making; and, how the decision-making process itself handles information and uncertainty. In evaluating alternate means of meeting the identified research needs, facilitators may ask participants to consider and discuss the following questions which have been forwarded to them ahead of time.

- What is it critical to know about the impacts of climate change on the future operating environment of utilities in order to support the most important decisions?
- Where does the understanding of climate change impacts on the future operating environment most need improvement in order to improve decision-making?
- What is it critical to know about the range of adaptation/mitigation options, and about their efficacy, in order to support good decisions? (Including hard and soft – i.e., institutional – options.)
- What is most needed to improve the understanding of the available range and efficacy of adaptation/mitigation options?
- What decision analysis methods and institutional capacity building efforts are needed to enhance the ability to cope with the inevitable uncertainties – with or without better information?
- Given the top ten research projects or related clusters of research projects that could be conceived and conducted in the near-term to meet or address these needs, what should these specific research projects or areas of research be like:
    - Specific research objectives
    - The important, climate-sensitive water supply and wastewater management decisions that the research would support
    - Specific research approaches or techniques to be studied or tried
    - Functionality, complexity, and accessibility of specific tools (or other research work products) that might be useful.

Outputs for Wednesday Morning, September 1

The desired output is a set of broad outlines of specific research projects or clusters of related projects that address the top ten areas of research need identified in each of the five breakout groups. The chairs will summarize these results in the report-out session.

APPENDIX D - CROSS-CUTTING THEMES AND RESEARCH TOPIC GROUPINGS

In the final plenary sessions, the attendees placed research topics in similar categories, to help identify cross-cutting issues and themes, and to provide broader context to the efforts of the individual workgroups. Key findings from the final plenary discussions are provided below, with the research topics organized by common themes.

The research topics listed below reflect the shorthand titles for research projects or tools as developed by the individual workgroups, and additional explanations and details for each can be found in the workgroup-specific write-ups. Those topics not fitting in a common theme are listed at the end of the discussion. The workgroups from which a research idea was generated are noted parenthetically using the following shorthand:

- Flooding and Wet Weather (Wet)
- Water Quality (WQ)
- Coastal Zone (CZ)
- Water Supply and Drought (Supply)
- Water Energy Nexus (Energy).

Theme A: Developing a fundamental decision-making process for adaptation in the context of uncertainty

- Augment utility management and planning to identify critical decisions (WQ)
- Develop new institutional management, planning and legal frameworks with respect to climate change issues (CZ)
- Develop a methodology to evaluate the effectiveness of Best Management Practices (BMP)s for water quality management under climate change; identify metrics (WQ)
- Create new federally supported hydrologic design standards for infrastructure(Wet)
- Identify a methodology to quantify the value of ecosystem functions (WQ).

Theme B: Evolving engineering and planning paradigms to increase flexibility

- Rethink educational curriculums to including uncertainties associated with climate change (CZ)
- Design for flexibility (Energy)
- Consider other paradigms (Supply)
- Develop methodology for more robust and flexible planning for treatment alternatives (WQ).

Theme C: Improving communication

- Develop tools for communicating uncertainty to appropriate audiences (boards, council, mayors, rate-setting bodies) (Supply)
- Improve risk communication to stakeholders on climate change impacts and adaptation (CZ)

- Communicate needs to invest in future reliability of infrastructure for climate change (Energy)
- Develop *effective* communication tools and mechanisms (Supply)
- Understand that communication is essential for decision support (Wet)
- Use surveys/focus groups/case studies to look at other industries; convene workshops (Supply)
- Coordinate water and energy producers/providers work and efforts, future planning (at very least better communicate on regular basis) (Energy).

Theme D: Coordinating development of consistent regional[8] data/information for planning scenarios that is useful for water utilities/downscaling models

- Develop website (Downscaled.Data.Gov): one-stop shop for sharing of available datasets and predictive tools for regions (Supply)
  - Evaluate efficacy of datasets for different regions
  - Produce data gap analysis of climate projections
  - Look at ongoing project at the Jet Propulsion Laboratory JPL that is developing a framework for evaluation of climate models and model outputs
- Develop an understanding of spatial and temporal data for downscaling; understand metadata for downscaled datasets; understand differences in metadata; vetting process is needed to identify best practices for using data (CZ)
- Identify parameters to save (Supply)
- Translate between the outputs of the GCMs to climate forcings that utilities can use (Wet)
- Provide guidance on the use of models for water quality and decision making, including strengths and weaknesses and guidance on model data interpretation (WQ)
- Determine how to quantify the model skill in projecting changes; compare different model outputs (Flooding)
- Focus on end-to-end: Identify ranges of a potential impact; develop methods and approaches for interface between climate experts and water managers (CZ)
- Develop methodology to distinguish between climate change effects and other effects on water quality parameters (WQ)
- Look at using climate models and natural variability to predict extreme events (Wet).

Theme E: Compiling and using observed data

- Develop a monitoring program for trend and change analysis; identify the questions that monitoring needs to answer (WQ)
- Improve interpretation of observed data for forecasting extreme events (Wet)
- Provide (identify and define) the wide range of data needed to plan for adaptations in the coastal zone (CZ)
- Look at field datasets and scale up to remote sensing technologies (Supply)
- Use new techniques to update PMP and PMF and use recent data (Wet).

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[8]. The meaning of “regional” needs to be defined, and may vary by application. Suitable “regional” scales may include the following: watershed, water management district, water basin, municipality, climate zones.

Theme F: Integrating adaptation and mitigation approaches

- Reduce energy demands of various water treatment alternatives (CZ)
- Understand water quantity and quality requirements of energy generation, extraction, and mitigation technologies (i.e., water footprinting) (Energy)
- Study potential consequences of today's solutions to adapt to or mitigate climate change (WQ).

Theme G: Promoting institutional changes

- Highlight climate ready regulation (evaluate regulatory changes to promote adaptation to climate change (WQ)
- Look at adaptive capacity in institutional and regulatory functions (CZ)
- Develop engineering design standards (Wet).

Theme H: Examining the potential role of decentralized and hybrid systems

- Identify implications of decentralized systems (risk, public health, institutional, etc.) and potential for hybrid systems to enhance climate resiliency; characterize the obstacles and incentives; also look at connecting larger systems (Supply).

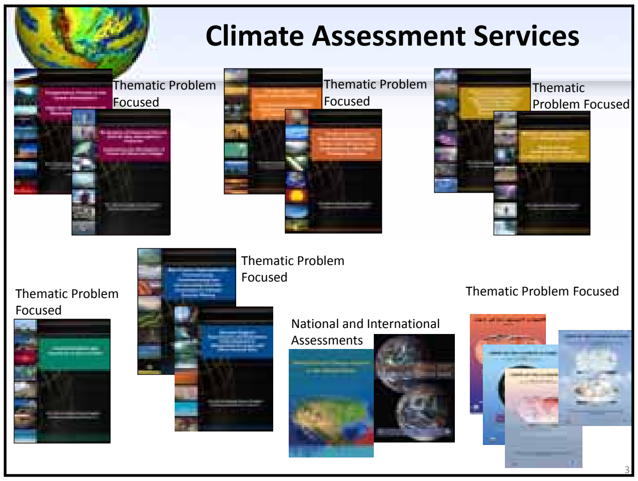
Additional research topics (not associated with above themes)

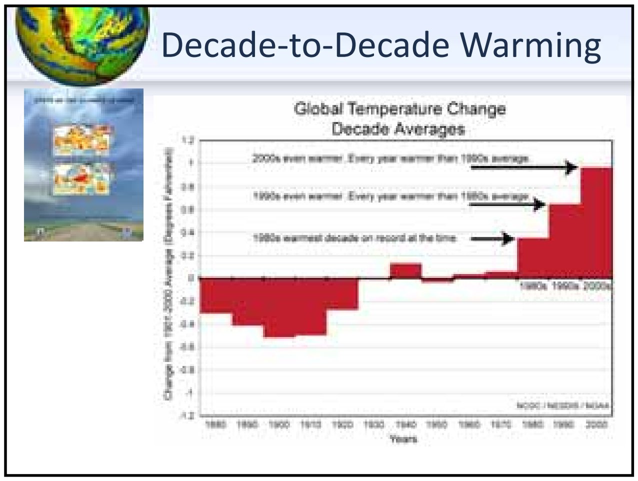
- Identify and implement unconventional opportunities for advancing adaptive capacity: i.e., water conservation or engage with other sectors like the Green Building Council or use reclaimed water to enhance the viability of a coastal wetland to mitigate impact of seawater rise (Supply)
- Establish new protocols for assessing vulnerability of existing infrastructure – need models that incorporate global climate science into them (Wet)
- Develop costs/benefits of adaptation approaches; evaluating it in comprehensive way to justify adaptation choices; valuing ecosystem services and the co-benefits of adaptation (CZ)
- Research managing water quality and availability in context of coastal climate change impacts; perhaps focused on things likely to occur as result of climate change (CZ)
- Examine climate impacts on socioeconomic impacts on water demand (e.g., municipal/industrial demand); focus not on temperature and precipitation but rather impacts on population shifts, migration, etc., that may drive water-intensive industry to relocate or change water use patterns (Supply)
- Understand/identify indicators and thresholds of ecosystem services that affect water supply management (i.e., availability, infrastructure) (Supply).

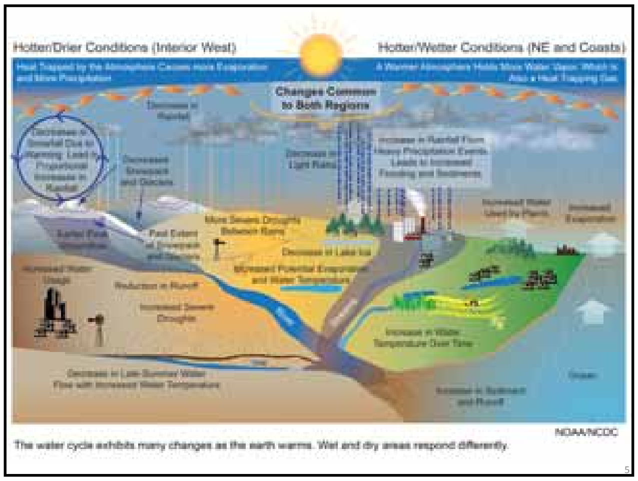
APPENDIX E – PRESENTATIONS BY FEDERAL AGENCY REPRESENTATIVES


"If America is to avoid the most damaging effects of climate change, we have to first understand it."
Secretary of Commerce
Gary Locke


NOAA CLIMATE SERVICE
An Idea Whose Time Has Come
August 2010
2


Climate Assessment Services
Thematic Problem Focused
Thematic Problem Focused
Thematic Problem Focused
Thematic Problem Focused
Thematic Problem Focused
Thematic Problem Focused
National and International Assessments


Decade-to-Decade Warming
Global Temperature Change
Decade Averages
2000s even warmer. Every year warmer than 1990s average.
1990s even warmer. Every year warmer than 1980s average.
1980s warmest decade on record at the time.
1980s 1990s 2000s
Years



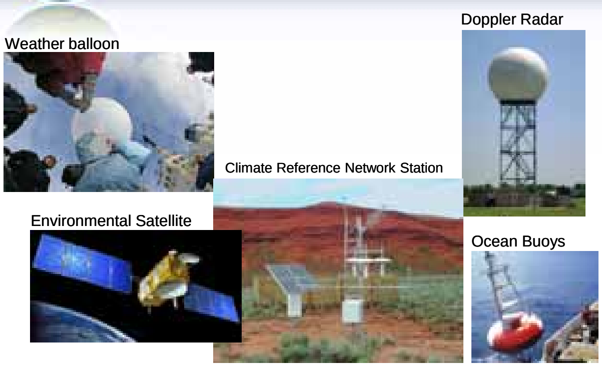
The water cycle exhibits many changes as the earth warms. Wet and dry areas respond differently.

Implementation Strategy

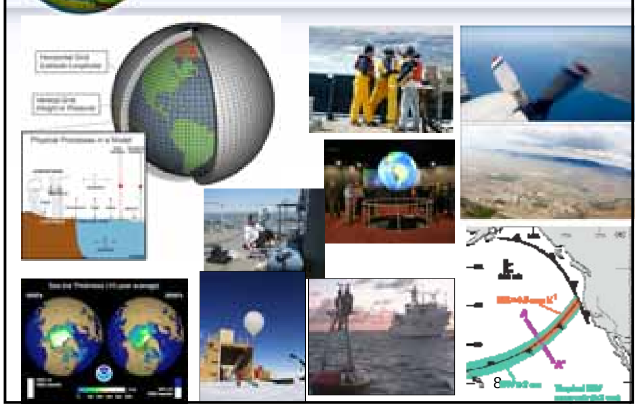
- **Basic services**
  - Climate information derived from the Core Capabilities, e.g., past, current, and future climate
  - Credible, transparent, reproducible, authoritative, and official
  - Foundation for development of enhanced and new services
  - Assessments as part of the service

6

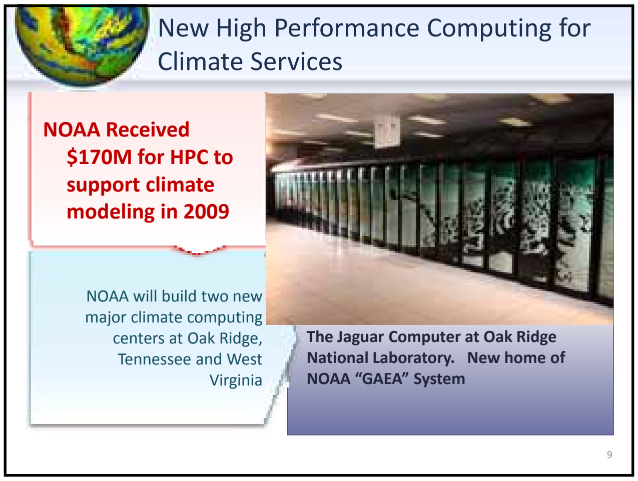
Tools for Tracking Climate

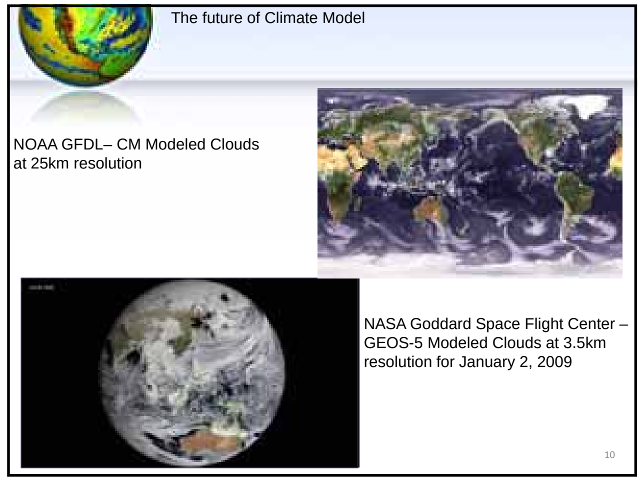


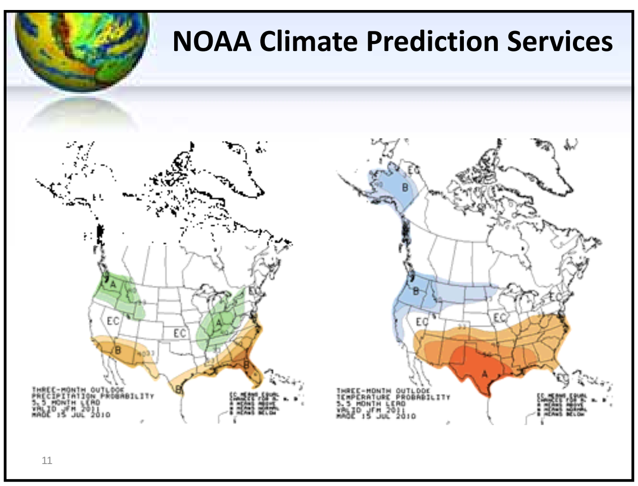
NOAA Climate Research

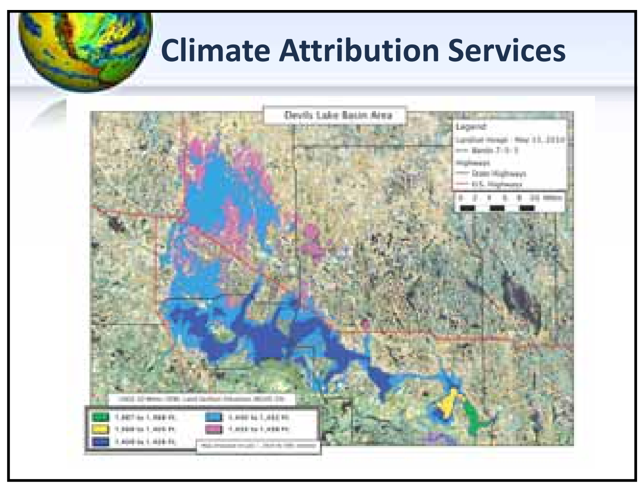


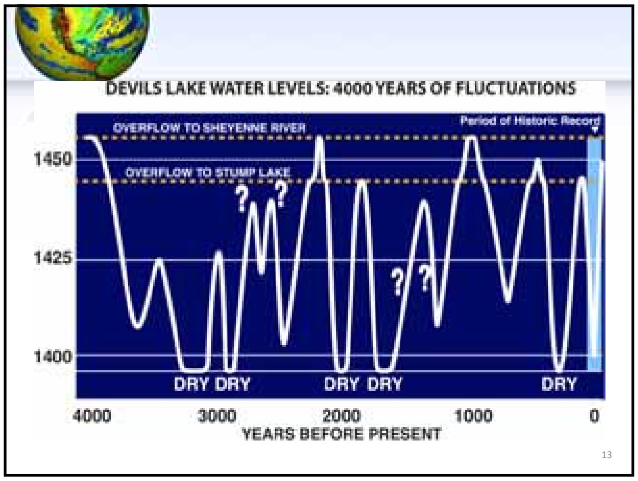
8

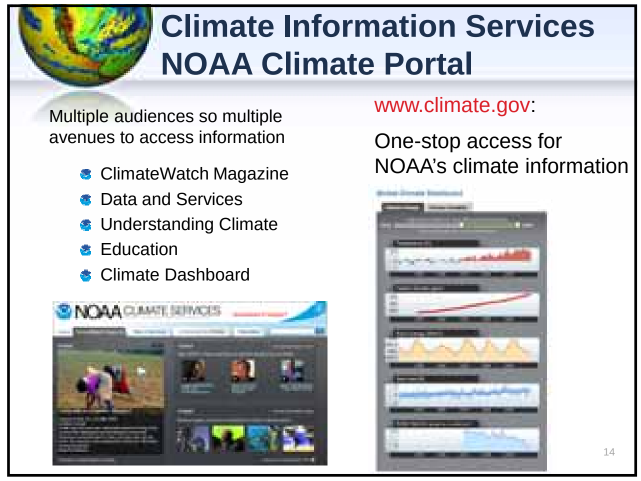

New High Performance Computing for Climate Services
NOAA Received $170M for HPC to support climate modeling in 2009
NOAA will build two new major climate computing centers at Oak Ridge, Tennessee and West Virginia
The Jaguar Computer at Oak Ridge National Laboratory. New home of NOAA "GAEA" System
9


The future of Climate Model
NOAA GFDL– CM Modeled Clouds at 25km resolution
NASA Goddard Space Flight Center – GEOS-5 Modeled Clouds at 3.5km resolution for January 2, 2009
10


NOAA Climate Prediction Services
THREE-MONTH OUTLOOK
PRECIPITATION PROBABILITY
5.5 MONTH LEAD
VALID JFM 2011
MADE 15 JUL 2010
THREE-MONTH OUTLOOK
TEMPERATURE PROBABILITY
5.5 MONTH LEAD
VALID JFM 2011
MADE 15 JUL 2010
11


Climate Attribution Services
Devils Lake Basin Area


DEVILS LAKE WATER LEVELS: 4000 YEARS OF FLUCTUATIONS
OVERFLOW TO SHEYENNE RIVER
Period of Historic Record
OVERFLOW TO STUMP LAKE
1450
1425
1400
DRY DRY
DRY DRY
DRY
4000
3000
2000
1000
0
YEARS BEFORE PRESENT
13


Climate Information Services
NOAA Climate Portal
Multiple audiences so multiple avenues to access information
ClimateWatch Magazine
Data and Services
Understanding Climate
Education
Climate Dashboard
www.climate.gov:
One-stop access for NOAA's climate information
NOAA CLIMATE SERVICES
14


Data Centers
National Snow and Ice Data Center
National Geophysical Data Center
National Oceanographic Data Center
Climate Prediction Center
National Climatic Data Center
National Data Buoy Center
National Coastal Data Development Center
NOAA Climate Service Partnerships


Laboratories
Pacific Marine Environmental Laboratory
Great Lakes Environmental Research Laboratory
Geophysical Fluid Dynamics Laboratory
Earth System Research Laboratory
Air Resources Laboratory
National Severe Storms Laboratory
Atlantic Oceanographic & Meteorological Laboratory
NOAA Climate Service Partnerships

NOAA Climate Service Partnerships

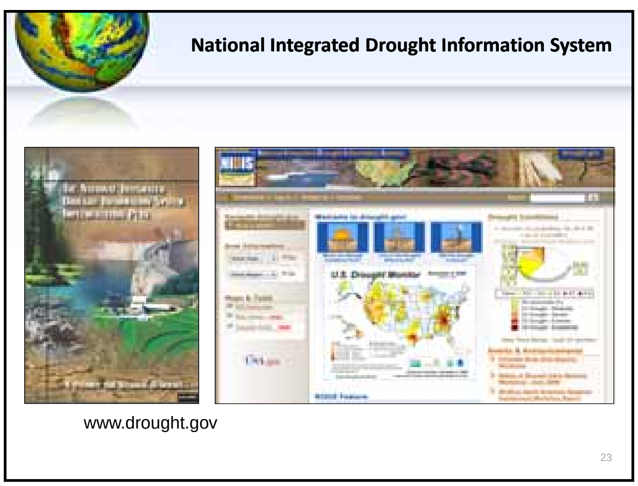
NOAA Climate Service Partnerships

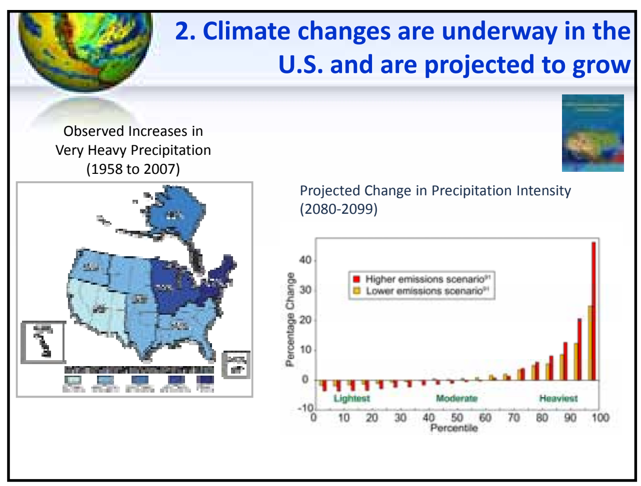
NOAA Climate Service Partnerships

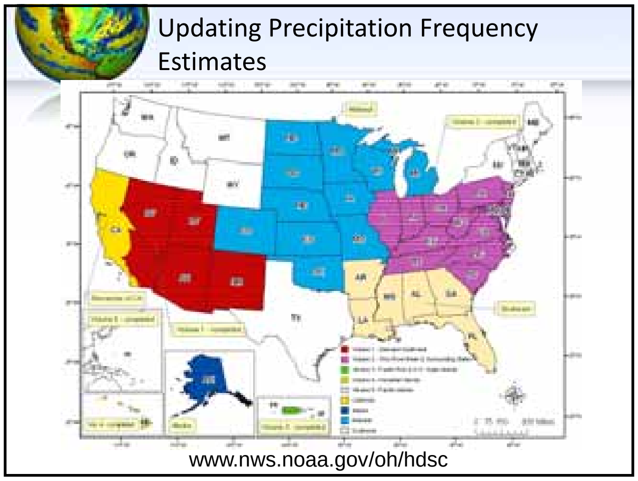
NOAA Climate Service Partnerships

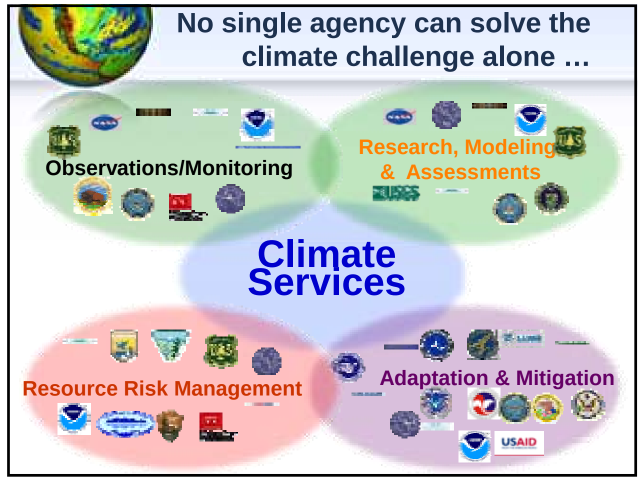

River Forecast Centers
Northwest
Northern Central
Northeast
California Nevada
Colorado Basin
Missouri Basin
Middle Atlantic
Ohio
Arkansas-Red Basin
Southeast
Lower Mississippi
West Gulf
Alaska
NOAA Climate Service Partnerships

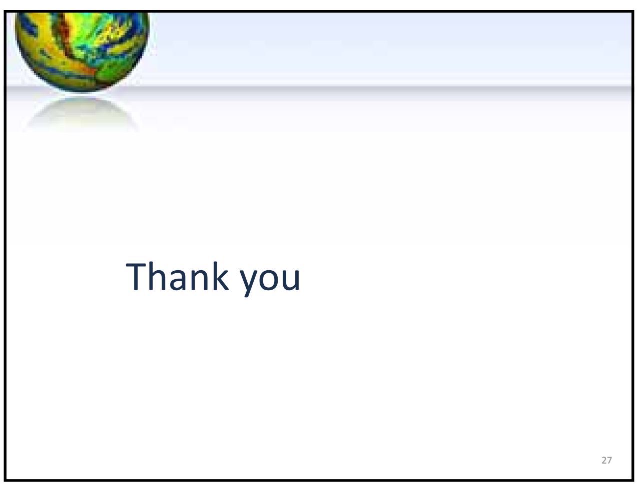

Societal Challenges
Water
Water Issues
• Precipitation Patterns; Drought and Floods
• Changes in snowpack (quantity and timing)
• River stream flow
• Fire outlooks
• Physical Infrastructure (i.e., dams, reservoirs, water delivery systems)
• Planning (e.g., urban, agriculture, health)
NOAA Products and Services
• Monitor and Forecast Drought and Flood Related Conditions
• NIDIS (Including Stakeholder Engagement)
Key Federal Agencies
NOAA, DOI, Army Corps of Engineers, USDA, EPA


National Integrated Drought Information System
U.S. Drought Monitor
www.drought.gov
23

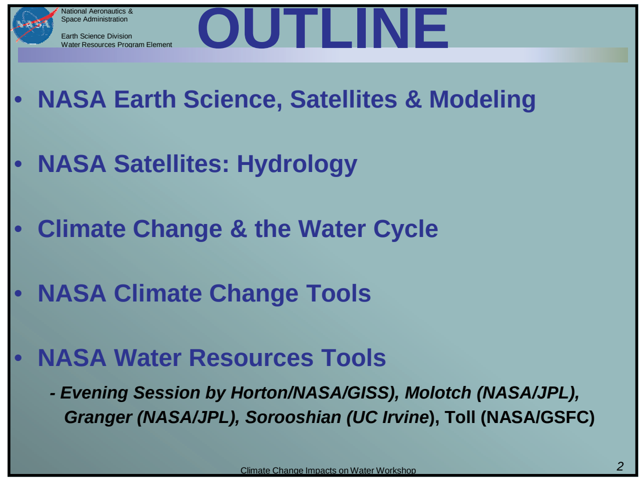

2. Climate changes are underway in the U.S. and are projected to grow
Observed Increases in Very Heavy Precipitation (1958 to 2007)
Projected Change in Precipitation Intensity (2080-2099)
Higher emissions scenario
Lower emissions scenario
Percentage Change
Percentile
Lightest
Moderate
Heaviest

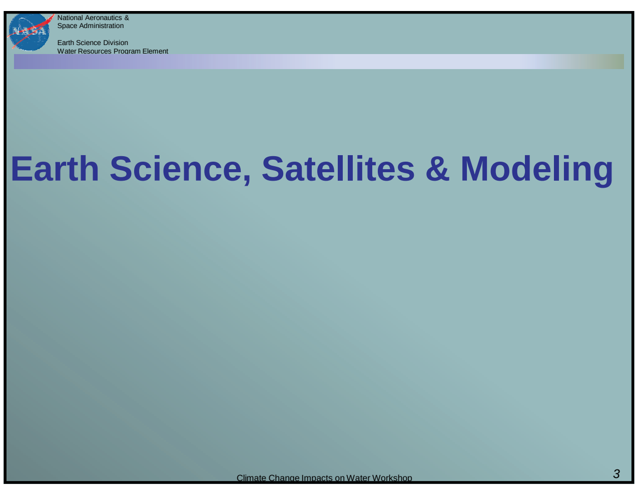

Updating Precipitation Frequency Estimates
www.nws.noaa.gov/oh/hdsc

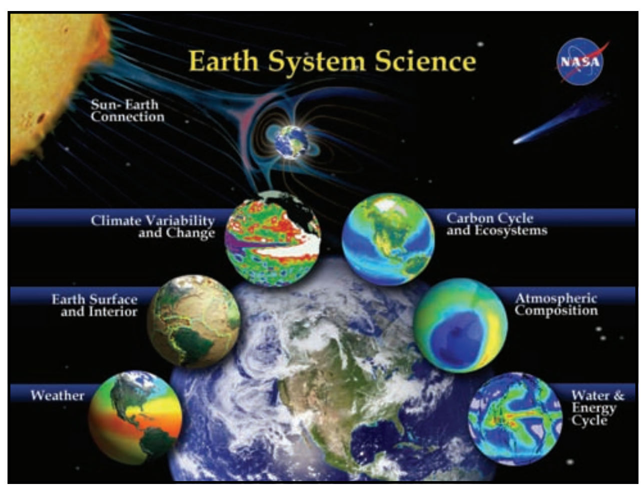

No single agency can solve the climate challenge alone …
Observations/Monitoring
Research, Modeling & Assessments
Climate Services
Resource Risk Management
Adaptation & Mitigation
USAID

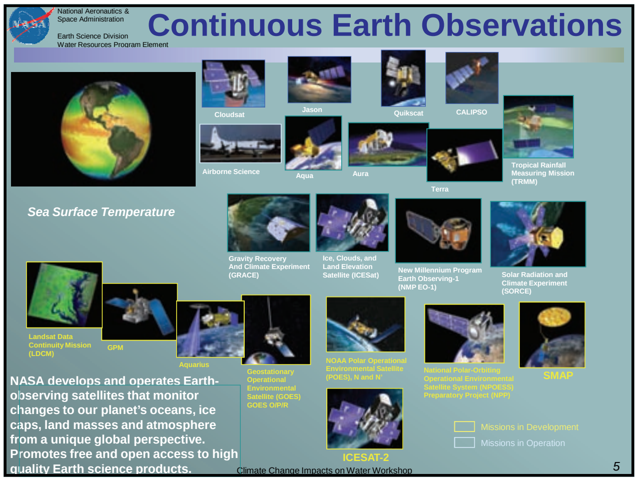

Thank you
27


NASA
NASA's Roles in Climate Change Science & Water Related Applications
David Toll
Deputy Program Element Manager
Water Resources
Hydrological Sciences NASA/GSFC
Brad Doorn
Program Manager
NASA Applied Sciences Program
Washington D.C.
31 Aug 2010


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
OUTLINE
• NASA Earth Science, Satellites & Modeling
• NASA Satellites: Hydrology
• Climate Change & the Water Cycle
• NASA Climate Change Tools
• NASA Water Resources Tools
- Evening Session by Horton/NASA/GISS), Molotch (NASA/JPL), Granger (NASA/JPL), Sorooshian (UC Irvine), Toll (NASA/GSFC)
Climate Change Impacts on Water Workshop
2


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Earth Science, Satellites & Modeling
Climate Change Impacts on Water Workshop
3


Earth System Science
NASA
Sun-Earth Connection
Climate Variability and Change
Carbon Cycle and Ecosystems
Earth Surface and Interior
Atmospheric Composition
Weather
Water & Energy Cycle

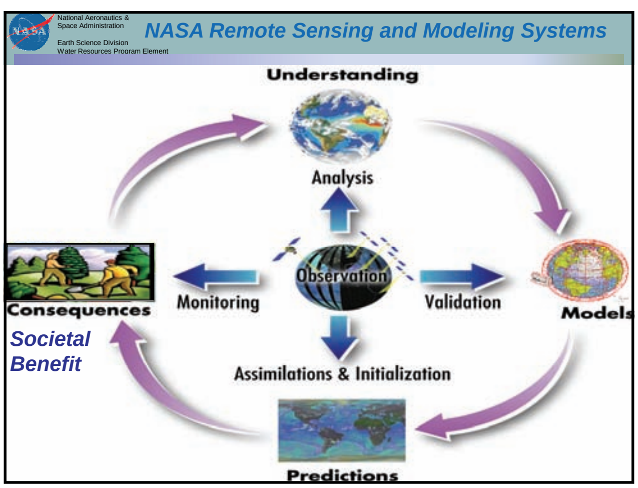


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element

Why Satellite-Based Observations?

- Ground-based measurements of climate:
  - Are declining and globally difficult to collect
    - Particularly outside N. America and Europe
  - Lack the uniform calibration needed to assess climate variability and change
- Satellite-based observations of Earth's global climate:
  - Provide uniform global coverage
  - Can be calibrated against validating measurements
    - Ground and airborne
  - Explain climate change forcing:
    - Radiation, Aerosols, Atmospheric chemistry, Global ocean circulation, Clouds explain climate change impacts:
    - Sea level rise, Ozone depletion, Sea ice depletion, Ice sheet melt, Mountain glacier melt, Air quality, Longer growing season in high latitudes and on high mountains, etc.

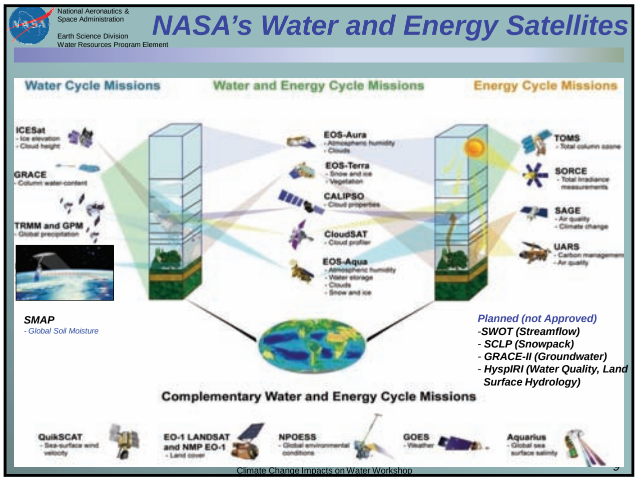
Climate Change Impacts on Water Workshop 6

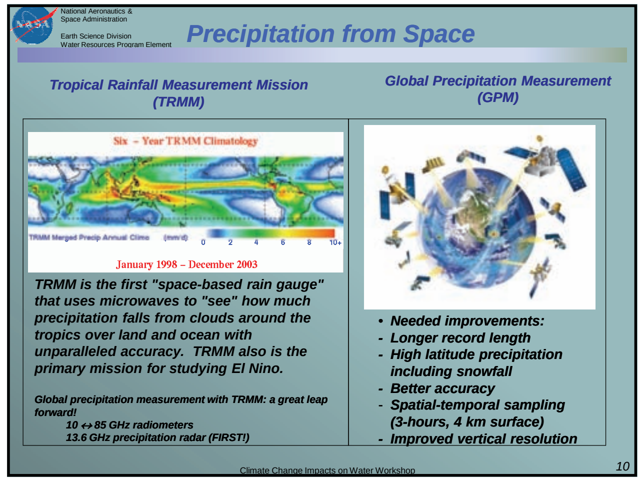


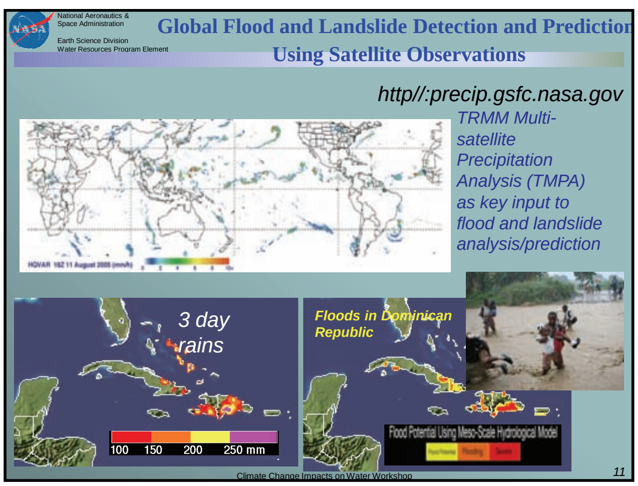
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element

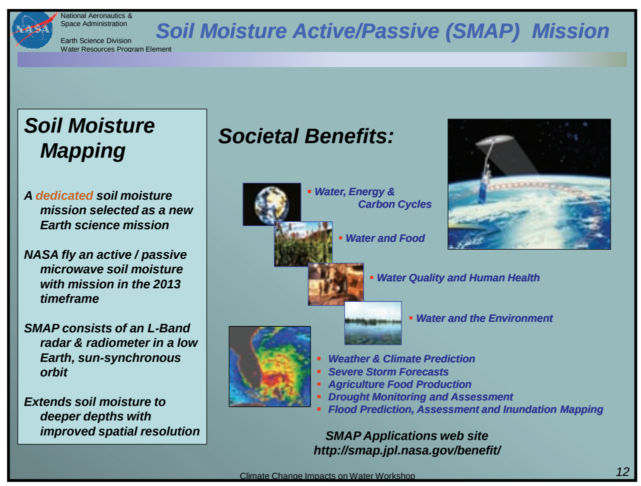
NASA Satellites – Hydrological

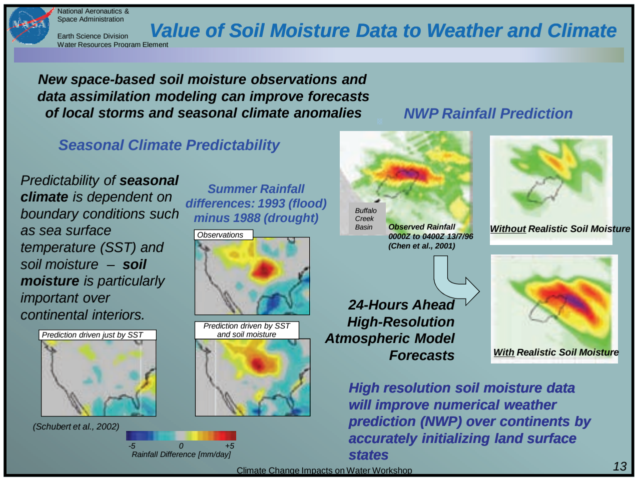
Climate Change Impacts on Water Workshop 8


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
NASA's Water and Energy Satellites
Water Cycle Missions
Water and Energy Cycle Missions
Energy Cycle Missions
ICESat
GRACE
TRMM and GPM
EOS-Aura
EOS-Terra
CALIPSO
CloudSAT
EOS-Aqua
TOMS
SORCE
SAGE
UARS
SMAP
- Global Soil Moisture
Planned (not Approved)
-SWOT (Streamflow)
- SCLP (Snowpack)
- GRACE-II (Groundwater)
- HyspIRI (Water Quality, Land Surface Hydrology)
Complementary Water and Energy Cycle Missions
QuikSCAT
EO-1 LANDSAT and NMP EO-1
NPOESS
GOES
Aquarius
Climate Change Impacts on Water Workshop


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Precipitation from Space
Tropical Rainfall Measurement Mission (TRMM)
Global Precipitation Measurement (GPM)
Six – Year TRMM Climatology
January 1998 – December 2003
TRMM is the first "space-based rain gauge" that uses microwaves to "see" how much precipitation falls from clouds around the tropics over land and ocean with unparalleled accuracy. TRMM also is the primary mission for studying El Nino.
Global precipitation measurement with TRMM: a great leap forward!
10 ↔ 85 GHz radiometers
13.6 GHz precipitation radar (FIRST!)
• Needed improvements:
- Longer record length
- High latitude precipitation including snowfall
- Better accuracy
- Spatial-temporal sampling (3-hours, 4 km surface)
- Improved vertical resolution
Climate Change Impacts on Water Workshop
10


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Global Flood and Landslide Detection and Prediction Using Satellite Observations
http//:precip.gsfc.nasa.gov
TRMM Multi-satellite Precipitation Analysis (TMPA) as key input to flood and landslide analysis/prediction
3 day rains
100 150 200 250 mm
Floods in Dominican Republic
Flood Potential Using Meso-Scale Hydrological Model
Climate Change Impacts on Water Workshop
11


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Soil Moisture Active/Passive (SMAP) Mission
Soil Moisture Mapping
A dedicated soil moisture mission selected as a new Earth science mission
NASA fly an active / passive microwave soil moisture with mission in the 2013 timeframe
SMAP consists of an L-Band radar & radiometer in a low Earth, sun-synchronous orbit
Extends soil moisture to deeper depths with improved spatial resolution
Societal Benefits:
• Water, Energy & Carbon Cycles
• Water and Food
• Water Quality and Human Health
• Water and the Environment
• Weather & Climate Prediction
• Severe Storm Forecasts
• Agriculture Food Production
• Drought Monitoring and Assessment
• Flood Prediction, Assessment and Inundation Mapping
SMAP Applications web site
http://smap.jpl.nasa.gov/benefit/
Climate Change Impacts on Water Workshop
12


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Value of Soil Moisture Data to Weather and Climate
New space-based soil moisture observations and data assimilation modeling can improve forecasts of local storms and seasonal climate anomalies
Seasonal Climate Predictability
Predictability of seasonal climate is dependent on boundary conditions such as sea surface temperature (SST) and soil moisture – soil moisture is particularly important over continental interiors.
Summer Rainfall differences: 1993 (flood) minus 1988 (drought)
Observations
Prediction driven just by SST
Prediction driven by SST and soil moisture
(Schubert et al., 2002)
-5
0
+5
Rainfall Difference [mm/day]
NWP Rainfall Prediction
Buffalo Creek Basin
Observed Rainfall 0000Z to 0400Z 13/7/96 (Chen et al., 2001)
Without Realistic Soil Moisture
24-Hours Ahead High-Resolution Atmospheric Model Forecasts
With Realistic Soil Moisture
High resolution soil moisture data will improve numerical weather prediction (NWP) over continents by accurately initializing land surface states
Climate Change Impacts on Water Workshop
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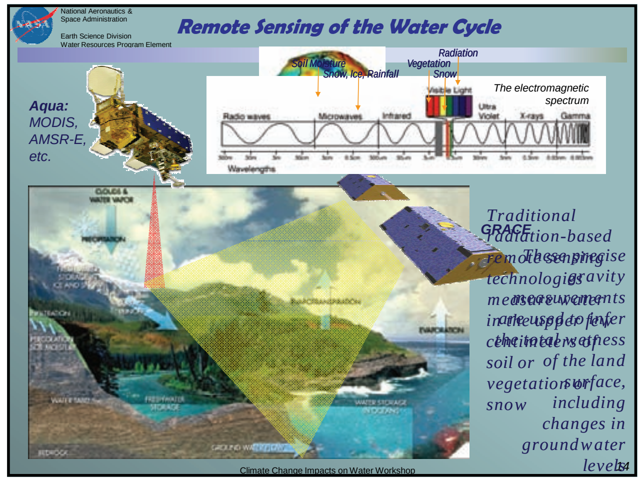
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Remote Sensing of the Water Cycle
Radiation
Soil Moisture
Vegetation
Snow, Ice, Rainfall
Snow
The electromagnetic spectrum
Radio waves
Microwaves
Infrared
Visible Light
Ultra Violet
X-rays
Gamma
Wavelengths
Aqua: MODIS, AMSR-E, etc.
GRACE
Traditional radiation-based remote sensing technologies measure water in the upper few centimeters of soil or vegetation or snow
These precise gravity measurements are used to infer the total wetness of the land surface, including changes in groundwater levels
Climate Change Impacts on Water Workshop
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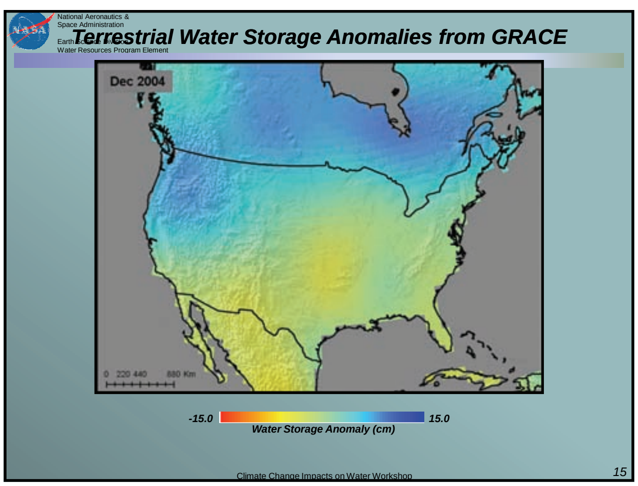
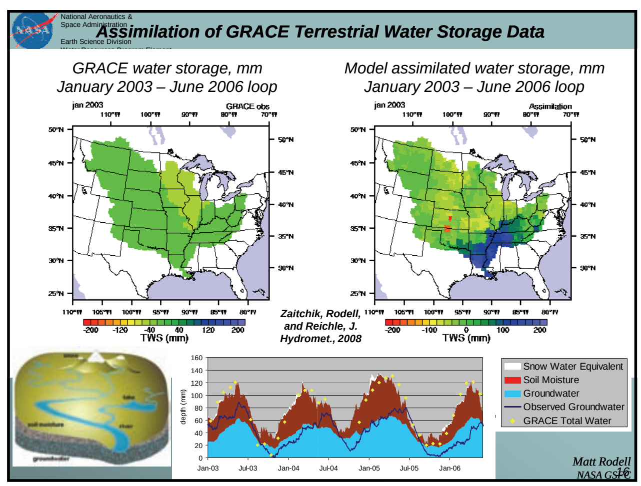
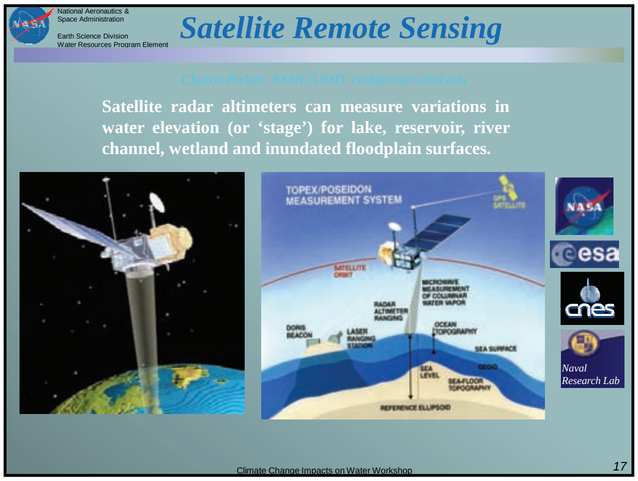

National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Terrestrial Water Storage Anomalies from GRACE
Dec 2004
0 220 440 880 Km
-15.0
15.0
Water Storage Anomaly (cm)
Climate Change Impacts on Water Workshop
15


National Aeronautics & Space Administration
Earth Science Division
Assimilation of GRACE Terrestrial Water Storage Data
GRACE water storage, mm
January 2003 – June 2006 loop
Model assimilated water storage, mm
January 2003 – June 2006 loop
jan 2003
GRACE obs
Assimilation
TWS (mm)
Zaitchik, Rodell, and Reichle, J. Hydromet., 2008
depth (mm)
Snow Water Equivalent
Soil Moisture
Groundwater
Observed Groundwater
GRACE Total Water
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Matt Rodell
NASA GSFC
16


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Satellite Remote Sensing
Satellite radar altimeters can measure variations in water elevation (or 'stage') for lake, reservoir, river channel, wetland and inundated floodplain surfaces.
TOPEX/POSEIDON MEASUREMENT SYSTEM
NASA
esa
cnes
Naval Research Lab
Climate Change Impacts on Water Workshop
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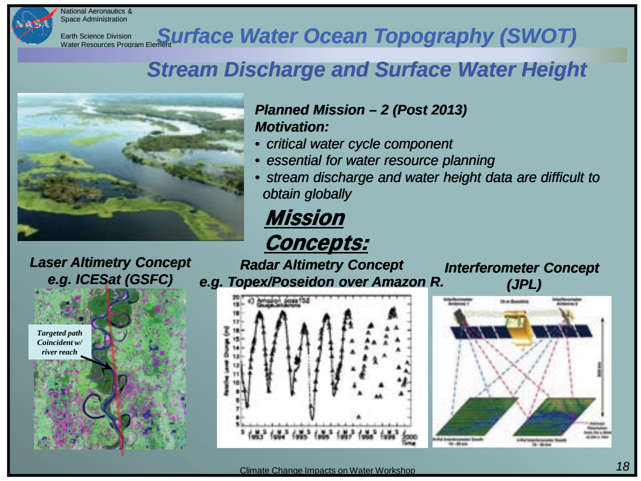
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Surface Water Ocean Topography (SWOT)
Stream Discharge and Surface Water Height
Planned Mission – 2 (Post 2013)
Motivation:
• critical water cycle component
• essential for water resource planning
• stream discharge and water height data are difficult to obtain globally
Mission Concepts:
Laser Altimetry Concept
e.g. ICESat (GSFC)
Radar Altimetry Concept
e.g. Topex/Poseidon over Amazon R.
Interferometer Concept
(JPL)
Targeted path Coincident w/ river reach
Climate Change Impacts on Water Workshop
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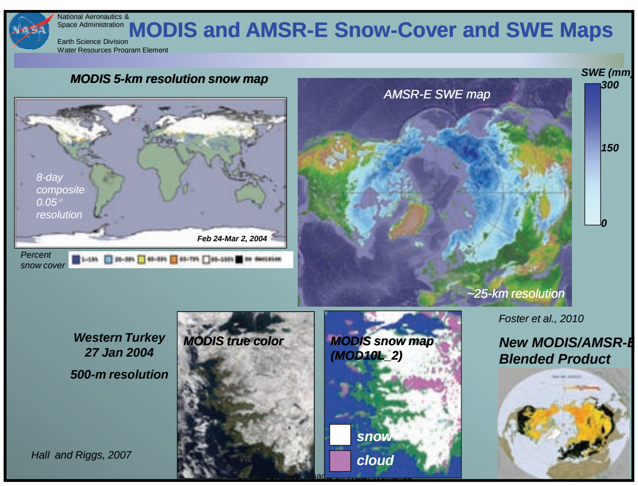
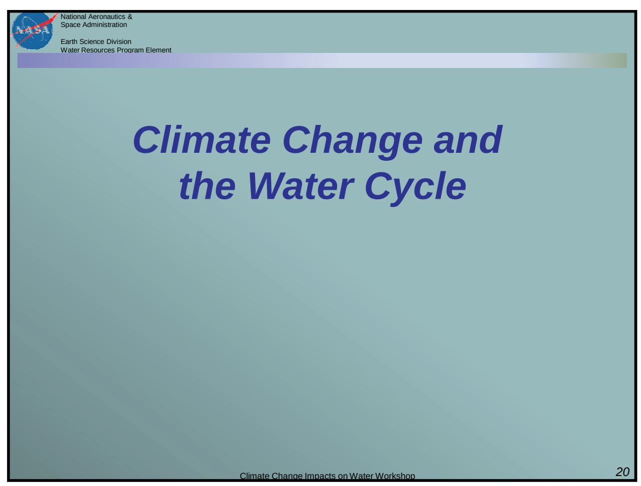

National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
MODIS and AMSR-E Snow-Cover and SWE Maps
MODIS 5-km resolution snow map
8-day composite 0.05° resolution
Feb 24-Mar 2, 2004
Percent snow cover
AMSR-E SWE map
SWE (mm)
300
150
0
~25-km resolution
Foster et al., 2010
Western Turkey
27 Jan 2004
500-m resolution
MODIS true color
MODIS snow map (MOD10L_2)
snow
cloud
New MODIS/AMSR-E Blended Product
Hall and Riggs, 2007


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Climate Change and the Water Cycle
Climate Change Impacts on Water Workshop
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National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Arctic Ice Changes 1979-2008 Using Microwave Satellite Data
Climate Change Impacts on Water Workshop
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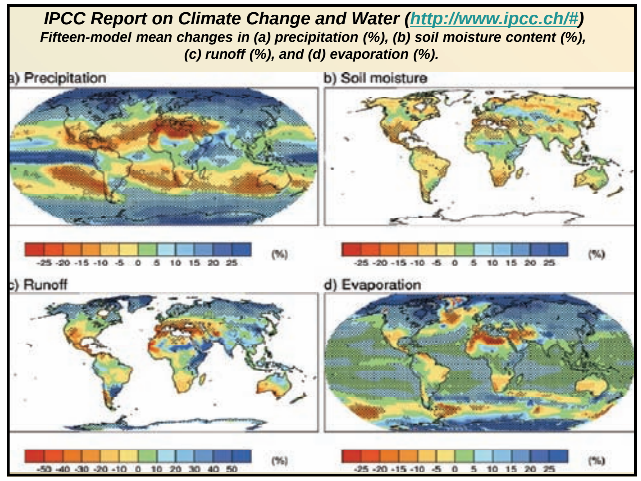
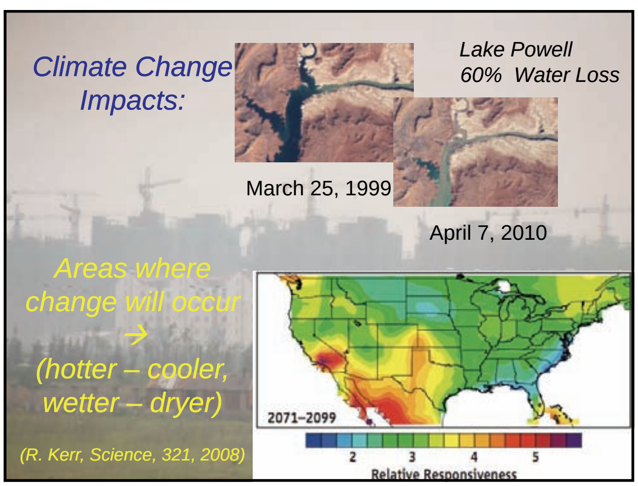
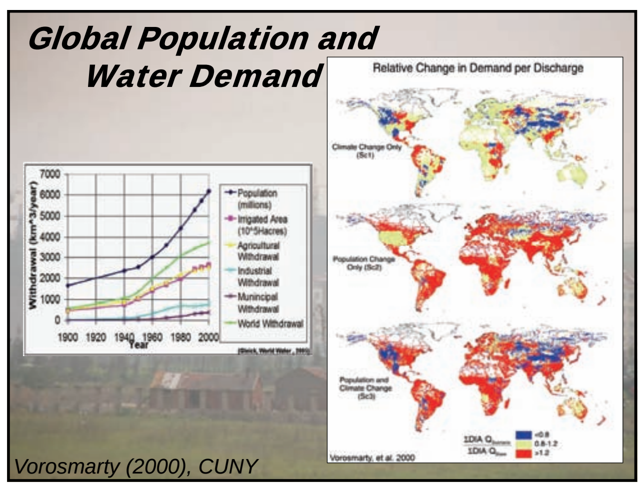
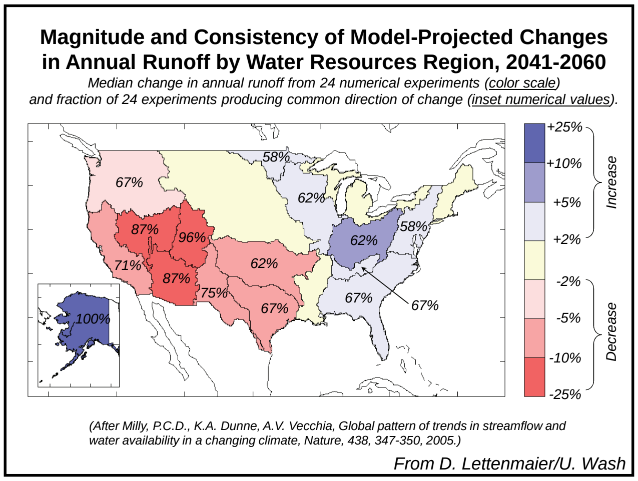
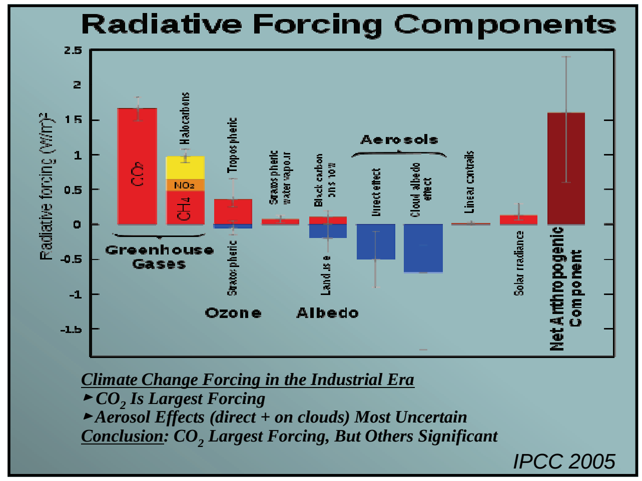
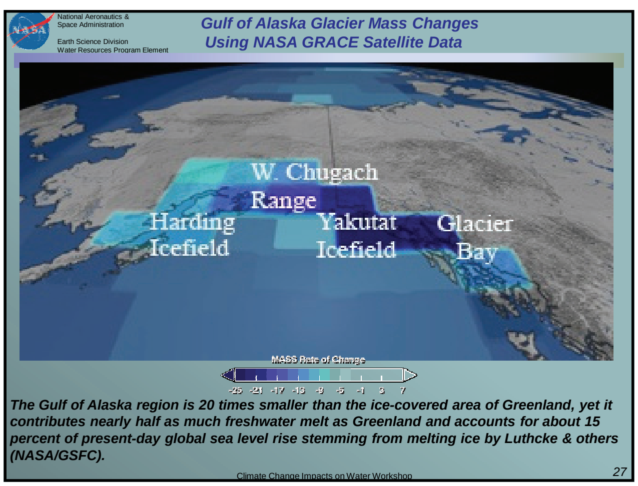

IPCC Report on Climate Change and Water (http://www.ipcc.ch/#)
Fifteen-model mean changes in (a) precipitation (%), (b) soil moisture content (%), (c) runoff (%), and (d) evaporation (%).
a) Precipitation
b) Soil moisture
c) Runoff
d) Evaporation
(%)


Climate Change Impacts:
Lake Powell
60% Water Loss
March 25, 1999
April 7, 2010
Areas where change will occur → (hotter – cooler, wetter – dryer)
2071–2099
Relative Responsiveness
(R. Kerr, Science, 321, 2008)


Global Population and Water Demand
Relative Change in Demand per Discharge
Withdrawal (km^3/year)
Year
Population (millions)
Irrigated Area
Agricultural Withdrawal
Industrial Withdrawal
Municipal Withdrawal
World Withdrawal
Climate Change Only (Sc1)
Population Change Only (Sc2)
Population and Climate Change (Sc3)
Vorosmarty, et al. 2000
Vorosmarty (2000), CUNY


Magnitude and Consistency of Model-Projected Changes in Annual Runoff by Water Resources Region, 2041-2060
Median change in annual runoff from 24 numerical experiments (color scale) and fraction of 24 experiments producing common direction of change (inset numerical values).
+25%
+10%
+5%
+2%
-2%
-5%
-10%
-25%
Increase
Decrease
67%
58%
62%
87%
96%
62%
58%
71%
87%
75%
62%
67%
67%
67%
100%
(After Milly, P.C.D., K.A. Dunne, A.V. Vecchia, Global pattern of trends in streamflow and water availability in a changing climate, Nature, 438, 347-350, 2005.)
From D. Lettenmaier/U. Wash


Radiative Forcing Components
Radiative forcing (W/m²)
Greenhouse Gases
Ozone
Albedo
Aerosols
Halocarbons
NO2
CH4
Tropospheric
Stratospheric
Land use
Direct effect
Cloud albedo effect
Linear contrails
Solar radiance
Net Anthropogenic Component
Climate Change Forcing in the Industrial Era
►CO2 Is Largest Forcing
►Aerosol Effects (direct + on clouds) Most Uncertain
Conclusion: CO2 Largest Forcing, But Others Significant
IPCC 2005


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Gulf of Alaska Glacier Mass Changes
Using NASA GRACE Satellite Data
W. Chugach Range
Harding Icefield
Yakutat Icefield
Glacier Bay
MASS Rate of Change
The Gulf of Alaska region is 20 times smaller than the ice-covered area of Greenland, yet it contributes nearly half as much freshwater melt as Greenland and accounts for about 15 percent of present-day global sea level rise stemming from melting ice by Luthcke & others (NASA/GSFC).
Climate Change Impacts on Water Workshop
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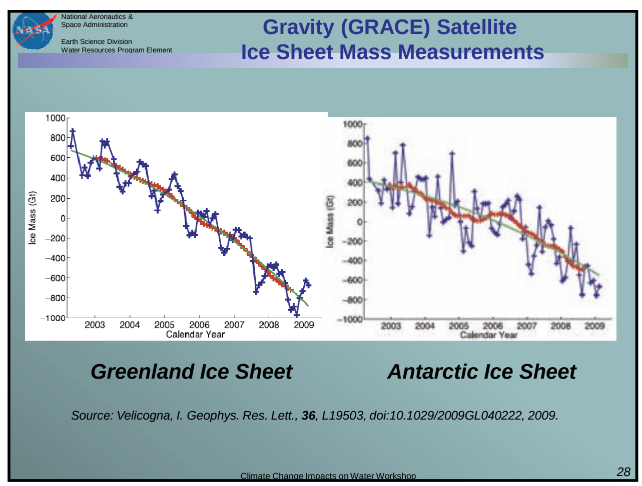
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Gravity (GRACE) Satellite
Ice Sheet Mass Measurements
Ice Mass (Gt)
Calendar Year
Greenland Ice Sheet
Antarctic Ice Sheet
Source: Velicogna, I. Geophys. Res. Lett., 36, L19503, doi:10.1029/2009GL040222, 2009.
Climate Change Impacts on Water Workshop
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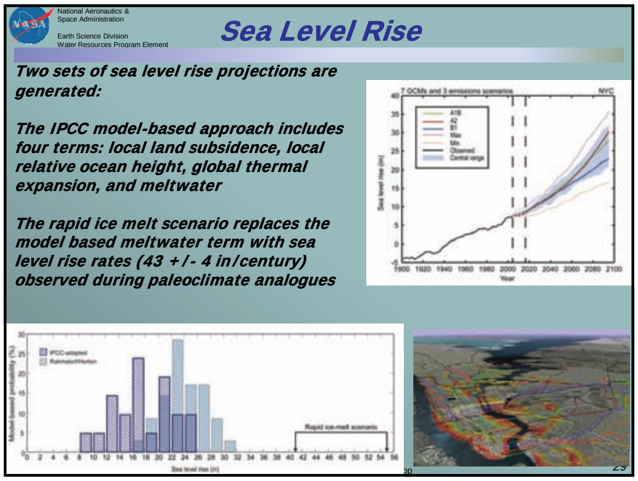
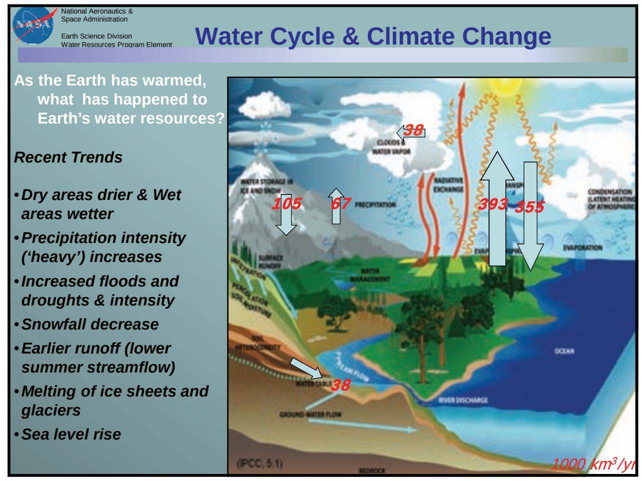
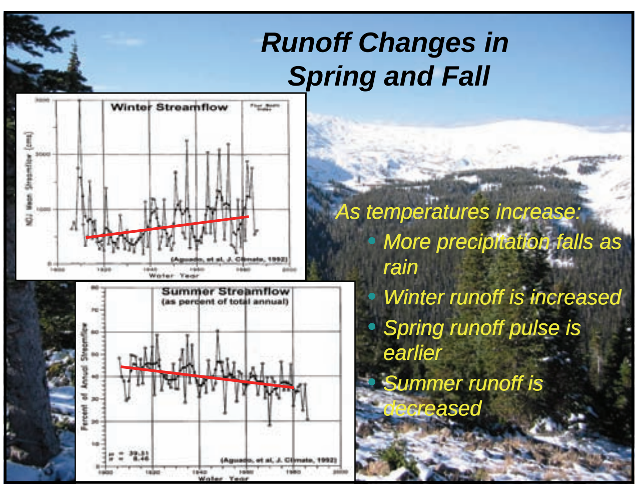
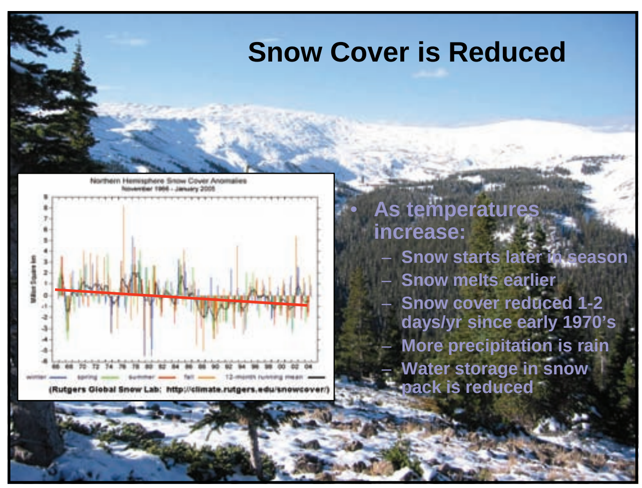
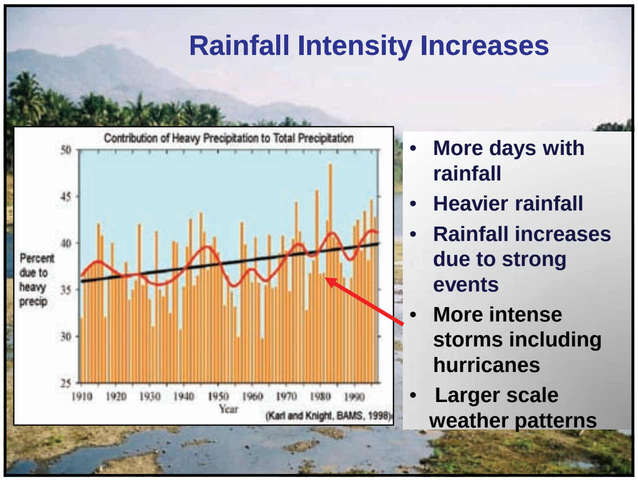

National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Sea Level Rise
Two sets of sea level rise projections are generated:
The IPCC model-based approach includes four terms: local land subsidence, local relative ocean height, global thermal expansion, and meltwater
The rapid ice melt scenario replaces the model based meltwater term with sea level rise rates (43 +/- 4 in/century) observed during paleoclimate analogues
7 GCMs and 3 emissions scenarios
NYC
Rapid ice-melt scenario


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Water Cycle & Climate Change
As the Earth has warmed, what has happened to Earth's water resources?
Recent Trends
• Dry areas drier & Wet areas wetter
• Precipitation intensity ('heavy') increases
• Increased floods and droughts & intensity
• Snowfall decrease
• Earlier runoff (lower summer streamflow)
• Melting of ice sheets and glaciers
• Sea level rise
38
105
67
393
355
38
(IPCC, 5.1)
1000 km³/yr


Runoff Changes in Spring and Fall
Winter Streamflow
(Aguado, et al, J. Climate, 1992)
Summer Streamflow (as percent of total annual)
(Aguado, et al, J. Climate, 1992)
Water Year
As temperatures increase:
• More precipitation falls as rain
• Winter runoff is increased
• Spring runoff pulse is earlier
• Summer runoff is decreased


Snow Cover is Reduced
Northern Hemisphere Snow Cover Anomalies
(Rutgers Global Snow Lab: http://climate.rutgers.edu/snowcover/)
• As temperatures increase:
– Snow starts later in season
– Snow melts earlier
– Snow cover reduced 1-2 days/yr since early 1970's
– More precipitation is rain
– Water storage in snow pack is reduced


Rainfall Intensity Increases
Contribution of Heavy Precipitation to Total Precipitation
Percent due to heavy precip
Year
(Karl and Knight, BAMS, 1998)
• More days with rainfall
• Heavier rainfall
• Rainfall increases due to strong events
• More intense storms including hurricanes
• Larger scale weather patterns


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
NASA Earth Science Tools
Climate Change Impacts on Water Workshop
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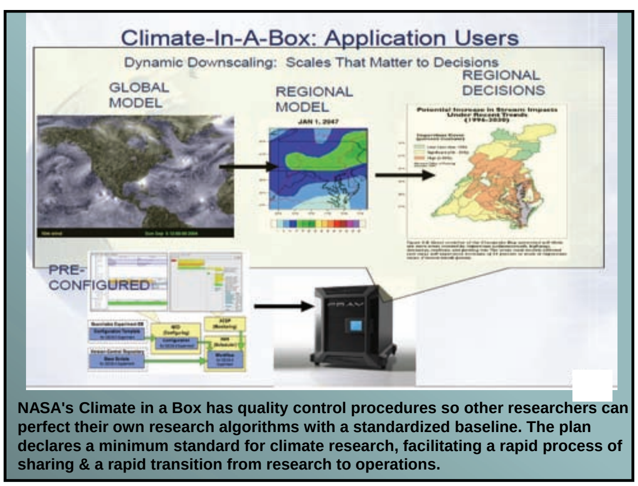
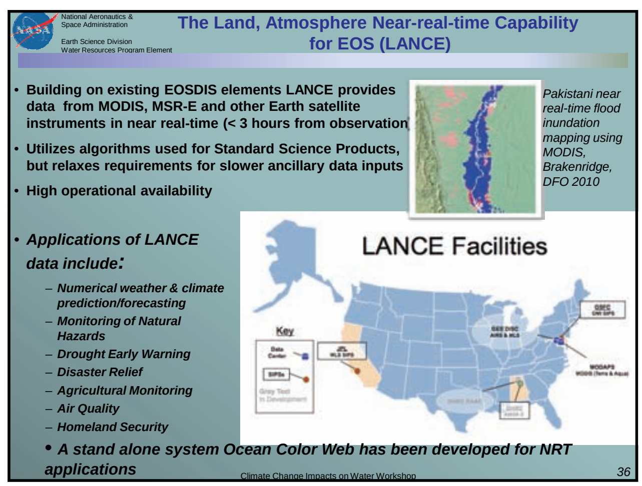

Climate-In-A-Box: Application Users
Dynamic Downscaling: Scales That Matter to Decisions
GLOBAL MODEL
REGIONAL MODEL
REGIONAL DECISIONS
PRE-CONFIGURED
NASA's Climate in a Box has quality control procedures so other researchers can perfect their own research algorithms with a standardized baseline. The plan declares a minimum standard for climate research, facilitating a rapid process of sharing & a rapid transition from research to operations.


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
The Land, Atmosphere Near-real-time Capability for EOS (LANCE)
• Building on existing EOSDIS elements LANCE provides data from MODIS, MSR-E and other Earth satellite instruments in near real-time (< 3 hours from observation)
• Utilizes algorithms used for Standard Science Products, but relaxes requirements for slower ancillary data inputs
• High operational availability
Pakistani near real-time flood inundation mapping using MODIS, Brakenridge, DFO 2010
• Applications of LANCE data include:
– Numerical weather & climate prediction/forecasting
– Monitoring of Natural Hazards
– Drought Early Warning
– Disaster Relief
– Agricultural Monitoring
– Air Quality
– Homeland Security
LANCE Facilities
Key
• A stand alone system Ocean Color Web has been developed for NRT applications
Climate Change Impacts on Water Workshop
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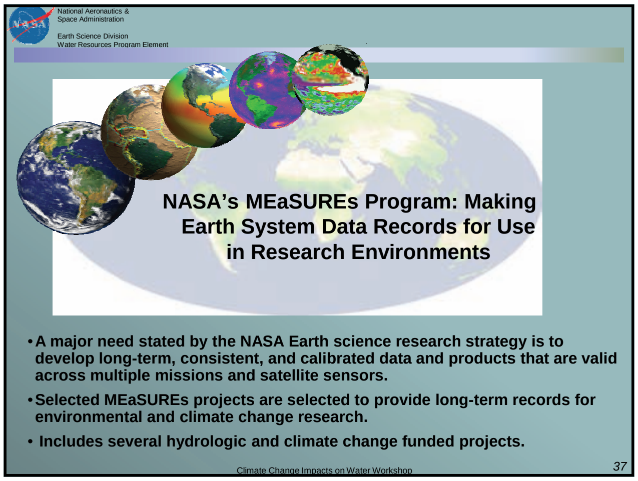
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
NASA's MEaSUREs Program: Making Earth System Data Records for Use in Research Environments
• A major need stated by the NASA Earth science research strategy is to develop long-term, consistent, and calibrated data and products that are valid across multiple missions and satellite sensors.
• Selected MEaSUREs projects are selected to provide long-term records for environmental and climate change research.
• Includes several hydrologic and climate change funded projects.
Climate Change Impacts on Water Workshop
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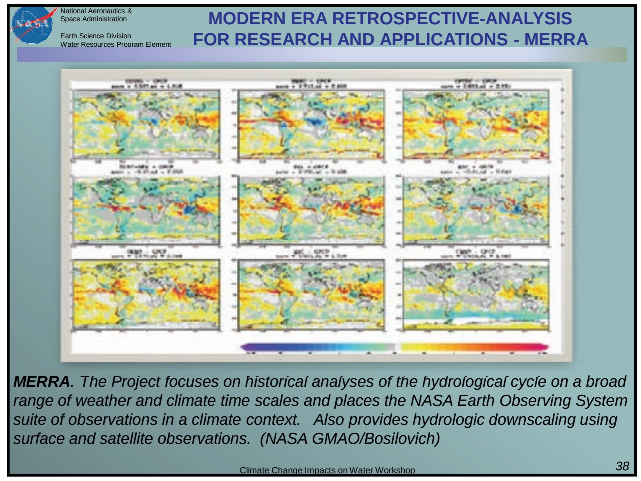
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
MODERN ERA RETROSPECTIVE-ANALYSIS FOR RESEARCH AND APPLICATIONS - MERRA
MERRA. The Project focuses on historical analyses of the hydrological cycle on a broad range of weather and climate time scales and places the NASA Earth Observing System suite of observations in a climate context. Also provides hydrologic downscaling using surface and satellite observations. (NASA GMAO/Bosilovich)
Climate Change Impacts on Water Workshop
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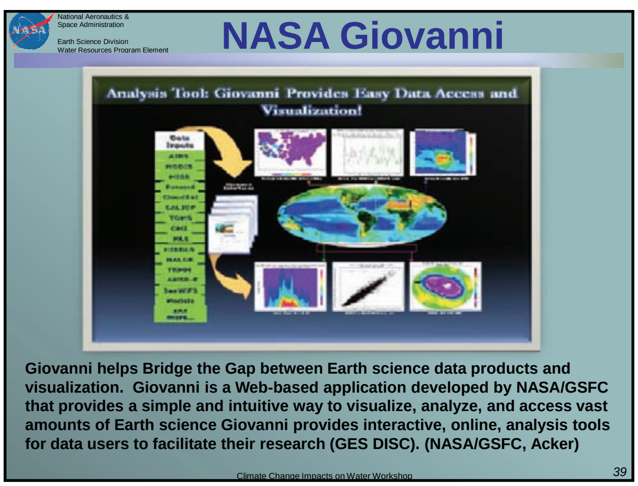
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
NASA Giovanni
Analysis Tool: Giovanni Provides Easy Data Access and Visualization!
Giovanni helps Bridge the Gap between Earth science data products and visualization. Giovanni is a Web-based application developed by NASA/GSFC that provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science Giovanni provides interactive, online, analysis tools for data users to facilitate their research (GES DISC). (NASA/GSFC, Acker)
Climate Change Impacts on Water Workshop
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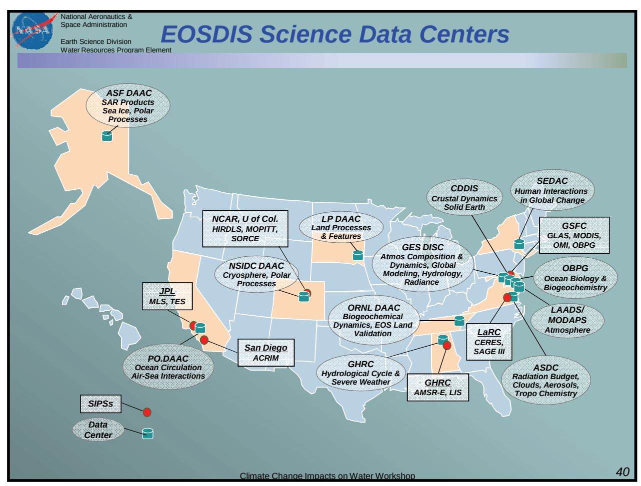
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
EOSDIS Science Data Centers
ASF DAAC SAR Products Sea Ice, Polar Processes
CDDIS Crustal Dynamics Solid Earth
SEDAC Human Interactions in Global Change
NCAR, U of Col. HIRDLS, MOPITT, SORCE
LP DAAC Land Processes & Features
GSFC GLAS, MODIS, OMI, OBPG
GES DISC Atmos Composition & Dynamics, Global Modeling, Hydrology, Radiance
NSIDC DAAC Cryosphere, Polar Processes
OBPG Ocean Biology & Biogeochemistry
JPL MLS, TES
ORNL DAAC Biogeochemical Dynamics, EOS Land Validation
LAADS/ MODAPS Atmosphere
LaRC CERES, SAGE III
San Diego ACRIM
PO.DAAC Ocean Circulation Air-Sea Interactions
GHRC Hydrological Cycle & Severe Weather
GHRC AMSR-E, LIS
ASDC Radiation Budget, Clouds, Aerosols, Tropo Chemistry
SIPSs
Data Center
Climate Change Impacts on Water Workshop
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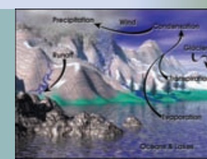
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element

NASA HYDROLOGICAL TOOLS

National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element

Goals of NASA's Hydrology Research

Fundamental Research



Water and Energy Cycle Science

- *Global Hydrological Cycle*
- *Fresh Water Resources and Availability*
- *Climate Change*
- *Measure Water Cycle (Soil Moisture, Evapotranspiration, Snowpack, Aquifers, Runoff, & Precipitation)*

Applied Research

Science Utilization

- *Reservoir Regulation*
- *River Flow Management & Floods*
- *Agriculture Planning*
- *Hydro Power Planning*
- *Drought Assessment*
- *Weather Forecasting*
- *Water Quality*

National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element

Summary Space-Based Hydrologic Observations Current Capability

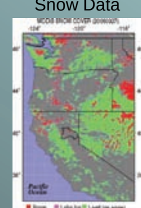
Water Cycle & Related Variable	Sensor	Technology	Horizontal Resolution	Repeat Frequency	Swath Width
Precipitation	TRMM, GOES, DMSP, Meteosat GPM	Precip Radar (JAXA) TMI, VIRS	25 km 0.25x0.25deg	daily	247 km 878 km
Soil moisture	SSMI AMSR-E SMAP	Multifrequency Radiometers	12-56 km	5-day	1445 km
Groundwater	GRACE GRACE-II	gravity	100,000 km2	30 days	
Lake/reservoir levels	Topex/Poseidon Jason-1 SWOT	Altimetric radar	350 m	10 day	Single track
Evapotranspiration	MODIS, Landsat, LDCM includes IR	Visible/NIR	250-1000m	1-2 days	
Stream discharge	Topex Poseidon Jason-1, SWOT	Altimetric radar	350m	10-day	Single track
Snow water equivalent	SSMI, AMSR-E, CLPP	Multifrequency Radiometers	12-56 km	5-day	1445 km
Snow cover	MODIS	Vis/NIR	250-1000m	1-2 days	2330 km

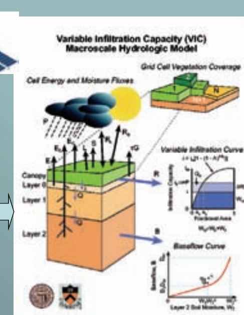
Future & Planned in Red

National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element

Hydrologic Forecasting(USDA-DOI-CA DWR) Snow Pack

Snow Data

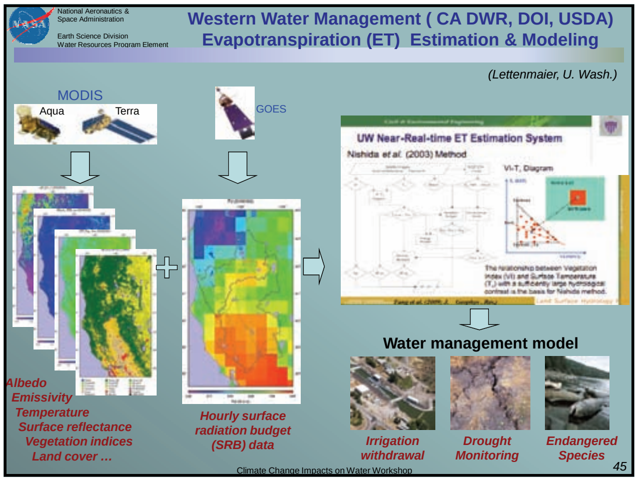




Snowpack Initial Condition

Reservoir Regulation

D. Lettenmaier/U. Wash.


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Western Water Management (CA DWR, DOI, USDA)
Evapotranspiration (ET) Estimation & Modeling
(Lettenmaier, U. Wash.)
MODIS
Aqua
Terra
GOES
UW Near-Real-time ET Estimation System
Nishida et al. (2003) Method
Water management model
Albedo
Emissivity
Temperature
Surface reflectance
Vegetation indices
Land cover …
Hourly surface radiation budget (SRB) data
Irrigation withdrawal
Drought Monitoring
Endangered Species
Climate Change Impacts on Water Workshop
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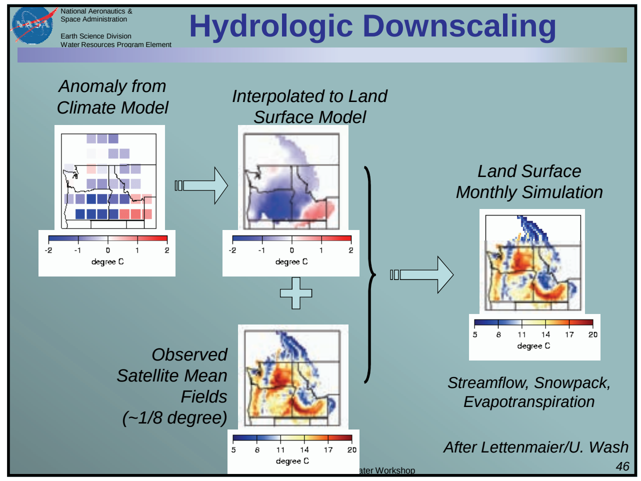
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Hydrologic Downscaling
Anomaly from Climate Model
Interpolated to Land Surface Model
Land Surface Monthly Simulation
Observed Satellite Mean Fields (~1/8 degree)
Streamflow, Snowpack, Evapotranspiration
After Lettenmaier/U. Wash
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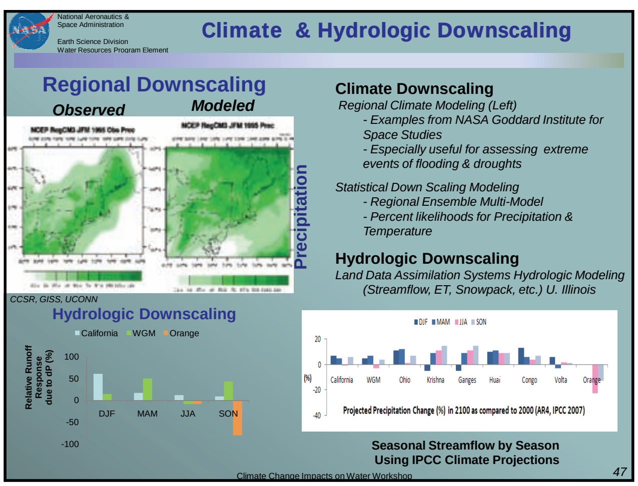
National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Climate & Hydrologic Downscaling
Regional Downscaling
Observed
Modeled
Precipitation
CCSR, GISS, UCONN
Climate Downscaling
Regional Climate Modeling (Left)
- Examples from NASA Goddard Institute for Space Studies
- Especially useful for assessing extreme events of flooding & droughts
Statistical Down Scaling Modeling
- Regional Ensemble Multi-Model
- Percent likelihoods for Precipitation & Temperature
Hydrologic Downscaling
Land Data Assimilation Systems Hydrologic Modeling (Streamflow, ET, Snowpack, etc.) U. Illinois
Hydrologic Downscaling
California
WGM
Orange
Relative Runoff Response due to dP (%)
DJF
MAM
JJA
SON
Projected Precipitation Change (%) in 2100 as compared to 2000 (AR4, IPCC 2007)
Seasonal Streamflow by Season Using IPCC Climate Projections
Climate Change Impacts on Water Workshop
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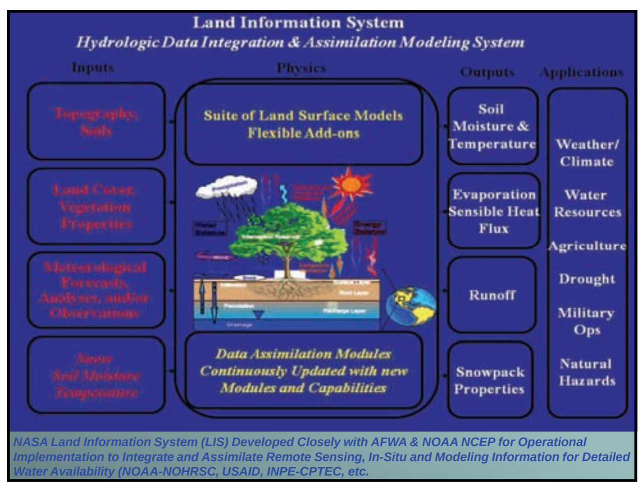
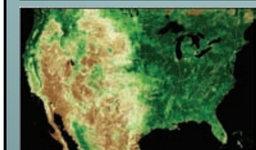

Land Information System
Hydrologic Data Integration & Assimilation Modeling System
Inputs
Physics
Outputs
Applications
Topography, Soils
Land Cover, Vegetation Properties
Meteorological Forecasts, Analyses, and/or Observations
Snow Soil Moisture Temperature
Suite of Land Surface Models Flexible Add-ons
Data Assimilation Modules Continuously Updated with new Modules and Capabilities
Soil Moisture & Temperature
Evaporation Sensible Heat Flux
Runoff
Snowpack Properties
Weather/ Climate
Water Resources
Agriculture
Drought
Military Ops
Natural Hazards
NASA Land Information System (LIS) Developed Closely with AFWA & NOAA NCEP for Operational Implementation to Integrate and Assimilate Remote Sensing, In-Situ and Modeling Information for Detailed Water Availability (NOAA-NOHRSC, USAID, INPE-CPTEC, etc.

National Aeronautics & Space Administration

Earth Science Division
Water Resources Program Element

MODIS System Characteristics for Inputs to US Drought Monitor – PI J. Verdin (USGS)

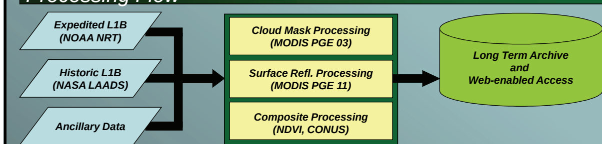
Product Characteristics



Example eMODIS product: Terra MODIS 1000m NDVI CONUS composite for August 2-8, 2006

	Expedited	Historic
Instruments	Aqua and Terra MODIS	
Extent	Continental U.S. (CONUS)	
Spatial Resolutions	250, 500, and 1000 meters	
Product Latency	~ 1 day after last input	< 30 days after last input
Archive Persistence	90 days	Indefinitely
Composite Period	7-day, Rolling	7-day, Interval
Layers	NDVI, Surface Refl. Bands, Quality, Acq. Date	
Projection/Format	Lambert Equal Area Azimuthal / GeoTIFF	

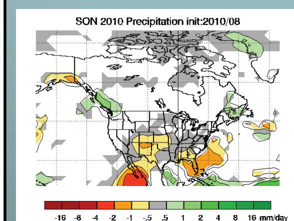
Processing Flow

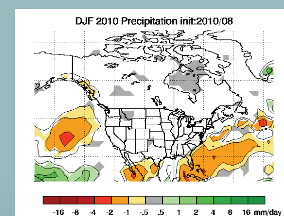


National Aeronautics & Space Administration

Earth Science Division
Water Resources Program Element

NASA SEASONAL PREDICTONS





- NASA complements NOAA, providing seasonal temperature and precipitation predictions globally, issued every month. NASA/GSFC, Koster. Current work to improve seasonal predictions and to provide hydrologic downscaling of results. http://gmao.gsfc.nasa.gov/forecasts/#}

National Aeronautics & Space Administration

Earth Science Division
Water Resources Program Element

Determining the Feasibility of Mapping and Monitoring the Extent of Cladophora in the Laurentian Great Lakes

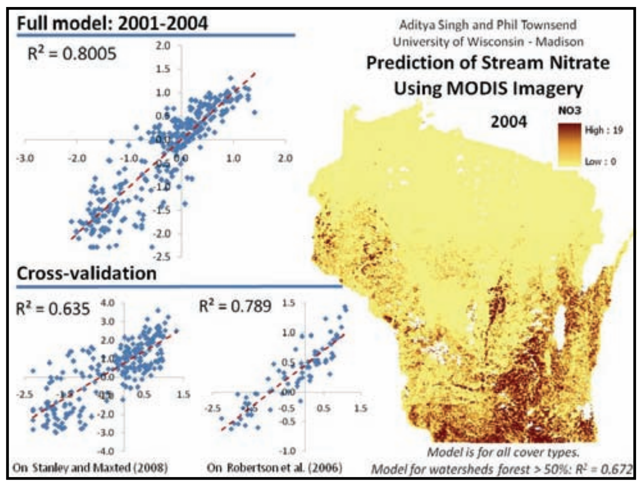
Dr. Robert Shuchman, Michigan Tech Research Institute

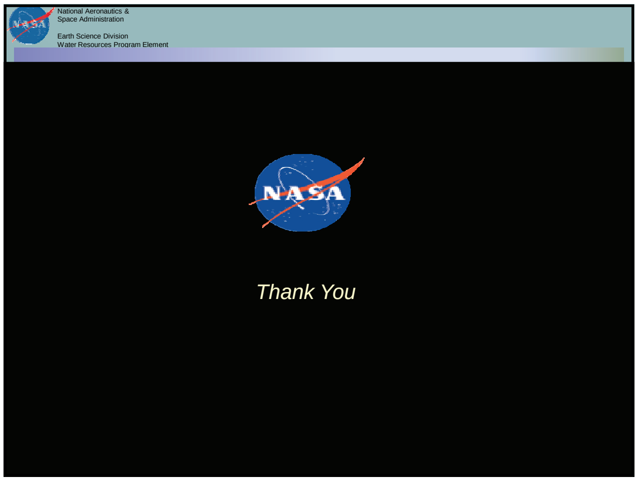
A depth invariant algorithm has been generated and successfully tested to map Cladophora in 0-15 meters depth using multi-spectral visible EO satellite data such as Landsat and GeoEye.

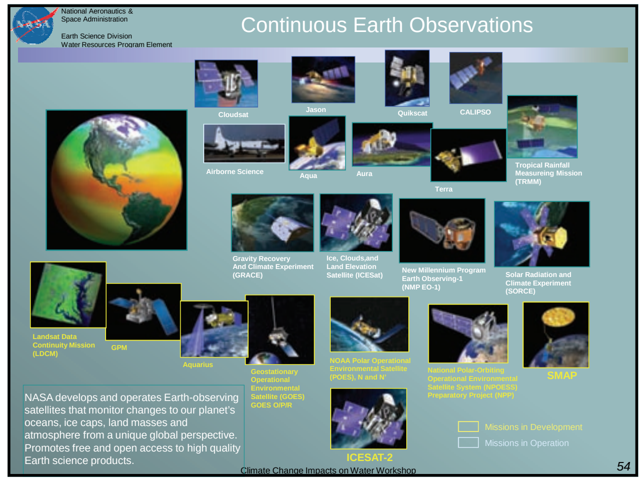
New methodology can be utilized in EPA's Great Lakes Restoration Initiative (GLRI) to create baseline Cladophora extent and biomass maps to support remediation efforts by resource managers of this nuisance algae.

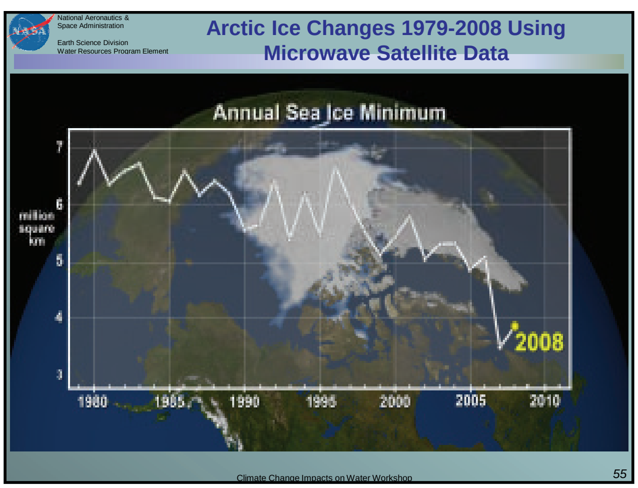
Bottom Type	Dry Weight Density (g/m²)	Area (m²)	Dry Weight Biomass (grams)	Approximate Dry Weight Biomass (tonnes)	Approximate Wet Weight Biomass (tonnes)
Dark-Optically Deep	0	41,069,700	0	0	0
Cladophora (Darker green)	31	19,947,600	618,375,600	618	6,184
Dense Cladophora (Lighter green)	53	81,578,700	4,323,671,100	4,324	43,237
Sand	0	167,585,400	0	0	0
				4,942	49,420

Example of a NASA Water Quality Project. NASA supports over 10 water quality projects in the US including directly estimating water quality parameters such as of nutrients and sediments and the evaluation of non-point source pollution (e.g., vegetation stress and land cover change) sources.




National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
NASA
Thank You


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Continuous Earth Observations
Cloudsat
Jason
Quikscat
CALIPSO
Airborne Science
Aqua
Aura
Terra
Tropical Rainfall Measureing Mission (TRMM)
Gravity Recovery And Climate Experiment (GRACE)
Ice, Clouds,and Land Elevation Satellite (ICESat)
New Millennium Program Earth Observing-1 (NMP EO-1)
Solar Radiation and Climate Experiment (SORCE)
Landsat Data Continuity Mission (LDCM)
GPM
Aquarius
Geostationary Operational Environmental Satellite (GOES) GOES O/P/R
NOAA Polar Operational Environmental Satellite (POES), N and N'
National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP)
SMAP
ICESAT-2
NASA develops and operates Earth-observing satellites that monitor changes to our planet's oceans, ice caps, land masses and atmosphere from a unique global perspective. Promotes free and open access to high quality Earth science products.
Missions in Development
Missions in Operation
Climate Change Impacts on Water Workshop
54


National Aeronautics & Space Administration
Earth Science Division
Water Resources Program Element
Arctic Ice Changes 1979-2008 Using Microwave Satellite Data
Annual Sea Ice Minimum
million square km
7
6
5
4
3
1980
1985
1990
1995
2000
2005
2010
2008
Climate Change Impacts on Water Workshop
55

USEPA National Water Program Climate Adaptation Goals and Research Strategy

Future Research on Climate Change Impacts on Water: Adaptation Strategies and Information Needs

James A. Goodrich, Ph.D.
August 31, 1010

Office of Research and Development

USEPA Office of Water
National Water Program Water Adaptation Goals and Key Challenges

1

National Water Program Strategy: Response to Climate Change

- Goal 1: **Water Program Mitigation of Greenhouse Gases:** Use core water programs to contribute to greenhouse gas mitigation
- Goal 2: **Water Program Adaptation to Climate Change:** Adapt implementation of core water programs to maintain and improve program effectiveness in the context of a changing climate and assist States and communities in this effort.
- Goal 3: **Climate Change Research Related to Water:** Strengthen the link between EPA water programs and climate change research.
- Goal 4: **Water Program Education on Climate Change:** Educate water program professionals and stakeholders.
- Goal 5: **Water Program Management of Climate Change:** Establish the management capability to engage climate change challenges on a sustained basis.

2

GHG Mitigation, Water Conservation, and Carbon Sequestration

Improve sustainability of water utilities and reduce greenhouse gases while conserving water supplies

- Reduce Energy Use at Water/Wastewater Plants
  - Energy efficiency of operations, motors, etc.
  - Co-generation
- Implement WaterSense Program to conserve water and reduce energy used for pumping & treating
- Water Reuse
- Protect Groundwater Quality via Geologic Sequestration Regulations

3

Develop Adaptation Tools & Information

- State-Tribal Climate Change Council
- Climate Ready Estuaries
  - 20 Pilots
- Climate Ready Water Utilities
  - FACA Working Group
  - Interactive Toolbox
  - CREAT and other Vulnerability Assessment Tools
  - Emergency Response Planning
- Green Infrastructure/Low Impact Development

4

Adapt Base CWA & SDWA Programs

- Incorporate Climate into Pollution Control Programs
  - NPDES Discharge Permits and Effluent Guidelines
    - Exploring climate in new stormwater rulemaking
  - TMDL Water Quality Analyses (impaired waters)
  - Nonpoint Source Pollution Management Programs
  - Management Measures for Nutrients and Sediments
- Consider Climate in Environmental & Health Assessments
  - Ocean acidification
  - Microbial Criteria - Risks of Waterborne Disease
  - Water Quality Criteria for Hydrologic Conditions
  - Biological Indicators for Water Quality
  - Water Quality Monitoring and Waterbody Surveys
  - Watershed Modeling

5

OW Interagency Engagement

- CEQ Interagency Adaptation Task Force (Oct. '10)
  - Co-Chair of Water Workgroup
  - Water Workgroup Priority Focus Areas:
    - Data and Models (SWAQ)
    - Vulnerability Assessments & Tools
    - Water Use Efficiency
    - Integrated Water Resources Management
    - Build Institutional Capacity (national & regional)
- SECURE Water Act Report to Congress (Mar. '11)
- Climate Change & Water WG (CCAWWG)
  - USGS, ACoE, BuRec, NOAA, EPA, FEMA

6

USEPA Office of Research & Development Global Change Research Program Overview

7

ORD GLOBAL CHANGE RESEARCH PROGRAM:

Provide critical **scientific information** and **tools** to support decision making related to climate change at the federal, **regional, state,** and **local** levels.

Assess the potential **impacts** of climate change, investigate **adaptation strategies** to reduce the risks posed by climate change, and evaluate the environmental and human health implications of **alternative strategies** for reducing greenhouse gas emissions.

8

Global Change Research Overview: Program Areas

- **Sustainable Energy Systems:** Provide information, data and tools to support development and implementation of GHG mitigation regulations and assess environmental implications of proposed mitigation technologies
- **Air Quality Adaptation:** Assess how climate change could impact future air quality and identify potential options to adapt to these impacts including evaluating policies that protect both air quality and global climate.
- **Water Adaptation:** Provide decision-support tools and conduct place-based built and natural infrastructure adaptive management approaches
- **Vulnerability Assessment:** Characterization of human health and ecosystem vulnerability, methods and scenario development and support to the USGCRP

9

WATER SECTOR ACTIVITIES

Water Adaptation

- Capacity Development – tools, information, models
- Place-Based Built Environment - treatment technology
- Place-Based Watershed Processes – aquatic ecosystems
- Sustainable Methods and Approaches – integrated adaptive management
- Monitoring and Evaluation – adaptation metrics, plans

10

WATER SECTOR ACTIVITIES (cont.)

Vulnerability Assessment

- Methods for characterizing and estimating vulnerability (e.g., scenario development, tools, addressing uncertainty)
- Human health, well being, and vulnerable populations (e.g., urban ecosystems, vulnerability metrics)
- Ecosystems focus (land use, aquatic ecosystems, impact assessments, wetlands)
- Support U.S. National Climate Assessment (USGCRP)

11

Selected Recent/Ongoing Activities

12

Tangible Place-Based Climate Change Water Resource Adaptations

- Integrated Adaptive Water Management Regional case studies of vulnerable utilities and their tool box of adaptive strategies
  - Southeast US -Tampa
  - Southwest US - Las Vegas/Phoenix
  - Ohio River Basin
  - Other regions pending – Pacific NW, Upper Midwest, Great Lakes

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Integrated Adaptive Water Resource Management

- Ohio River Basin Adaptive Management
  - multiple sub-watersheds piloted
  - cross water sector users
  - leverage small and medium sized utilities
  - identify water resource planning approaches
  - identify data availability/gaps
  - develop overall framework
  - verify approach

14

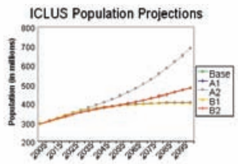
Watershed modeling to assess the sensitivity of streamflow and water quality to climate and land-use change in 20 U.S. watersheds

Goals:

- Sensitivity of U.S. streamflow and nutrient and sediment loading to climate change across a broad range of plausible mid-21st Century climate futures
- Potential interactions of these climate changes with increasing urbanization in these watersheds
- Methodological challenges associated with integrating existing tools (e.g., climate models, land-use models, watershed models) and datasets to address these scientific questions
- The sensitivity of the results to a range of methodological choices available

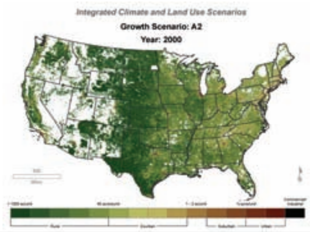
15

Integrating Climate and Land Use Scenarios (ICLUS)



Goals:

- Create seamless land use change scenarios for the U.S. consistent with IPCC emissions storylines
- Decadal projections of housing density (1 ha) and impervious cover (1km) through 2100 based on demographic model and SERGoM spatial allocation model
- New ARCGIS plug-in tool allows users to run additional, user defined scenarios



16

Climate Change Effects on Biological Indicators

- Developed initial categorization of biological indicators according to sensitivity to climate change
- Conducted case studies on effects on reference and non-reference sites and monitoring strategies
- Conducting analysis of traits conveying climate sensitivity
- Held workshops for biocriteria managers (Spring ’07 & ’08)

http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190304

17

Climate Ready Estuaries: Pilot projects in Massachusetts Bays and San Francisco Bay

Vulnerability Assessment Approach

- Examine management goals, ecosystem components, and indicators
- Create conceptual models for key indicators
- Summarize observed and projected climate change impacts
- Assess vulnerabilities of management goals
- Develop an Adaptation Plan
- In partnership with SFEP, BCDC, MBP, OAR and OW

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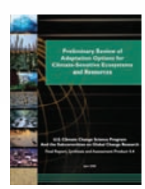
SAP 4.4: Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources



http://www.climatescience.gov/Library/sap/sap4-4/final-report/

Identify and assess:

- Climate sensitive management goals for

National Forests	Wild and Scenic Rivers
National Parks	National Estuaries
National Wildlife Refuges	Marine Protected Areas

- Implications of climate change for achieving management goals
- Adaptation approaches that reduce the risk of negative impacts on management goals
- Characteristics of human and ecological systems that enhance or inhibit implementation

Outcome: Enhance adaptive capacity of resource management community to respond to future changes in climate

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Water and Aquatic Ecosystem Available Tools

- ***BASINS CAT*** *– (Climate Assessment Tool):* Extends the existing *capabilities of BASINS to facilitate watershed-based assessments of the potential implications of climate variability and change on water and watershed systems using the HSPF model.*
- ***WEPP CAT*** *– (Water Erosion Prediction Project)* An on-line tool that provides a flexible capability for creating user-determined climate change scenarios for assessing the potential impacts of climate change on sediment loading to streams.
- ***ICLUS*** *– (Integrated Climate and Land Use Scenarios):* Housing and impervious surface cover scenarios for US through 2100 with IPCC CC outputs
- ***CREAT*** *– (Climate Resilience Evaluation Awareness Tool):* Development of a PC based tool to help utilities understand climate change impacts, threats, and planning responses related to individual utilities.

TOOL	DATE	WATER RESOURCE ADAPTATION DECISION SUPPORT TOOLS	STATUS	POSSIBLE NEXT STEPS
Ethanol Calculator		Determine water supply impacts of Biofuel facilities	Completed	- Case study validation - Add new reuse calculator
Water Treatment Plant Model	2012	Determine cost and drinking water treatment technology needed to adapt to new source water quality	Being integrated with CREAT	- Case study validation - Add treatment unit processes
Water Availabilty Index	2012	Methodology to identify short to long-term water availability at the local level incorporating site specific features	Initial methodology completed, ongoing fine tuning and development	- Additional theoretical development - Case studies
ASR/Reuse	2013	ASR and water reuse as water adaptation engineering measures	Ongoing experimental studies	- Pilot scale testing - Modeling
Engineering Adaptation Methodology under Uncertainty	2013	A suite of engineering adaptation tools for hydrological and water infrastructure engineering with probabilistic uncertainty management	Theoretical basis development	- Case Study
Engineering Design Standards under Climate Change	2014	Supplemental infrastructure design standards appendix for precipitation under future climate uncertainty	Theoretical basis development	- Case Study

STAR GRANT Program – Water Related

Ecological Impacts from the Interactions of Climate Change, Land Use Change and Invasive Species: A Joint Research Solicitation - EPA, USDA (2007)

Nonlinear Responses to Global Change in Linked Aquatic and Terrestrial Ecosystems and Effects of Multiple Factors on Terrestrial Ecosystems: A Joint Research Solicitation- EPA, DOE (2005)

Effects of Climate Change on Ecosystem Services Provided by Coral Reefs and Tidal Marshes (2004)

Assessing the Consequences of Global Change for Aquatic Ecosystems: Claimte, Land-use, UV Radiation (2001)

Regional Hydrologic Vulnerability to Global Climate Change (1995)

2008 STAR GRANTS - Consequences of Global Change for Water Quality Water

- Consequences of Global Climate and Emissions Changes on U.S. Water Quality: An Integrated Modeling Assessment - Liang, Xin-Zhong
  - **University of Illinois at Urbana-Champaign**
- US Freshwater Resources in the Coming Decades: An Integrated Climate-hydrologic Modeling Study - Reinfelder, Ying Fan
  - **Rutgers University**
- Modeling of the Hydrochemical Response of High Elevation Watersheds to Climate Change and Atmospheric Deposition - Driscoll, Charles
  - **Syracuse University**
- Impact of Climate Change and Variability on the Nation's Water Quality and Ecosystem State - Vörösmarty, Charles J.
  - **City College of the City University of New York**

2008 STAR GRANTS- Consequences of Global Change for Water Quality Water

- A Probabilistic Framework for Projections of Watershed Services in US Headwaters under Climate Change Scenario - Wagener, Thorsten
  - **Pennsylvania State University**
- Consequences of Global Climate Change for Stream Biodiversity and Implications for the Application and Interpretation of Biological Indicators of Aquatic Ecosystem Condition - Hawkins, Charles P.
  - **Utah State University**
- Combining Climate Model Predictions, Hydrological Modeling, and Ecological Niche Modeling Algorithms to Predict the Impacts of Climate Change on Aquatic Biodiversity - Knouft, Jason
  - **St. Louis University**
- Assessing the Impact of a Warmer Climate on Stream Water Quality Across the Mountainous Western United States - Stewart-Frey, Iris
  - **Santa Clara University**

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Future Research Needs

- Improved analysis of monitoring data (flow, water quality, precip) to understand 'nonstationary' trends and describe future risk
  - Including new engineering practices and methods that incorporate nonstationarity
- Translation of climate projections for use in hydrological and management models. Example Parameters of Interest:
  - flow & critical low flow (e.g. 7Q10), water temperature, precipitation (e.g., 25-year/24-hour or 2-year/24-hour), aquatic species shifts & diversity; pollutant loadings & dissolved oxygen
- Methods to understand interdependencies that might result (due to causation or correlation) in compounding of impacts due to extreme events

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Future Research Needs (cont'd)

- Additional Adaptation and Vulnerability Assessment Case Studies
  - Water Quantity/Supplies
  - Intense precip/Flood/Storms
  - Water Quality
  - Sea Level Rise
- Regional Models/Tools
  - Testing different vulnerability assessment methods for robustness
  - Develop suites of regionally-validated tools, e.g., locally relevant, plausible scenarios for conducting vulnerability assessments
- Monitoring changes in waterbody characteristics
  - Surface water flow and water quality
  - Groundwater recharge
  - Wetlands and headwaters .
  - Species migration.
  - Salinization of coastal freshwater aquifers
  - Affects of sea level rise on estuaries and bays; wetland migration
  - Ocean acidification and effects

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Information Sources

- **Office of Water**
  - » www.epa.gov/water/climatechange
- **Water Adaptation and Vulnerability Assessments**
  - » http://www.epa.gov/nrmrl/wswrd/wqm/wrap/index.html
  - » http://www.epa.gov/wed/
  - » http://www.epa.gov/nheerl/
- **Water and Air Quality Assessments, USGCRP**
  - » http://www.epa.gov/ncea/global/
  - » http://www.epa.gov/appcdwww/apb/globalchange/
- **STAR Grant Program** (all program focus areas)
  - » http://epa.gov/ncer/science/globalclimate/
- **Air Quality Modeling (CIRAQ)**
  - » http://www.epa.gov/asmdnerl/Climate/index.html
- ***Proceedings of the First National Expert and Stakeholder Workshop on Water Infrastructure Sustainability and Adaptation to Climate Change***
  - » http://www.epa.gov/nrmrl/wswrd/wqm/wrap/workshop.html

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EPA
United States Environmental Protection Agency
SEVERE DROUGHT
Mandatory Water Restrictions Are in Effect
Thank You!
Jim Goodrich
28

Information, Data, and Adaptation Tools for the Water and Wastewater Sectors:

Stakeholder-Driven Research at NASA-GISS and Columbia University CCSR

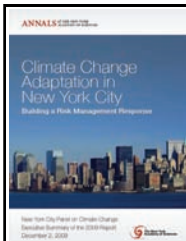
Radley Horton[1,2] and Cynthia Rosenzweig[1],
[1]NASA Goddard Institute for Space Studies
[2]Columbia University Center for Climate Systems Research

A View of the Future for Research on Climate Change Impacts on Water: Workshop Focusing on Adaptation Strategies and Information Needs

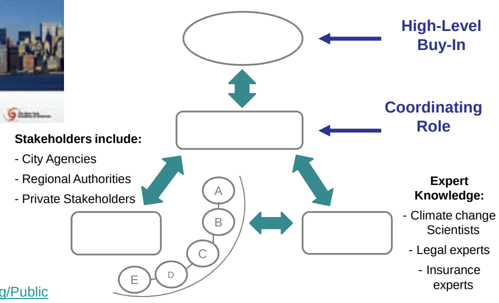
Denver, Colorado

August 31, 2010

1



NYC Climate Change Adaptation Process



http://www.nyas.org/Publications/Annals/
http://www3.interscience.wiley.com/

Integration across Sector-specific Working Groups

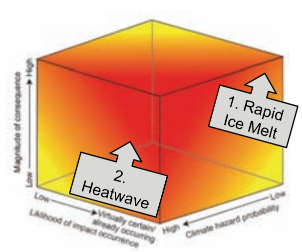
New York City Panel on Climate Change

Adaptation Assessment Steps

1. Identify current and future climate hazards
2. Conduct inventory of infrastructure and assets and begin to identify vulnerabilities
3. Characterize risk
4. Develop initial list of adaptation strategies and prioritization framework
5. Identify opportunities for coordination
6. Link strategies to capital and rehabilitation cycles
7. Prepare and implement Adaptation Plans
8. Monitor and reassess

New York City Panel on Climate Change

Step 3: Characterize Risk



Red	risks for which adaptation strategies should be developed
Orange	risks for which adaptation strategies may need to be developed or for which further information is needed
Yellow	risks for which impacts should be monitored but which may not need actions at this time

Source: Columbia University Center for Climate Systems Research

To determine risk of climate change on infrastructure

1. Probability of a climate change hazard
2. Likelihood of that hazard causing an impact
3. Magnitude of consequence, should that impact occur

New York City Panel on Climate Change

Step 4: Develop and Prioritize Adaptation Strategies

Potential Strategy Prioritization Categories

- Cost
- Feasibility
- Timing of Implementation
- Efficacy
- Resiliency Rating
- Co-benefits

Adaptation Strategy	Strategy Cost (1 = low to 3 = high)	Strategy Feasibility (1 = high to 3 = low)	Timing of implementation (1 = high to 3 = low)	Efficacy (1 = high to 3 = low)	Resiliency rating (1 = high to 3 = low)	Co-benefits (1 = high to 3 = low)	Average*	Notes & institutional considerations
Clean drains	1	1	1	2	2	2	1.8	
Build flood walls	3	2	2	1	3	2	2.2	

*1 = high priority strategy, 2 = medium priority strategy, 3 = low priority strategy

New York City Panel on Climate Change

Water Sector Strategies

Operations and Management

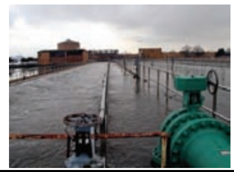
- Improve repair, fix leaks, survey tidegates

Infrastructure

- Hard: NYCDEP is raising pumps and generators at Far Rockaway Wastewater Treatment Plant

- Soft: Expand Staten Island Bluebelt Constructed Wetlands Program

Treatment tanks overflowed at Hunts Point, Bronx WPCP March 2001 storm; unusually high tide elevations prevented discharge of treated sewage into East River, caused back-up



NPCC Report, 2010

Water Availability and Quality--Adaptation

Water Availability

- Diversify water sources (desalinization, expand groundwater system)
- Expand water conservation and usage restrictions
- Expand water transfer capabilities

Water Quality

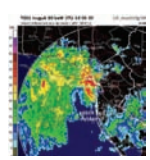
- Acquire additional land and expand conservation programs
- Increase operational flexibility
- Treat with chemicals as necessary

NYC Department of Environmental Protection, 2008

Drainage and Wastewater Management--Adaptation

Rainwater Drainage

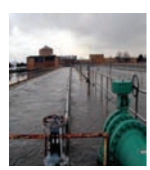
- Improve collection (expand sewers and pumps, and retain stormwater above ground)
- Enhance natural landscape and drainage
- Plan for controlled flooding



August 8, 2007

Storm Surge & Water Treatment

- Raise elevation of key infrastructure
- Use watertight containment of key equipment
- Have reserves of key equipment
- Install local protective barriers
- Allow some inundation in defined areas



NYC Department of Environmental Protection, 2008

Consortium for Climate Risk in the Urban Northeast (CCRUN) Overview

(Pending Approval from NOAA Grants)

Columbia University (Rosenzweig, Lall, Kinney), University of Massachusetts – Amherst (Palmer), City University of New York, Stevens Institute of Technology (Blumberg), Drexel University (Montalto)

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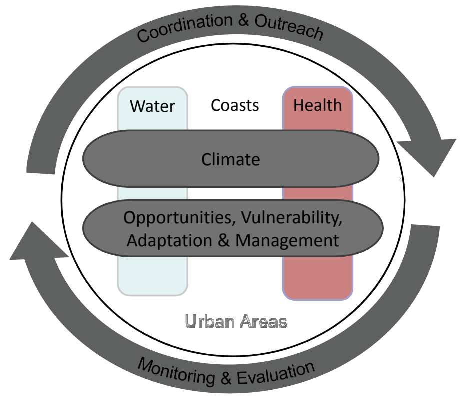
CCRUN Project Diagram



DRAFT as of July 26, 2010

10

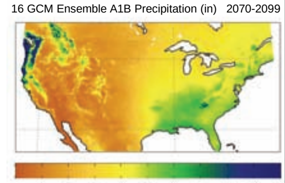
CCRUN Proposed Water Resource Management Projects

- Flooding and Stormwater Management for the Massachusetts Water Resources Authority and Connecticut River Basin
- Delaware River Basin-New York City Water System Management
- Climate Information for Water Harvesting and Re-use Strategies in Philadelphia

CCRUN Proposed Climate Products for Water Sector

- Historical analysis of multi-century trends and variability
- Statistically downscaled projections at seasonal to multi-decadal timescales
- Extreme events
- Stakeholder-driven analysis and presentation

16 GCM Ensemble A1B Precipitation (in) 2070-2099



WCRP/PCMDI bias corrected and spatially downscaled projections

NASA Climate Adaptation Science Investigator (CASI) Workgroup: Mission

To apply and advance NASA's scientific expertise and products to the development of climate adaptation strategies that support NASA's overall mission by minimizing risks to each center's operations, physical assets, and personnel

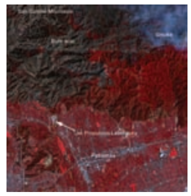


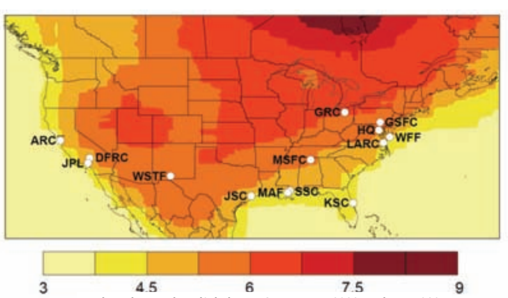
Photo and satellite image of September 2009 fires at JPL

Climate Adaptation Science Investigator Workshop, July 27-28, 2010

Initial CASI Activities

- Create center-specific downscaled climate hazard information
- Partner with decision-making point of contact at respective center, in order to disseminate climate science knowledge tailored to center-specific impacts and adaptation solutions
- Develop inventory of center's existing climate and impact data and research activities
- Participate in 1-3 adaptation workshops, as well as monthly telecons and video conferences
- Based on identification of data and research gaps, develop or support targeted research initiatives

CASI Centers



Projected warming (°F) by NASA center, 2080s minus 1980s averaged across 16 GCMs under the A1B emissions scenario

ARC=Ames Research Center	LaRC=Langley Research Center
DFRC=Dryden Flight Research Center	MSFC=Marshall Space Flight Center
GRC=Glenn Research Center	MAF=Michoud Assembly Facility
GSFC=Goddard Space Flight Center	SSC=Stennis Space Center
JPL=Jet Propulsion Laboratory	WFF=Wallops Flight Facility
JSC=Johnson Space Center	WSTF=White Sands Test Facility
KSC=Kennedy Space Center	HQ=Headquarters

Stakeholder Requests

- **GCM hindcast validation at local scale**
  - **-the idea that historical performance at large spatial scales is a better**
  - **local predictor than local historical performance is counterintuitive**
- **Coordinated scenarios throughout regions**
  - **-and beyond (human and ecosystem health, migration, trade)**
- **High temporal resolution outputs for impact models (hydrological, crop, infrastructure risk, etc.)**
- **Distribution of extremes**
- **Decadal predictions**
- **Generally little interest in projections beyond 2100**
  - **-natural resources community may be an exception**

CCSR

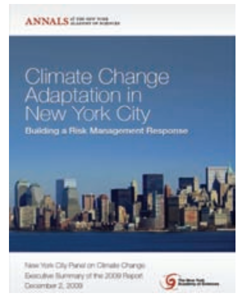
Key Information Gaps / Research Needs

- **Expanded knowledge of historical variability, including extremes (e.g. the 1 in 100 year coastal flood event, drought)**
- **Better understanding of how modes of variability and their teleconnections may change with climate change**
- **Climatic importance of local forcings relative to greenhouse gas forcing**
- **Regional assessment of how sensitive impacts results and decision-making are to different scenarios and downscaling approaches (dynamical, statistical, change factors/delta method)**
- **Examination of how mitigation efforts may be affected by climate change and impacts**
- **Modeling that integrates climate and impacts, such as regional atmospheric modeling experiments (climate and air quality)**

CCSR

Climate Change Adaptation in New York City

Building a Risk Management Response



Cynthia Rosenzweig

NCCARF Seminar Series

June 28, 2010

http://www.nyas.org/Publications/Annals/

http://www3.interscience.wiley.com/

New York City Panel on Climate Change

http://www.nyas.org/Publications/Annals/

http://www3.interscience.wiley.com/

- Convened by Mayor Bloomberg in August 2008
- Served as an independent advisory body for the New York City Climate Change Adaptation Task Force
- Composed of climate change and impacts scientists, legal, insurance and risk management experts
- Focused on adaptation and infrastructure
- Tasked with producing a foundation report and tools to assist Task Force stakeholders

New York City Panel on Climate Change

CCRUN RISA Overview

- Five years, beginning in fall of 2010
- Geographic scope is Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania, with a focus on the Boston – New York – Philadelphia urban corridor
- Focus on vulnerable populations, infrastructure, and sectors (watersheds, coastal zones, and health)

CCRUN Objectives

- Develop risk assessments of weather, climate variability, and climate change tailored to urban stakeholder needs
- Integrate inter-disciplinary research with stakeholder management of climate risks in the areas of water, health, and coastal zones
- Create and evaluate tools, training activities, and outreach efforts to support enhanced stakeholder capacity to understand climate risks and formulate adaptation strategies

Infrastructure Impacts

Climate Risk Factor → Likelihood → Potential Implications for NYC Infrastructure

- Degradation of and increased strain on materials
- Increase in peak electricity load, resulting in more frequent power outages
- Increase of demand on HVAC systems

- Increase of street, basement and sewer flooding
- Increase in delays on public transportation and low-lying highways
- Decrease in average reservoir storages

- Encroachment of saltwater on freshwater sources and ecosystems
- Increase in pollution released from brownfields & other waste sites
- Increase in structural damage to infrastructure from flooding and wave action

Mission

CCRUN's stakeholder-driven research will reduce vulnerability and advance opportunities for adaptation in the urban Northeast

March 12-15, 2010
Downed utility poll and tree branches in Westchester County, NY
Source: James Estrin / New York Times

March 12-15, 2010
Flooded subway station in Manhattan, NY
Source: Librado Romero / New York Times

DRAFT as of July 26, 2010 23

Assessment of Urban Vulnerability to Climate and Adaptation

- Community-level, and inclusive of ethnographic, cultural, and economic considerations
- Will also explore network risks, the role of uniquely urban institutions, and the role of ecology in urban settings

NASA Climate Adaptation Science Investigator (CASI) Workgroup: Background and Timeline

- During Fall 2009, Dr. Cynthia Rosenzweig and NASA GISS were selected to lead and coordinate the science efforts
- An internal NASA call for proposals was issued early in 2010, with awardees informed in May 2010
- Science team held a kick-off meeting at NASA GISS in July 2010; initial funding extends through 2011

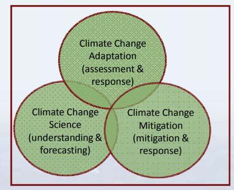
The National Climate Assessment
September 2, 2010

Kathy Jacobs
Assistant Director for Climate Assessments and Adaptation, OSTP

Office of Science & Technology Policy
Executive Office of the President

U.S. Global Change Research Program

- Mandated by Congress in the Global Change Research Act of 1990
- Goals:
  - -To **improve understanding** of uncertainties in climate science
  - -To **expand the global observing systems**
  - -To develop science-based resources to **support policymaking and resource management**
  - -To **communicate findings** among scientific and stakeholder communities

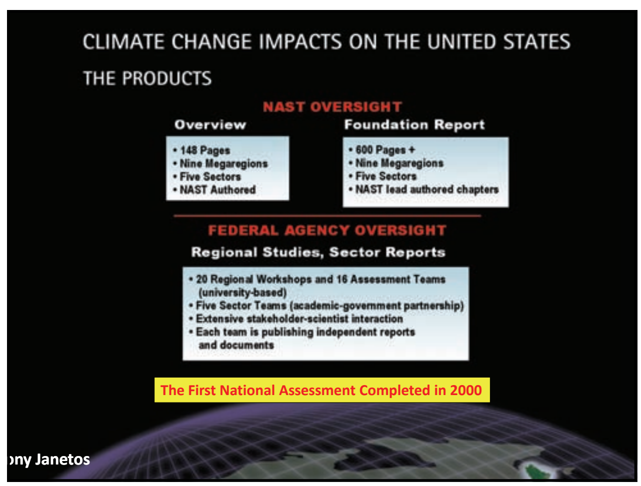


Office of Science & Technology Policy
Executive Office of the President

The National Climate Assessment

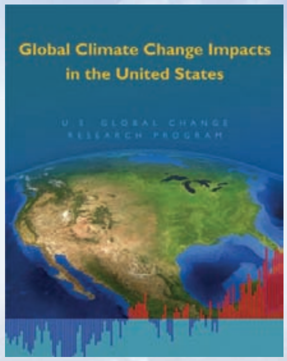
Section 106: Scientific Assessment

- On a periodic basis (**not less frequently than every 4 years**), the Council, through the Committee, shall prepare and submit to the President and the Congress an assessment which –
- **integrates, evaluates, and interprets the findings of the Program** and **discusses the scientific uncertainties** associated with such findings;
- **analyzes the effects of global change** on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- **analyzes current trends in global change, both human-induced and natural**, and projects major trends for the subsequent 25 to 100 years.



The 2nd National Assessment

1. Improve knowledge of climate and environment.
2. Improve quantification of forces driving changes to climate.
3. Reduce uncertainty in projections of future climate change.
4. Understand sensitivity and adaptability of natural and manmade systems.
5. Explore uses and limits of managing risks and opportunities.



2009
http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

The new National Climate Assessment

- Sustainable process with multiple products
- Risk-based framework
- New topics, cross-sectoral studies
- Consistent national matrix, nested studies
- Central coordination, multiple partners
- Regional and sectoral networks; building assessment capacity
- Peer review of assessment materials
- Recognizes international context
- Education and communications focus
- Web-based data and tools

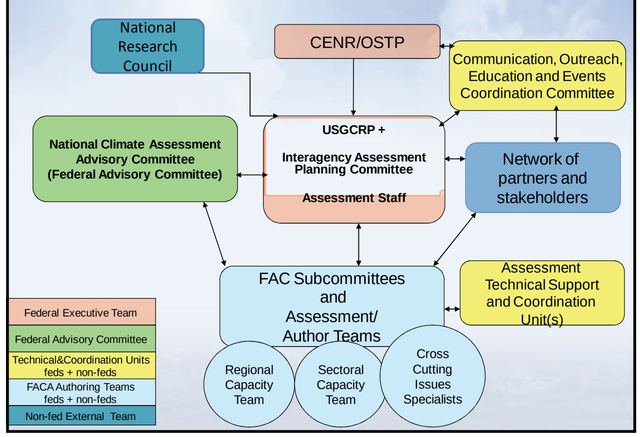
Mission

...to establish a continuing, inclusive National process that:

1) synthesizes relevant science and information
2) increases understanding of what is known and not known
3) identifies information needs related to preparing for climate variability and change, and reducing climate impacts and vulnerability
4) evaluates progress of adaptation and mitigation activities
5) informs science priorities
6) builds assessment capacity in regions and sectors.

First major Assessment report by June, 2013

Preliminary Suggestion for Assessment Structure



Assessment Activities to date

- Held strategic planning and regional workshops in Chicago (and wrote associated workshop reports)
- Established Interagency National Climate Assessment (INCA) team – 18 agencies; held 9 meetings to date
- Developed strategic plan draft
- Discussed strategic plan with four Academy panels: Climate Research Committee, Human Dimensions of Global Change, America's Climate Choices and BASC
- Presented/discussed strategic plan with multiple departments and agencies: NASA, NOAA, EPA, NSF, DOT, USGS, USFWS, USAID, DOE, AG, DHS, DOI, OMB
- Received approval for NOAA sponsored external FACA Committee
- Developed the outline and workplan for the 2013 document
- Conducted an International Context workshop

Next Steps

- Process workshops: (* = workshop proposal has been developed)
  – Communication scoping, September
  – * International context scoping, August
  – *Data management, documentation and peer review, September;
  – *Approach to regional and sectoral assessments, November;
  – *Ecological components of the long-term assessment matrix, November
  – *Scenario methodologies, development and selection, December;
  – *Modeling/*downscaling strategy for the Assessment, December;
  – *Social and economic valuation techniques, January;
  – *Vulnerability and risk assessment techniques, January;
  – Monitoring Climate Change and its Impacts: Indicators, Detection, Attribution and Impacts (2 workshops) January – March;

Next Steps

- Discussions with agencies about their budget commitments
  – FY 2011 "bootstrap budget"; FY 2012 Coordinated budget development
- Establish FACA
- Detailees/hires in place for the following positions:
  – Regional coordinator (NASA?)
  – Sectoral coordinator (USGCRP)
  – FACA administrator (pending)
  * Database/web manager (NOAA-Asheville)
  * Network/engagement manager
  – Administrator/Events coordinator
  – Science integration/assessment coordinator (USGS)
- Implementation of engagement and communications strategies
- Deployment of networks
- Regional and sectoral workshops

Time Line

–FAC in place November 2010
–Process Workshops completed March 2011
–Regional and Sectoral Workshops completed December of 2011
–First Draft Report June 2012
–Final Report June 2013

Report Outline

I. Background and Context for the Process:.

II. The Scientific Basis for Climate Change:

III. Sectors: (1) Natural environment (ecosystems), (2) Biological diversity, (3) Agriculture and forestry, (4) Land resources, (5) Water resources, (6) Marine resources, (7) Air quality, (8) Energy production and use, (9) Transportation, (10) Human health and welfare, and (11) Human social systems (including impacts on cultures and cultural resources).

IV. Regions: (1) Northeast, (2) Southeast, (3) Midwest, (4) Great Plains, (5) Southwest, (6) Northwest, (7) Alaska, (8) Islands, and (9) Coasts; and a new region: (10) Arctic.
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Report Outline

V. Climate change impacts in specific, integrated issue areas. Short case studies (distributed throughout the report) and individual chapters. Topics under consideration include: (1) Water supply, energy, and agriculture; (2) Biogeochemical cycles (e.g., carbon, nitrogen) (3) Land use change, land cover, and human settlements (e.g., urban environments, rural environments, and/or traditional use rights); (4) Migratory species; (5) Tipping points, thresholds, and extreme events; (6) Ecosystem services and human and natural systems trade-offs; (7) Disaster, recovery, risk management, and perception; and (4) International context: U.S. / global systems interactions (e.g., trade, migration, economics, food security, disaster preparedness and response, water, and health).

VI. Human Responses to Climate Change

VII. Future Scientific and Societal Needs

Report Outline

VIII. Appendices:
Methodologies: (1) long-term data sets; (2) models (3) scales and interactions; (4) scenarios; (5) risk; (6) impact assessment; (7) vulnerability assessment; (8) economic and alternative valuation techniques; (9) dealing with uncertainty; (10 detecting changes through monitoring and observations; (11) knowledge management strategies; (12) communications and engagement; (13) interactions with other types of assessments; and (14) building capacity within regions and sectors for conducting and using assessments in the future.

The Future of Research on Climate Change Impacts on Water

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ISBN 978-1-60573-131-5
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WERF6C10
1P-3C-4340-2/11-FP