National Climate Assessment Development and Advisory Committee
Ad Hoc Working Group 3: Scenarios and regional summaries

Members:

Bull Bennett
Jim Buizer
Terry Chapin
Camille Coley
Placido dos Santos
Guido Franco
Gary Geernaert
Aris Georgakakos
John Hall
Tony Janetos
Chet Koblinsky
Jo-Ann Leong
Richard Moss (Chair)
Philip Mote
Jayantha Obeysekera
Lindene Patton
Sara Pryor
Gerry Schwartz
Don Wuebbles

Charge:

This ad hoc working group was asked to prepare recommendations for scenarios and the development of regional climate data and outlooks. The draft scenarios and modeling workshop reports, and presentations by Tony Janetos, Ken Kunkel, and Richard Moss at the NCADAC meeting in April, provided an information base for this ad hoc group's consideration.

Background:

As used in this document, the term "scenarios" describes qualitative and quantitative information about different aspects of the future developed to investigate the potential consequences of climate change. The major types of scenarios this working group deemed relevant to the NCA include: climate scenarios, sea level change scenarios, land cover/use scenarios, and socioeconomic scenarios.

An important consideration in designing scenarios is how they will be used. We assume that scenarios will be used in the National Climate Assessment to provide context about the possible magnitude, rate, distribution, and timing of climate and related changes in sea level and land cover/use; similarly, socioeconomic scenarios will provide context about population, economic, and other conditions related to vulnerability and adaptive capacity. This information needs to be provided in a way that makes it accessible to lay participants in the assessment, as well as to researchers and other expert participants to use in constructing the chapters of the 2013 report. In addition, it is hoped that the scenarios will also be useful to modelers and researchers who may be undertaking modeling projects or other work that could be incorporated into the assessment. This will depend, however, on timing and availability of resources to support such work, issues that this working group is unable to address.

This document sets forth recommendations for scenarios developed with inputs from members and additional experts consulted in the process. More detailed information about the recommendations, including the options considered, appears in a series of appendices that reflect the joint work of the members and additional experts. The working group balances practicality, so that materials can be readied quickly to support the 2013 report, and the ability of the approaches to contribute to capacity building to support future assessment activities.

It is important to note that some aspects of these recommendations are still incomplete due to the limited time available to the working group. In particular, we note a focus primarily on supporting preparation of the 2013 report, and that more attention will need to be directed to building capacity for development and use of scenarios to support future assessments. We hope enough information is provided to enable the NCADAC to move forward with decisions, and, in any event, suggest the NCADAC guard against over-specifying the scenarios to enable those developing them to fine tune variables, data sources, means of dissemination, and other issues as needed.

General Recommendation I: We recommend that climate scenarios, sea level change scenarios, land cover/use scenarios, and socioeconomic scenarios be provided for the National Climate Assessment 2013 report. Further, in the process of preparing the 2013 report, the assessment should identify and inventory ongoing scenario planning efforts and encourage a small number of pilot scenario planning activities. Finally, the report should include an assessment of needs and opportunities for development and use of scenarios to support future assessments in the long term.

General Recommendation II: We recommend that an ad hoc working group or groups continue to work on topics related to scenario development for the National Climate Assessment.

Issue 1: Climate scenarios

See Appendix 1 for a more detail about the options considered and the recommended climate information and scenarios.

Recommendation 1.1: Regional Climatologies

A description of historical variability and change is desirable to provide a context for potential future changes and to illuminate climate factors important to a specific region. This description should include historical time series of key climate variables and specific historical events. **We recommend that the Midwest climatology draft distributed at the first meeting of the NCADAC be used as a guide for the development of such climatologies for all of the regions.** The use of the term “vulnerabilities” in the draft should be replaced by “Important Climate Factors”. Additional specific recommendations about the content of the climatologies are given in the Appendix. Regional teams can be organized around a core membership component that includes the NOAA RISAs, RCCs, DOI CSCs, the NWS RSCDs, and other specific centers/individuals identified by the INCA Task Force members, who can then arrange for the involvement of other federal, university, state, local and NGO organizations to ensure the participation of scientists, resource managers, policy makers, and citizen groups. Teams should include both physical and impacts-focused scientists. Assuming that there are adequate resources to support the involvement of the above core organizations, draft climatologies should be completed in time for the regional workshops and finalized by December 2011.

Recommendation 1.2: Basis of the high and low climate futures

We recommend use of simulations forced by the A2 emissions scenario as the primary basis for the high climate future and by the B1 emissions scenario as the primary basis for the low climate future for the 2013 report. These scenarios constitute a minimum common set, and the group recommends that impacts studies using other scenarios be assessed and considered for the 2013 report .The group’s recommendation is heavily influenced by considerations of data availability and the wealth of information on these model simulations. The group also considered adding a mid-range scenario, specifically simulations forced by the A1B emissions scenario. For reasons provided in Appendix 1, the group decided against including a third scenario.

Finally, regional teams should be given the latitude to incorporate results from the CMIP5 RCP8.5 and RCP2.6 simulations as time and resources permit. This is because RCP8.5 is near the upper end of all scenarios and thus could be considered "worst case", and RCP2.6 is near the lower end of all scenarios and thus could be considered "best case". Thus these two RCP scenarios represent a wider range of possible outcomes than SRES A2 and B1. It will be necessary to provide information to enable users to relate the SRES-forced runs to the RCP-based simulations, and to highlight insights emerging from CMIP5 as they become available. This could be done in a section or chapter of the assessment.

A question that was raised late in the group's deliberations was whether quantification of the probability bounded by the range of scenarios should be provided. The group was not able to come to closure on this issue but suggests that the issue be further investigated.

Recommendation 1.3: Downscaling data sets

We propose the use of both statistically and dynamically downscaled data sets. Due to the coarse spatial resolution of most global models, downscaled data sets are more appropriate than the direct output of global models for most impacts studies. In order to address requirements of the Information Quality Act, the ad hoc working group recognizes the need for standards. **We recommend that downscaled data sets meet the following criteria:**

a. Control and future simulations of sufficient length to evaluate model credibility and climate variability (preference for 30 years control and 30 years future with the understanding that the minimum is 20 years for each)
b. The driving global model data are from the CMIP3 (or later) suite of model simulations
c. Publication of some model results in peer-reviewed journals
d. Willingness and ability to make data available to other groups to perform assessment analyses and publish results (similar to open access pioneered in AR4 for global model results and adopted in the North American Regional Climate Change Assessment Program, NARCCAP).
e. The model group is agreeable to an independent evaluation of model performance and dissemination of performance metrics to users

A standardized basis should be established and used for analyzing the different downscaled datasets, in order to evaluate best practices in selection and application of the downscaled projections. We acknowledge that resources are likely to be needed to meet this criteria.

We recommend that an ad hoc working group of the NCADAC be formed to evaluate whether downscaled data sets that cover the US domain meet the above criteria. If regional teams choose to use downscaling data sets that cover a smaller domain, the regional team will be responsible for evaluating adherence to the criteria.

Changes in tropical cyclone frequency and intensity are a very important consideration in some regions. This is a topic of considerable uncertainty. The ad hoc working group recommends that the newest research be assessed and made available to regional and sectoral teams for their consideration.

Recommendation 1.4: Technical guidelines for regional outlook teams and related items

Regional teams should be formed with the appropriate expertise, including physical and impacts scientists, to prepare both the regional climatologies and the future outlooks.

The outlooks should include the following major aspects:

- a narrative description of model credibility in simulating climate processes of importance in that region
- a general narrative description (perhaps with key tables and maps) of the changes in relevant core variables (temperature, precipitation, wind, humidity, solar radiation, ET, etc), including uncertainties, produced by models for the high, mid-range, and low scenarios
- a narrative description (perhaps with key tables and maps) of the projected changes in the derived variables
- a narrative description of changes in climate modes of variability that are relevant to the particular region

A centrally-coordinated systematic effort should be undertaken to produce a set of metrics regarding model credibility to simulate present-day U.S. climate conditions for all global and downscaled data sets used in the NCA.

Issue 2: Sea level change scenarios

See Appendix 2 for more detail about the options considered and the recommended sea level change information and scenarios.

Global sea level rise (SLR) does not affect coastal areas of the United States uniformly. There are spatial variations between and within ocean basins, temporal variations over alternating periods of climate patterns (e.g. El Nino Southern Oscillation), and local effects on relative sea level (e.g. tectonic uplift or regional subsidence). Thus, producing relevant and credible sea level change scenarios for scientists and stakeholders participating in the 2013 NCA would require a substantial effort to assemble temporally and spatially dispersed data sets from locations and regions across the US over a short time frame. The recommendations below would provide consistent information about global trends, pilot assessments of anomalies in a small number of regions, guidance and information on the choice of climate information for analyzing potential changes in the frequency and severity of extreme sea level events, and factors in addition to global sea level rise that might affect coastal exposure and hence vulnerability.

Recommendation 2.1: Provide a four to five page summary document containing, at a minimum, a range of estimates for global mean sea level rise.

The document would also address regional sea level fluctuations, recommendations for incorporating the climate scenarios to assess extreme events in coastal areas, and a list of variables to consider in conducting coastal vulnerability assessment (see following recommendations). Several key components of this document could be decided upon by a small group of experienced and recognized experts in climate, coastal processes, and coastal management, including possibly two or three members of the NCADAC. If possible, it is also recommended to engage experts who have been involved in the development of global mean sea level rise projections. A meeting could be convened in early June 2011 to start drafting this document, leaving time to produce and review the document for final preparation by late July 2011.

The product of this meeting would be preliminary selection of: global estimates of mean sea level rise from the relevant literature (to be prepared in advance); sample regions for which additional information on sea level anomalies and extreme events will provided as examples for the regional assessment teams; guidance on the limitations of different climate models to use in evaluating extreme sea level events and impacts in the coastal zone; and a list of physical parameters to populate a sea level rise guidance template such as outlined in Appendix 2.

Recommendation 2.2: Provide a table with a high and low estimates of global mean sea level rise for both mid- and end-of-century (2041 – 2050 and 2091 – 2100 respectively) coupled with observed rates and amounts of sea level change from tide gages, altimetry records, and possibly paleo-environmental records.

Since the last IPCC report, there has been additional research on the contribution of ice sheet melting that could change existing assessments of coastal vulnerability by increasing the magnitude of impacts (Rignot et al 2011, Grinsted et al 2008, Pfeffer et al 2008). The table would include a breakdown of the contributions from thermal expansion, ice-sheet melting, and, to the extent possible, land runoff.

Recommendation 2.3: Provide a brief description of sea level anomalies from one or two sample regions, accompanied by tables, figures, and a template for compiling estimates of sea level change from regional and sectoral teams.

Some U.S. coastal regions are encountering higher rates of sea level rise than previous global mean sea level rise estimates from the IPCC. Accelerated rates of sea level rise are due to a range of factors including the strength of western boundary currents, such as the Gulf Stream (Yin et al, 2009), and gravitational effects associated with partial melting of ice sheets (Mitrovica et al, 2009). Observations from tide gages and satellite altimetry records have shown that trends in mean sea level in the Gulf of Mexico and the Pacific Coast of the US deviate from those at the global scale.

It is infeasible to collect and compile all this data for central distribution to the teams for all the NCA regions. Therefore, a description of sea level trends in sample regions will provide regional and sectoral teams with examples of useful products to develop for participatory assessment. Sample regions might include southeast Florida, the urban coast surrounding New York City, the Gulf of Mexico, Pacific Islands, or California. The final decision of a sample region should be based, in part, on the presence or absence of paleo-environmental records documenting long-term sea level change, as well as on the availability of expertise and interest in potential sponsoring agencies. Information on the sample regions might include: graphs and interpretation of water level observations over the past several decades, maps of elevation change based on the most updated topographic and bathymetric data, and paleo-environmental records of sea level over longer timescales (e.g. sediment cores, foraminifera, etc)

Regional estimates would be developed by the regional assessment teams based on the contributing variables outlined in the template provided in advance by the scenarios team. For the final 2013 NCA, a national map of regional trends would be compiled from the regional estimates. The map note deviations from the global trend and provide an explanation of ranges found within the region. It would also highlight outliers or locations where communities are particularly vulnerable due to changes in sea level and other coastal processes. Regional estimates would be more relevant to regional stakeholders participating in the assessment process.

Recommendation 2.4: Provide, to the extent possible, guidance on the choice of climate information for analyzing potential changes in the frequency and severity of extreme sea level events.

This guidance may vary regionally. For example, in southeast Florida, the El Nino Southern Oscillation (ENSO) and the Atlantic Multi-decadal Oscillation (AMO) have been shown to affect the frequency of storm surge on the Florida coast (Park et al 2010a, Park et al 2010b). A number of climatic variables affect both sea level and storm surge including temperature, air pressure, wind, and precipitation.

The regional and sectoral assessment teams would likely want to integrate information on global and regional sea level with information from the climate scenarios on changes in precipitation, wind, and air pressure. For example, while changes in storm frequency and intensity are highly uncertain, it could be very useful to demonstrate how sea level rise projections, when combined with projected or perhaps historical storm data, would impact the magnitude and frequency of coastal flooding. The implication of these changes upon the present or projected landscape of ecosystems, development and infrastructure is an important facet of the regional assessment.

Most climate models provide projections of temperature and precipitation over land, while only a handful of climate models provide projections of pressure and wind over oceans. This limitation of certain models makes the choice of climate information for coastal vulnerability assessment particularly important. Where the ocean component cannot be robustly represented in analyzing extreme events, it is imperative to represent this uncertainty in the assessment process.

Recommendation 2.5: Provide a list of factors that, in addition to global sea level rise, might affect coastal exposure.

A number of other climate-related and non-climatic variables contribute to changes in the frequency and severity of flooding in coastal communities and changes in coastal ecosystems. These variables include, but are not limited to substrate (i.e. rock or sediment of different size classes), exposure to winds, the slope from the coastal to nearshore environments, subsidence, accretion of sediment or organic materials, tide range, or the presence or absence of sea ice. All of these variables determine the processes that affect coastal landscapes, broadly defined as coastal geomorphology. Regional and sectoral assessment teams should utilize frameworks and tools that have already been assembled and implemented by recent impacts analyses, building upon existing flood projections, some of which have already been incorporated into a visualization platform to help facilitate use of the materials in participatory processes.

Recommendation 2.6: Questions to assess knowledge gaps for future assessments of sea level rise and coastal vulnerability

For the sustained NCA assessment process, the regional and sectoral assessment teams should also gather information that can inform future assessments of sea level change and coastal vulnerability. Questions might include:

- What process should be used for the 2013 NCA and for future NCAs?
- How would more recent global and regional projections of SLR affect the existing flood projections and vulnerability and risk assessments taking place in the region or sector?
- Are there thresholds beyond which impacts of water level change and associated impacts become disproportionately greater? Does the current SLR scenario provide sufficient temporal and spatial resolution to consider the distribution and changes in extremes?
- If not, is the global projection insufficient or is there a lack of data, data resolution, and/or scientific knowledge on local factors (e.g. land elevation, coastal erosion or deposition, tides and water levels, anatomy of extreme historical events, etc.)?
- Does the information that would be supplied satisfy needs of different communities and sectors (e.g. transportation, ecosystem conservation and restoration)?

Issue 3: Land cover/use scenarios

A sub-group of this ad hoc working group produced an initial white paper (see Appendix 3) on the issues and formats for both baseline and scenario information for land-cover and land-use that could be used for analysis by regional and sectoral groups. This white paper has provided the framework for subsequent activities, although we note that the ad hoc working group did not have enough time to discuss the specifications for these scenarios at great length.

Land-cover and land-use baseline information is important for both regional and sectoral studies for a wide variety of reasons. Land-cover influences important ecosystem services, from the ability of ecosystems to sequester carbon, to regulating water flow and water quality, to providing products for human use, such as food crops and timber. The way the land is used provides everything from opportunities for recreation and conservation to increases in agricultural productivity.

There have been important changes in both land-cover and land-use over the past several decades in the US. Urban areas have grown, mostly at the expense of formerly agricultural lands. The area of land in forest has increased since the 1960's, with concomitant increases in the ability of forests to sequester carbon on a national scale. The patterns of land-cover and land-use provide important context for studies of both adaptation and mitigation on a regional basis and for sectors of importance to the NCA.

Land-cover and land-use futures, however, are determined by a wide variety of factors: economic demand for agricultural and forest products, policies for land and habitat conservation, continued urban and suburban expansion, and climate variability and change being just a few. It is therefore important to use both modeling-derived information and local context and knowledge to develop scenarios for how use of the land, and the subsequent land-cover that results for the coming decades.

Starting in the last week of May, some members of the ad hoc working group will be reaching out to agency and university researchers to discuss the proposed strategy for land-cover and land-use baseline information, and methods for developing scenarios for the future for both regional and sectoral analyses. There are many operational and research programs in the government agencies and the broader research community for both land-cover and land-use, taking advantage of satellite, in situ, and statistical data, and the product(s) for the NCA need to specified not only with respect to intended use, but also with respect to data sources and data quality. There are still unanswered questions vis-a-vis the desired products - e.g., will regional or sectoral analysts want land-cover or land-use as an input to other studies, or will they want information (e.g. above-ground carbon content of ecosystems) that is derived from land-cover. Other issues include the importance of being consistent with ongoing programs in the agencies, and in other national reporting or major research exercises, e.g. US emissions reporting to the Framework Convention on Climate Change and the USGCRP State of the Carbon Cycle Report.

Scenarios for changes in land-cover and land-use are similarly fairly common throughout the agencies and research community, both in operational and research programs. There are several calls planned to discuss the details of the USGS land-cover scenarios that are part of their project on assessing the potential for biological carbon sequestration, and EPA research on scenarios of urban expansion and demography.

The ad hoc working group could continue to work on this issue to provide further details at the next meeting of the NCADAC Executive Secretariat. This may include more specific recommendations on baseline information on land-cover and land-use, a short document that identifies outstanding issues for resolution by the NCADAC, and an assessment of the available resources for producing information for subsequent analysis, and timelines for when products can be delivered.

Issue 4: Socioeconomic scenarios

The central place of socioeconomic conditions in evaluating potential impacts of climate change and understanding the context for both adaptation and mitigation requires that data and information on these factors be made available to participants in the NCA. Exactly which socioeconomic factors matter depends on the precise issue being addressed, but obvious factors of general importance include demography (e.g., population size and distribution, percentage urban, educational attainment, age structure, life expectancy), economics (e.g., wealth and its distribution, productivity, labor force characteristics, sectoral distribution of economic activity), and technology (e.g., in a range of activities including energy production, transportation, industry, agriculture). But other factors are also crucial, including institutions, social networks, perceptions, consumer preferences, and others.

There are a number of sources for socioeconomic trends and scenarios. Data on historical trends is available from both government and private sector sources. Projections are also developed by a number of statistical agencies (e.g., the Social Security Administration, the Congressional Budget Office) for specific purposes, as well as by private sector entities (e.g., insurers) and research institutions (e.g., by integrated assessment modeling teams). The ad hoc working group recommends relying on a mix of these sources for socioeconomic trends and scenarios, as indicated below. Staff at the Census Bureau have indicated that they can lead compilation of information. Options for dissemination and user support still need to be identified, although Census can provide support for their own data.

Recommendation 4.1: Provide historical trends and current conditions using data from statistical agencies of the USG

We recommend that historical trend information be provided at the level of states, the NCA regions, and the nation as a whole. Because of time constraints, we suggest that the predominant focus of this information be on demographic and economic variables, although it may be possible to explore including data on some additional variables identified at the societal indicators workshop. The period of analysis is proposed to be 1981-2010. Data will be provided by the Census Bureau and the Bureau of Economic Analysis.

Recommendation 4.2: Provide projections to mid-century from U.S. Government statistical agencies

Near-term decadal projections to mid-century (2041-2050) could be provided for a smaller set of variables, primarily for regional averages and the nation as a whole. The sources of this information have not been determined yet –evaluation is ongoing. One option is to rely on publicly available projections prepared by the Bureau of the Census and the Social Security Administration, and possibly from Congressional Budget Office or Council of Economic Advisers. Another option is to use information from private sector or university sources. Information about assumptions and methods will be included with the materials provided. If resources allow, the information will be provided in a variety of graphical forms, as well as data sets. Variables would focus on measures population size, growth rate, age structure, migration, aggregate and household wealth, percentage of population below an identified income threshold, labor productivity, labor force participation, and broad sectoral composition of the economy.

Recommendation 4.3: Provide long-term (to 2100) projections from integrated assessment models

Long-term decadal projections to 2100 will be provided for minimal set of variables, only at national averages (confined to total population and GDP). These projections will most likely draw from information provided by university or private sector research groups, for example integrated assessment modeling teams. Methods and assumptions will be included with the projections.

Issue 5: Participatory scenario planning

See Appendix 4 for more detail about the options considered and the recommended sea level change information and scenarios.

The primary purpose of participatory scenario processes has been the application of information about the range of potential future conditions to identify potential robust options for development, resource and land management, and other activities. There are a number of different approaches to participatory scenario planning suited to different applications and stakeholder communities. Some benefits of a participatory approach are communication and understanding of uncertainties, consideration of local, indigenous, and other place-based knowledge and perspectives, co-creation of scenarios that stretch thinking of scientists and decision makers about adaptation options, and development of motivation to act on the information gained.

The overall approach to scenario planning recommended for the near-term 2013 report is to 1) identify and inventory ongoing scenario planning efforts, 2) integrate results of ongoing scenario planning activities into relevant sectoral or regional chapters, 3) encourage a small number of pilot scenario planning activities focused on the issue of adaptation, and 4) evaluate “lessons learned” from these experiences and assess needs and opportunities for expanded use of these techniques in future assessments. Scenario planning activities should be conducted in a way that promotes engagement of a broad cross section of stakeholders and draws on diverse sources of information consistent with standards established for the NCA.

Recommendation 5.1: Inventory ongoing activities

There are many ongoing participatory processes using scenarios to address climate change challenges. An inventory of ongoing activities would highlight the initiative of groups that are currently contributing to adaptation planning and provide examples for others to emulate. Characteristics of ongoing scenario planning activities that would be useful to catalog include what scenarios are being used, how the scenarios are created and used, how uncertainties are handled, reliance of the process on numerical models relative to expert opinion or community values, how non-climate stresses are integrated, the scope of the management questions and adaptation options considered, how the scenarios and adaptation options are linked, how the scenarios are linked with monitoring of key indicators, and the spatial and temporal scales. Practical aspects would be useful, too, including the time, money, and effort required, the type of people that can participate effectively, and the ease with which the scenario process can include new conditions or uncertainties. The inventory could be published as an NCA interim report and/or included in the 2013 assessment. It would also provide information for subsequent steps outlined below, and thus needs to be undertaken quickly. A quick initial survey could be completed in the next 2 months and used to identify activities, with the fuller inventory taking place over the next 5-6 months.

Recommendation 5.2: Incorporate results of case studies into relevant regional or sectoral chapters

Each of the scenario planning case studies identified in recommendation 5.1 provide insight about how a specific group views and responds to climate change. Collectively, the case studies inform an assessment of how climate change intersects with the goals, vulnerabilities, adaptive capacities, and values within or among regions or sectors – from the perspective of the participants themselves. The collective case studies also can provide insight about the unique challenges or opportunities within and across regions and sectors, perspectives on uncertainty, tolerance to risk, and willingness to consider novel futures or adaptation options. As results are identified through the inventory, they should be made available to relevant regional, sectoral, and cross-sectoral activities for consideration in their assessment process.

Recommendation 5.3: Encourage a small number of pilot scenario planning activities in the regional and sectoral engagement processes focused on adaptation

An optional scenario planning process should be encouraged in a number of regions or sectors as a part of their engagement activities. The focus of the pilots would be to create a range of local or sectoral scenarios and associated adaptation actions. Researchers, experts, stakeholders, and facilitators would interact in the scenario planning process and use available national/regional climate, environmental, and socioeconomic information to capture the range of potential change. From these scenarios participants can develop, analyze and evaluate possible adaptation actions. Implementation of this recommendation will depend on identification of capacity, interest, and resources of participating agencies in the regions and sectors of the assessment. Several agencies have ongoing programs in this area and may be able to make resources available—this is currently under discussion.

Recommendation 5.4: Evaluate "lessons learned" and prepare a short assessment of needs and opportunities for future assessments that will be included in the 2013 report

Lessons based on the ongoing and pilot scenario planning activities will improve the capacity of groups to conduct effective climate change planning activities in the context of future assessments. The lessons will help groups choose and implement an effective scenario planning process aligned with their goals, and appropriately use climate, sea level rise, land cover, and socioeconomic projections and historical data. The assessment will also identify how different types of scenario and adaptation planning processes complement or connect to each other, whether there are advantages to using certain scenario planning methods for specific sectors or management questions, and how to effectively implement a scenario planning process. An assessment of needs and opportunities for future assessment will encourage development scenario planning tools that support participatory planning, and better ways to provide information from models or observations. It is recommended that an assessment and writing team be formed to identify lessons learned as well as needs and opportunities for the future assessment process.

Appendix 1

Regional Physical Climate Information
Recommendations to NCADAC from Climate Model Expert Subgroup and NCADAC Ad Hoc Group on Scenarios & Regional Summaries

Ken Kunkel, Guido Franco, Aris Georgakakos, Tony Janetos, Jerry Melillo, Richard Moss, Philip Mote, Jayantha Obeysekera, Sara Pryor, Don Wuebbles, Isaac Held, Linda Mearns, Jerry Meehl

The climate model expert subgroup (CMES) met twice by conference call and the NCADAC Ad Hoc Group on Scenarios and Regional Summaries also met twice by conference call to discuss issues related to regional climatologies and regional climate outlooks. These two groups have the following recommendations:

1. Regional Climatologies

A draft Midwest climatology was prepared for dissemination at the first meeting of the National Climate Assessment Development and Advisory Committee (NCADAC). The CMES reviewed this draft and agreed that it provides a useful context for the future outlooks. ***The CMES recommends that it be used as a guide for the development of climatologies for all of the regions. The use of the term "vulnerabilities" in the draft should be replaced by "Important Climate Factors".*** Additional specific recommendations include:

- Historical time series should have a minimum of 30 years of data.
- Core time series for temperature, precipitation, selected extremes, and drought, based on data from the NWS Cooperative Observer Network, should be included for all regions and displayed for the period of 1895-present.
- The regional teams should be given wide latitude to include information for regionally-specific features, as long as it meets the information quality standards of the assessment
- Regional teams can be organized around a core membership component that includes the NOAA RISAs, RCCs, DOI CSCs, the NWS RSCDs, and other specific centers/individuals identified by the INCA Task Force members, who can then arrange for the involvement of other federal, university, state, local, tribal, and NGO organizations to ensure the participation of scientists, resource managers, policy makers, and citizen groups. Teams should include both physical and impacts-focused scientists.
- Assuming that there are adequate resources to support the involvement of the above core organizations, draft climatologies should be completed in time for the regional workshops and finalized by December 2011.
- If significant sub-regional spatial and temporal variations exist, these should be identified and discussed.

- Important regional teleconnections to climate modes of variability (e.g. ENSO, NAO, PDO, etc.) should be recognized and discussed.
- Time series included in the regional summaries should be analyzed for the statistical significance of trends. Potential anthropogenic influences (e.g. land use changes) should be discussed.

2. Basis for a range of climate futures

There are 3 possible options for choice of climate model simulations to use as a basis for a high (warming) climate future. These are simulations forced by (1) A2 SRES emissions scenarios, (2) A1FI SRES emissions scenario, and (3) RCP8.5 scenario. The pros and cons of each option are as follows:

<u>A2</u>

Pros:

Simulations available from all participating CMIP3 models
Large number of simulations available from regional climate models
Statistically downscaled datasets available for many SD methods
Large number of scientific papers evaluating CMIP3 models
Simulations are available now

Cons:

Forcing is not as high as either A1FI or RCP8.5 and recent observed trends are higher than A2; thus this may not be viewed as a realistic estimate of the high end

<u>A1FI</u>

Pros:

High forcing scenario, about as high as the RCP8.5
Large number of scientific papers evaluating CMIP3 models
Simulations are available now

Cons:

Few CMIP3 models produced simulations for this scenario
Few RCM simulations or SD datasets available

<u>RCP8.5</u>

Pros:

High forcing scenario
Required simulation for CMIP5 models; thus large number of simulations will be available

Cons:

GCM simulations are just now becoming available and incorporation of results will be challenge
Very few RCM simulations are likely to be available in time for inclusion in 2013 report
Results of evaluations of CMIP5 models may not be available in time for inclusion

The CMES recommends use of simulations forced by the A2 emissions scenario as the primary basis for the high climate future outlooks. The group's recommendation is heavily influenced by considerations of data availability and the wealth of information on model performance.

There are also 3 possible options for choice of climate model simulations to use as a basis for a low (warming) climate future. These are simulations forced by (1) B1 SRES emissions scenarios, (2) A1B SRES emissions scenario, and (3) RCP2.6 scenario. The pros and cons of each option are as follows:

<u>B1</u>

- Pros:
  - Simulations available from all participating CMIP3 models
  - This is lowest forcing option for the commonly available CMIP3 simulations
  - Statistically downscaled datasets available for many SD methods
  - Large number of scientific papers evaluating CMIP3 models
  - Simulations are available now
- Cons:
  - Forcing is not as low as RCP2.6
  - Few RCM simulations available

<u>A1B</u>

- Pros:
  - Simulations available from all participating CMIP3 models
  - Statistically downscaled datasets available for many SD methods
  - Large number of scientific papers evaluating CMIP3 models
  - Simulations are available now
- Cons:
  - Forcing is the highest of these three options
  - Few RCM simulations available

<u>RCP2.6</u>

- Pros:
  - Lowest forcing scenario of these three options
  - Required simulation for CMIP5 models; thus large number of simulations will be available
- Cons:
  - GCM simulations are just now becoming available and incorporation of results will be challenge
  - It is not know if any RCM simulations will be available in time for inclusion in 2013 report
  - Results of evaluations of CMIP5 models may not be available in time for inclusion

The group recommends use of simulations forced by the B1 emissions scenario as the primary basis for the low climate future outlooks. The group's recommendation is heavily influenced by considerations of data availability and the wealth of information on model evaluations.

The group considered use of simulations forced by the A1B emissions scenario as an additional mid-range option but decided against this option. The suggestion for this mid-range scenario was influenced primarily by considerations of data availability, ample information on model evaluations, and availability of a number of impacts studies using this scenario. The addition of this scenario would help characterize the nonlinear and threshold-controlled response of key sectors (such as water resources, agriculture, energy, and ecology). However, it was also pointed out that the A1B forcing is not very distinct from the forcing of the A2 scenario (and in fact is the highest scenario, for a period of time). In addition, including a "middle" scenario often leads users to interpret that scenario as "the most likely" and to discount the importance of the high and low scenarios.

While the group recommends A2, A1B, and B1 as the principal foundation for the outlooks, it also recognizes that (1) results of analysis of CMIP5 simulations will be coming out during the development of the 2013 report and these results will be of potential interest to the regional and sectoral teams, and (2) some regional teams may wish to explore a larger range of potential future outcomes. ***Thus, the CMES recommends that regional teams be given the latitude to incorporate results from the CMIP5 RCP8.5 and RCP2.6 simulations as time and resources permit.*** This is because RCP8.5 is near the upper end of all scenarios and thus could be considered "worst case", and RCP2.6 is near the lower end of all scenarios and thus could be considered "best case". Thus these two RCP scenarios represent a wider range of possible outcomes than SRES A2 and B1
Some additional specific recommendations include:

- All available independent global model simulations should be used to establish uncertainty ranges.
- Downscaled data sets should also primarily be for the A2, A1B, and B1 scenarios, or the RCP8.5 and RCP2.6 if available.

3. Downscaling data sets

We propose the use of both statistically and dynamically downscaled data sets. Due to the coarse spatial resolution of most global models, downscaled data sets are more appropriate than the direct output of global models for most impacts studies. In order to address requirements of the Information Quality Act, the CMES recognizes the need for standards. ***The CMES recommends that downscaled data sets meet the following criteria:***

f. ***Control and future simulations of sufficient length to evaluate model credibility and climate variability (minimum of 20 yrs control and 20 yrs future)***
g. ***The driving global model data are from the CMIP3 (or later) suite of model simulations***

h. ***Publication of some model results in peer-reviewed journals***
i. ***No restrictions on use of data by other groups to perform assessment analyses and publish results (similar to open access pioneered in AR4 for global model results and adopted in the North American Regional Climate Change Assessment Program, NARCCAP). We recognize that the extent of data availability may be subject to resource constraints.***
j. ***The model group is agreeable to an independent evaluation of model performance and dissemination of model performance metrics to users***

The National Climate Assessment staff at NCDC proposes to support the work of the regional and sectoral teams by centrally producing and disseminating selected pertinent derived information from the downscaled data sets. The capabilities exist to calculate the following derived variables:

<u>Derived Variables</u>

Seasonal and annual temperature changes for mean and variability
Seasonal and annual precipitation changes for mean and variability
Changes in precipitation extremes (threshold exceedances) and # days >0
Changes in temperature extremes [threshold exceedances]
Frost-free season changes
Changes in # of frost days
Changes in degree days
Snow cover changes
Snow water equivalent changes
Seasonal and annual changes in mean wind, humidity, solar radiation/cloud cover, ET

The CMES recommends that it is appropriate to calculate the above derived variables from the downscaled data sets and make these variables available to regional and sectoral teams. These variables are to be considered as a resource for possible use by the sectoral teams, and the teams may choose to calculate other metrics from the model datasets for use in their assessments. Input from the NCADAC members and other scientists involved in the assessment is needed to determine relevant thresholds for extremes. The credibility of estimates of values of extremes from model simulation data is a function of the length of the model simulation, the rarity of the extreme, and the fidelity of the model in simulating relevant physical processes, among other factors. The usefulness of such extreme estimates is related to the overall uncertainties connected to the extreme value. In general, the usefulness is qualitatively proportional to the approximate ratio of the magnitude of the future change to the magnitude of the uncertainty (in other words, a signal to noise ratio). ***It is recommended that uncertainty bounds be calculated based on state-of-the-art methods in order to provide the regional and sectoral teams with a basis for judging whether the extreme values are useful to the application***.

Changes in tropical cyclone frequency and intensity are a very important consideration in some regions. This is a topic of considerable uncertainty. ***The CMES recommends that the newest research be assessed and made available to regional and sectoral teams for their consideration.***

4. Technical guidelines for regional outlook teams and related items

Regional teams should be formed with the appropriate expertise, including physical and impacts scientists, to prepare both the regional climatologies and the future outlooks.

This outlook should include the following major aspects:

- a narrative description of model credibility in simulating climate processes of importance in that region
- a general narrative description (perhaps with key tables and maps) of the changes in relevant core variables (temperature, precipitation, wind, humidity, solar radiation, ET, etc), including uncertainties, produced by models for the high, mid-range, and low scenarios
- a narrative description (perhaps with key tables and maps) of the projected changes in the derived variables listed in section 3
- a narrative description of changes in climate modes of variability that are relevant to the particular region

Regional teams will be provided with online access to maps and tables of changes in primary (temperature and precipitation) and derived variables (listed in section 3). Draft outlooks should be completed in time for distribution prior to the regional workshops. Final versions of the outlooks should be completed by December 2011. Statistically downscaled datasets are generally available only for temperature and precipitation. Other variables will only be available from the global and regional climate models and availability will depend on what the model groups have chosen to store and make accessible to a wider user community.

For downscaling data sets that cover the US domain, the CMES will evaluate whether they meet the criteria in Section 3. If regional teams choose to use downscaling data sets that cover a smaller domain, the regional team will be responsible for evaluating adherence to the criteria.

The CMES recommends that a centrally-coordinated systematic effort be undertaken to produce a set of metrics regarding model credibility to simulate present-day U.S. climate conditions for all global and downscaled data sets used in the NCA.

Current accessibility to high temporal resolution time series from global model and downscaled data sets is highly variable. It is highly desirable that access to downscaled data not be determined by factors other than the inherent quality of the data. It is recommended that resources be made available to arrange access in order to support modeling studies on impacts and adaptation.

If additional downscaling data sets are available in a region, the regional team needs to relate these to the nationally-coordinated inputs. For RCM simulations, this should include a comparison of the projected temperature and precipitation changes in the locally-available model simulation with the range of projections in the nationally-coordinated inputs. If the simulations are used to illuminate a specific feature (e.g. North American Monsoon), the team should assess this feature in the nationally-coordinated inputs.

Appendix 2

Sea Level Change Scenarios for the National Climate Assessment

Adam Parris, Jo-Ann Leong, Richard Moss, Jayantha Obeysekera, Adrienne Antoine, Virginia Burkett, Dan Cayan, Mary Culver, Radley Horton, Paul Scholz

Background

As part of the next National Climate Assessment (NCA), the NCA Development and Advisory Committee (NCADAC) is considering strategies to provide climate, environmental, and socioeconomic scenarios to participants in the 2013 NCA process. Input from participants in several NCA planning workshops indicates that it would be useful for regional and sectoral assessment teams and stakeholders in coastal areas to receive information on historic and future trends in sea level. Sea level change scenarios and coastal vulnerability assessments have not been undertaken in previous iterations of the NCA.

Global sea level rise does not affect coastal areas of the United States (US) uniformly. There are spatial variations between and within ocean basins, temporal variations over alternating periods of climate patterns (e.g. El Nino Southern Oscillation), and local effects on relative sea level (e.g. tectonic uplift or regional subsidence). Thus, producing relevant and credible sea level change scenarios for scientists and stakeholders participating in the 2013 NCA would require a substantial effort to assemble temporally and spatially disperse data sets from locations and regions across the US over a short time frame.

This document provides recommendations on the process for developing a SLR scenario and the information that could feasibly be contained in the scenario including guidance to regional and sectoral teams for compiling additional sea level data at regional to local scales for assessing coastal impacts, vulnerabilities, and adaptation options.

Process for Developing the Sea Level Change Scenario

The sea level rise scenario for the 2013 NCA would consist of a four to five page summary document containing, at a minimum, ranges of estimates for global mean sea level rise that could be a consistent starting point for regional and sectoral assessment teams. The document would also address regional sea level fluctuations, recommendations for incorporating the climate scenarios to assess extreme events in coastal areas, and a list of variables to consider in conducting coastal vulnerability assessment (see following sections).

Several key components of this document would be decided upon by a small group of experienced and recognized experts in climate, coastal processes, and coastal management, including possibly two or three members of the NCADAC. If possible, it is also recommended to engage experts who have been involved in the development of global mean sea level rise projections. This meeting could take place in early June leaving time to produce and review the document for final preparation by late July.

At the initial meeting in early June, the group would discuss:

- What can we learn from regional sea level rise assessments that have already been conducted by US groups (e.g. MD, CA, and NC), and by other international teams (e.g. New Zealand, Great Britain, etc) (Westin et al. 2010)?
- Are "high" and "low" forcing scenarios sufficient for assessment or should additional scenarios be considered?
- Should the sea level change scenarios that are provided focus on a small set of time periods (e.g. mid-century and end-of-century)? Or, will regional groups, including coastal planners and managers), require continuous estimates throughout the 21st Century?
- What methodology(s) should be used to estimate global sea level rise? Should these estimates be linked to the climate model simulations that will be used to underpin the other parts of the NCA? What are advantages and disadvantages of relying on global climate model outputs for sea level rise impacts analysis versus combining GCMs with semi-empirical approaches (Rahmstorf et al 2009)?
- Should probabilistic treatments of both mean sea level rise and extremes be developed?

The product of this meeting would be: global estimates of mean sea level rise from the relevant literature (to be prepared in advance and reviewed at the meeting); sample regions for which additional information on sea level anomalies and extreme events will be provided as examples for the regional assessment teams; guidance on the limitations of different climate models to use in evaluating extreme events and impacts in the coastal zone; a list of physical parameters to populate a sea level rise guidance template such as outlined in the table below. This guidance will provide a consistent starting point for discussion between regional and sectoral assessment teams, including both the technical audience and their stakeholders. For the technical audience, additional information will be provided such as links to the relevant literature, links to global climate model data or other relevant information, and brief text on the limitations of using different GCM outputs for impact and vulnerability assessment (to be derived from discussion at the meeting).

<u>Global Mean Sea Level</u>

The sea level rise scenario would provide a table with a high and low estimate of global mean sea level rise for both mid- and end-of-century (2041 – 2050 and 2091 – 2100 respectively) coupled with observed rates and amounts of sea level rise from tide gages, altimetry records, and possibly paleo-environmental records. Since the last IPCC report, there has been additional research on the contribution of ice sheet melting that could change existing assessments of coastal vulnerability by increasing the magnitude of impacts (Rignot et al 2011, Grinsted et al 2008, Pfeffer et al 2008). And, concurrently, regional, state and local coastal planners from across the US have expressed a need for consistent scenarios (Culver et al 2010).

Table 1. Template for providing historic sea level fluctuations and global mean sea level rise estimates

Components	**1870 – 2000 (tide gauge)**	**1981 – 2010 (combined tide gauge and altimetry)**	**1993 – 2011 (altimetry)**	**2041-2050**		**2091-2100**	
				Low	High	Low	High
Thermal Expansion							
Land-Based Ice (ice sheets and glaciers)							
Land storage (dams), ground water pumping							
Total Amount							
Total Rate							

<u>Regional Trends in Sea Level</u>

The sea level change scenarios should include a template for compiling regional estimates of sea level change that demonstrate variations from the global trend based on factors such as land elevation change and boundary currents. For example, the strength of western boundary currents, such as the Gulf Stream (Yin et al, 2009), and gravitational effects associated with partial melting of ice sheets (Mitrovica et al, 2009) may cause higher rates of sea level rise in the US than previous global mean sea level rise estimates from the IPCC. Furthermore, observations from tide gages and satellite altimetry records have shown that trends in mean sea level in the Gulf of Mexico and the Pacific Coast of the US deviate from those at the global scale.

Regional estimates would be determined by the regional assessment teams based on the contributing variables outlined in the template below in Table 2 and provided in advance by the scenarios team. For the final 2013 NCA, a national map of regional trends would be compiled from the regional estimates. The map would display "+" or "-" signs to denote deviations from the global trend and provide an explanation of ranges found within the region. It would also highlight outliers or locations where communities are particularly vulnerable due to changes in sea level and other coastal processes. Regional estimates would be more relevant to regional stakeholders participating in the assessment process.

Table 2.Template for compiling trends in relative sea level

Contributing Variables	**Long-term historical trend***	**Historical baseline 1981- 2010**	**Future projection**	
			2040 - 2060	2090 - 2110
Land surface elevation trend (subsidence or uplift)				
Basin trends in mean sea level (difference from global mean)				
Net effect – "relative sea level"				

The regional and sectoral assessment teams should be encouraged to augment the global mean sea level rise estimates and the regional sea level estimates with the following outputs:

- Graphs and interpretation of water level observations over the past several decades (Figure 1)
- Maps of elevation change based on the most updated topographic and bathymetric data (Figure 2)
- Paleo-environmental records of sea level over longer timescales (e.g. sediment cores, foraminifera, etc)

The sea level rise scenario should include data and information on regional sea level from one or two sample regions demonstrating the types of tables, graphs, and maps that provide the information described above as an example to scientists on the regional assessment teams. Sample regions might include the urban coast surrounding New York City, the Gulf of Mexico, or California. The final decision of a sample region should be based, in part, on the presence or absence of paleo-environmental records documenting long-term sea level change. The final decision should be made by the SLR scenarios group mentioned in the first section of this document.

Regional Climate and Extreme Events

Coastal communities in the US are vulnerable to higher water levels that cause flooding during storms (i.e. extreme events). Sea level rises or falls in small increments over long periods of time. Incremental increases in sea level cause large increases in flooding by changing the key factors that contribute to water levels along the coast, including both tide heights and storm surge, a result of low air pressure (Cayan et al 2009). In southeast Florida, the El Nino Southern Oscillation

(ENSO) and the Atlantic Multi-decadal Oscillation (AMO) have been shown to affect the frequency of storm surge on the Florida coast (Park et al 2010a, Park et al 2010b). A number of climatic variables affect both sea level and storm surge including temperature, air pressure, wind, and precipitation.

The regional and sectoral assessment teams would likely want to integrate information on global and regional sea level with information from the climate scenarios on changes in precipitation, wind, and air pressure. For example, while changes in storm frequency and intensity are highly uncertain, it could be very useful to demonstrate how sea level rise projections, when combined with projected or perhaps historical storm data would impact the magnitude and frequency of coastal flooding. The implication of these changes upon the present or projected landscape of ecosystems, development and infrastructure is an important facet of the regional assessment.

The sea level rise scenario should provide, to the extent possible, guidance on the choice of climate information for analyzing potential changes in the frequency and severity of extreme events. Most climate models provide projections of temperature and precipitation over land, while only a handful of climate models provide projections of pressure and wind over oceans. This limitation of certain models makes the choice of climate information for coastal vulnerability assessment particularly important. Where the ocean component cannot be robustly represented in analyzing extreme events, it is imperative to represent this uncertainty in the assessment process.

Coastal Processes

A number of other climate-related and non-climatic variables contribute to changes in the frequency and severity of flooding in coastal communities and changes in coastal ecosystems. These variables include, but are not limited to substrate (i.e. rock or sediment of different size classes), exposure to winds, the slope from the coastal to nearshore environments, accretion of sediment or organic materials, tide range, or the presence or absence of sea ice. All of these variables determine the processes that affect coastal landscapes, broadly defined as coastal geomorphology.

The sea level rise scenario should include a list of factors that, in addition to global sea level rise, might affect coastal vulnerabilities. These variables should be considered in assessment of impacts, vulnerabilities, and adaptation options. They include, but aren't limited to:

- Wave heights
- Slope
- Substrate
- Accretion rates from inorganic deposition or organic accumulation
- Winds
- Surface water runoff

- Tide range
- Presence or absence of sea ice and permafrost and the rate of decline
- Long term sediment supply
- Historic trends in erosion and deposition

Data and information from selected regions, where coastal vulnerability assessments have been conducted, could serve as examples to scientists on the regional assessment teams. Sample regions might include southeast Florida, the urban coast surrounding New York City, the Gulf of Mexico, or California.

Coastal Vulnerability Assessment

Given the time constraints associated with the 2013 NCA, the sea level change scenarios should emphasize that, to the extent possible, regional and sectoral assessment teams should utilize the framework and tools that have already been assembled and implemented by recent impacts analyses. Regional and sectoral teams should identify and build upon existing flood projections that have been already built into a visualization platform (tool, website, format for Google Earth, etc) to facilitate a participatory process.

In summary, the NCA should be based upon a combination of information, including global and regional mean sea level, regional climate extremes, and coastal processes in order to assess vulnerability and adaptation. The regional teams might produce scenario-related maps of shoreline change, flood probability based on new sea level change scenarios, graphs comparing range of previously known projections of sea level rise with new sea level rise projections from the scenario, and/or regional ocean heights. The goal of producing these outputs is to facilitate assessment of different adaptation response in collaboration with stakeholders from the regions and sectors.

Gaps Analysis

For the sustained NCA assessment process, the regional and sectoral assessment teams should also gather information that can inform future assessments of sea level rise and coastal vulnerability. To accomplish this, a set of questions would be offered to participatory stakeholders such as:

- What process should be used for the 2013 NCA and for future NCAs?
- How would more recent global and regional projections of SLR affect the existing flood projections and vulnerability and risk assessments taking place in the region or sector?
- Are there thresholds beyond which impacts of water level change and associated impacts become disproportionately greater? Does the current SLR scenario provide sufficient temporal and spatial resolution to consider the distribution and changes in extremes?
    - If not, is the global projection insufficient or is there a lack of data, data resolution, and/or scientific knowledge on local factors (e.g. land

elevation, coastal erosion or deposition, tides and water levels, anatomy of extreme historical events, etc.)?

- Does the information that would be supplied satisfy needs of different sectors (e.g. transportation, ecosystem conservation and restoration, energy – information may be available in the proceedings from the sector workshops)?

References

Cayan, D.R., Bromirski, P.D., Hayhoe, K., Tyree, M., Dettinger, M.D., and R. E. Flick. 2008. Climate change projections of sea level extremes along the California coast. *Climatic Change*, **87**, Supplement 1, 57-73.

Culver, M.E., Schubel, J.R., Davidson, M.A., Haines, J., and K.C. Texeira (editors). 2010. Proceedings from the Sea Level Rise and Inundation Community Workshop, Landsdowne, MD, Dec 3-5, 2009. Sponsored by the National Oceanic and Atmospheric Administration and U.S. Geological Survey.

Grinsted, A., Moore, J.C., and S. Jevrejeva. 2008. Reconstructing sea level from paleo and project temperatures 200 to 2100 AD. *Climate Dynamics*, **34**, Number 4, 461-472.

Mitrovica, J. X., N. Gomez, and P. U. Clark, 2009: The sea-level fingerprint of West Antarctic collapse. *Science*, **323,** 753.

Mote, P., Petersen, A., Reeder, S., Shipman, H., and L.W. Binder. 2008. Sea Level Rise in the Coastal Waters of Washington State. Prepared by the Climate Impacts Group and the Washington Department of Ecology.

Park, J., Obeysekera, J. and J. Barnes. 2010a. Temporal energy partitions of Florida extreme sea level events as a function of Atlantic multidecadal oscillation. Ocean Science, **6**, 587-593.

Park, J., Obeysekera, J., Irizarry-Ortiz, M., Barnes, J. and Winifred Park-Said. 2010. Climate Links and Variability of Extreme Sea Level Events at Key West, Pensacola, and Mayport Florida. ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering

Pfeffer, W.T., Harper, J.T., and S. O'Neel. 2008. Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise. *Science*, **321**, 1340 – 1343.

Rignot, E., Velicogna, I., van der Broeke, M.R., Monaghan, A., and J. Lenaerts. 2011. Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise. *Geophysical Research Letters*, **38**, L05503.

Rahmstorf, S. 2007. A semi-empirical approach to projecting sea level rise. Science, **315**, no. 5810, 368-370.

Ramp, S, Chavez, F, and L. Breaker. Sea Level Off California: Rising or Falling? Central and Northern California Ocean Observing System (CenCOOS) website: http://www.cencoos.org/sections/news/sea_level.shtml

Verdonck, D. 2006. Contemporary vertical crustal deformation in Cascadia. *Technophysics,* **417**, 221–230.

Weston, J, B, Beavan, J, Bell, R, Bindschadler, R, Church, J, Hannah, J, Hunter, K, Kench, P, Mackintosh, A, Manning, M, Naish, T, Ramsay, D, Reinen-Hamill, R, Reisinger, A, Renwick, J, Rissel, Z, Saunders, C, Wratt, D, Zwartz, D. 2010. An Emerging Issues paper from the Royal Society of New Zealand looking at new research on sea level rise. http://www.royalsociety.org.nz/publications/policy/2010/emerging-issues-sea-level-rise/

Yin, J., M. E. Schlesinger, and R. J. Stouffer, 2009: Model projections of rapid sea-level rise on the Northeast coast of the United States. *Nature Geoscience*, **15,** 1-5.

Figures

Figure 1. Mean global sea level as measured from space from 1992 to the present. The mean rate of increase in ~3 mm per year (from the AVISO altimetry product) (Ramp et al.).

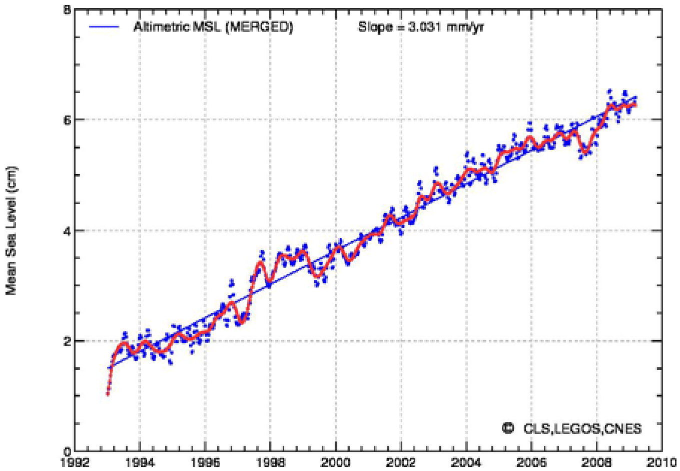
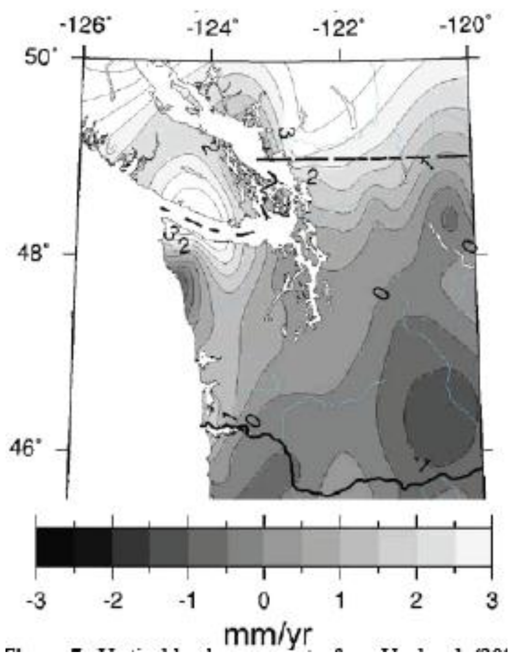


Figure 2. Vertical land movements in Washington state from Mote et al. 2008 and Verndock 2006.



Appendix 3

Land-Cover and Land-Use Scenarios for the National Climate Assessment

Anthony C. Janetos, Director, Joint Global Change Research Institute

Background: Scenarios of future land use share many of the same features as scenarios of future socioeconomic conditions. While there may be national or even global environmental and economic driving forces, the consequences for regional landscapes will also be determined strongly by a combination of local factors and the current condition and recent history of the land uses in any particular region.

As the FAC considers what will be possible to do to construct regional land-cover and land-use scenarios, it will be important to ensure that as much regional knowledge as possible is solicited and used. But regionally determined scenarios with no guidance at all from a national perspective are almost certain to lead to inconsistencies and difficulties in comparison.

Existing Resources: There are many data resources for characterizing current land-cover in regions around the country. Land use patterns are more difficult, but again, many resources currently exist in Federal agencies and in state, local, and non-governmental institutions that are relevant to determining current land-use. There are a few global land-cover or land-use history products, some of which are based on detailed examination of land-use records over time for some regions of the world.

There are fewer available resources for simulating land-cover and land-use trajectories into the future. While modeling and projecting land-use changes has been an important research goal for both the ecological and the human dimensions communities for many years, there are very few research efforts that integrate all the factors that determine patterns of land-use: economic decisions, policy frameworks, climate and soils, cultural considerations, etc.

However, what does exist for projections are a large number of studies in the ecological literature, the land-science literature, the agriculture and forestry literature, and recently, the integrated assessment literature that do different kinds of projections of land-cover and land-use change. In most cases, what the current literature represents are studies in which a single factor is varied, out of the many that actually control land-cover and land-use change, and the results analyzed from the standpoint of the sensitivity of the landscape to that particular variable. So, for example, studies of the potential changes in geographic distribution of tree species in the Northeastern US focus only on changes in the climate system as it might affect those species – they typically do not consider land-use changes, urbanization, soils, or which other species are already growing in those regions. Studies with dynamic global vegetation models consider changes in climate and atmospheric CO_2 as they affect water relations and potential productivity of plant functional types.

Integrated assessment studies primarily consider the value of carbon and demands for carbon sequestration and agricultural productivity as forces shaping the landscape. So each family of studies that currently exists in the literature considers some of the many factors that affect land-cover and land-use change and not others.

Proposed Phased Approach: An overall approach would be to provide two products to each regional team. The first phase would be a data product, maps, and short narrative description of current land-cover and land-use patterns in each region. The easiest way to do this might actually be to assemble or review the available data nationally and then subdivide by the NCA regional boundaries, since many of the existing data sets are in fact national (or global) in scale. A knowledgeable researcher could fairly quickly review the existing literature and datasets, and put together such a review, with commentary on strengths and weaknesses in each area in about 2-3 months time. Familiarity with existing USDA, DOI, NASA, USGS data sets and data quality would be necessary, and a clear view of the distinctions between land-cover and land-use. The product would be data and text descriptions and relevant figures, and this could be provided as background material to each region.

The second phase that might take a bit more time would be a review of the current literature of different kinds of projections of land-cover and land-use, from potential natural vegetation to changes in existing species distributions, to changes in land-use as a function of carbon and food demands. A commentary on the available studies could be written for each region, outlining what the current scientific literature has to say about each, and what has and has not been considered in the various studies. This product is likely to take 3-4 months of concentrated effort, and could be either national or regional in terms of spatial domain.

The regional teams would thus be provided a baseline with commentary for their region, and eventually a review of the existing literature on projections. They would be asked to come up with their own projections of land-cover and land-use change for their region by whatever method they feel is best suited to their particular situation. The NCA will need to make a judgment on the scientific soundness of their methodologies, and place the regional projections in the context of the broader scientific literature on the subject.

Appendix 4

Participatory Scenario Planning in Regional and Sectoral Stakeholder Activities in the National Climate Assessment (NCA)

Holly Hartmann, James Buizer, Placido Dos Santos, Richard Moss, Lindene Patton, Leigh Welling

I. Overview of participatory scenario planning processes and their possible use in the NCA

The primary purpose of participatory processes has been the exchange or production of *knowledge* across different groups of experts and stakeholders. Participation can range from *information* (communicating from experts to stakeholders) and *consultation* (eliciting from stakeholders to experts), to *collaboration* (co-production of knowledge). Participatory scenario studies on climate change develop or use the full spectrum of scenarios, from socio-economic drivers and emissions to impacts and responses. There are a number of methods and example applications of how participatory scenario studies engage scientists and stakeholders in the development or use of climate change scenarios to contend with uncertainty in local climate-change impacts and explore robust response options. A short statement of the approach is that participants identify attributes or objectives that are of greatest importance to them, consider how the range of potential climate and other futures could affect these attributes, develop adaptation strategies and action options, and then assess how local or sectoral options related to their mission or objectives (e.g., related to community economic development, infrastructure, land use, investment in renewable energy technologies, etc.) may perform under the range of potential future conditions. In one sense, the ultimate purpose of many participatory scenario exercises is to help decisionmakers to broaden the range of adaptation approaches under consideration and to help prioritize among these options.

Scenario planning in participatory processes includes a number of steps, including: (1) framing and identifying priority issues for planning; (2) identifying relevant methods and details (e.g., time frame, geographic scope, etc.); (3) collecting information to support analyses (e.g., data sets, conceptual models, literature reviews, expert and stakeholder opinion); (4) identifying notable system conditions and behaviors (e.g., trends, regimes, thresholds, triggers, discontinuities, cascading effects), and their uncertainties, resulting from interactions among boundary conditions, driving forces, and system components; (5) synthesizing scenario narratives, time series, or snapshots; (6) developing strategies and actions to address the implications of system changes for management of priority issues; (7) evaluating and prioritizing management strategies and actions using the scenarios (or others) and planning criteria; and (8) identifying indicators of the need to revisit scenarios, strategies, or actions in the future.

Different participatory processes can be used in each step of scenario planning, depending on time and resource availability and the skills and preferences of facilitators and participants. Aspects of some steps are especially challenging for participants, e.g., prioritizing the issues to address; structuring the collection and sharing of data and information about the forces of climate change and other stressors, and their impacts; distinguishing external system drivers that are outside the control of local and regional decision makers, from internal system responses that are subject to at least some local and regional influence; conceptually linking external drivers of climate and other change with anticipated impacts; creatively synthesizing the collective understanding and choices into scenario narratives; considering decision options that may be currently unacceptable; and evaluating a vast number of decision options.

With advances in computer and communications technology, a number of specialized tools to support use of scenarios in participatory processes have been developed and applied, including visualization, simulation tools, gaming methods, collaborative modeling, and web-based discussion support.

The workshop on scenarios held in December 2010 identified use of scenarios in participatory processes as an important potential new method for the NCA. Because the approach is still relatively new in its application in climate assessment and thus methods and approaches are still evolving, the NCADAC may wish to consider the following approach:

1. Inventory recent and ongoing participatory scenario planning processes and applications in regions and sectors as part of the 2013 report process
2. Use results from documented, ongoing processes as inputs to regional and sectoral chapters
3. Encourage a small number of pilot scenario planning activities in the regional and sectoral engagement processes in the NCA to focus on adaptation as part of their activities
4. Synthesize lessons from ongoing efforts and results to identify research gaps and needs for tools and methods to support use of scenario planning techniques in participatory processes in future assessments.

II. Examples

A variety of participatory processes using scenarios to support planning for climate change in the context of multiple stresses have been, or are being, used in the U.S. at local to regional scales. Collectively, they present both opportunities and challenges for supporting common or comparable approaches as part of the NCA. Some of the groups, e.g., the National Park Service, that have used scenarios for planning may be able to support participatory scenario processes in the NCA.

Example applications of participatory scenario processes are grouped here based on three general approaches to confronting uncertainty: (1) characterizing uncertainty,

(2) embracing uncertainty, and (3) reducing uncertainty. The first approach uses scenarios to explore system sensitivities and the impacts of changes in external driving forces, often through the use of integrated models and projections. It includes using scenarios to evaluate prospective management strategies and decision options, as well as using scenarios to test model integration. For example, the WaterSim model has been used to investigate how alternative climate conditions, rates of population growth, and policy choices could interact to affect future water supply and demand conditions in Phoenix, AZ (Gober et al., 2011); participants can interact with WaterSim at Arizona State University's Decision Theater, a multi-screen visualization and decision space, or via the Web. An ongoing participatory scenario process for the Florida Everglades uses input from stakeholders to help determine the types and extent of conservation and development strategies to be studied, and to help define the economic, visual, and ecological assessment models (Vargas-Moreno and Flaxman, 2010).

Approaches for using scenarios to embrace uncertainty develop widely divergent narratives or outlines of plausible futures, going beyond use of projections to foster strategic thinking about responses to low probability, high impact possibilities as a way to ensure adequate preparation for more likely, but not predictable, futures. The National Park Service process constructs scenario narratives by considering the impact of natural and human stressors on ecosystem, cultural, and built resources, and nesting climate scenarios within divergent sociopolitical contexts that influence the local and regional decision making environment; the process has used web-based collaboration and discussion tools with remote participants from multiple jurisdictions, as well as onsite workshops, to develop the scenario narratives and prospective management strategies and decision options (Hartmann and Welling, 2010). The Bureau of Reclamation is working with CH2MHill to implement a variant of the scenario planning process for the Lower Colorado Basin, but with hundreds of public participants (Freas, 2011). In the U.S. Southwest, scenario narratives developed from fast, informal participatory scenario definition processes have been integrated with user-guided decision support tools designed for participatory processes in other contexts (Mahmoud et al., in review). Tucson Water chains scenarios to incorporate different critical uncertainties for short- and long-term horizons, and to build on prior scenarios as short-term uncertainties are resolved and new ones appear at more distant time scales (Tucson Water, 2004, 2008). Denver Water is uses a suite of scenarios that each prioritize a different critical uncertainty, e.g., regulatory requirements, climate, economics, social values (Waage, 2010).

The use of scenarios in participatory processes enables stakeholders to examine the implications of uncertainty about future conditions on their plans and aspirations. The Wildlife Conservation Society (WCS) Adaptation Conservation Target (ACT) process begins with participants selecting concrete conservation targets and goals, and ultimately identifies conservation actions needed to achieve them in light of different scenarios, prioritizing actions recommended across multiple scenarios (Cross et al., 2010). The Shared Vision Planning process used by the Army Corps of

Engineers combines participatory processes with traditional planning approaches to focus on integrated water management and long-term horizons (Stephenson, 2009). The Federal Highway Administration describes a similar process for transportation planning (USDOT, 2010) in their Scenario Planning Guidebook.

III. Potential scenario planning exercises for regions/sectors in the 2013 report

As indicated by the examples above, there is emerging expertise in use of scenarios in participatory processes. An option for the NCA 2013 report process is to request that regions or sectors that have access to resources or experience in these techniques undertake an optional scenario planning process as a part of their activities. This trial scenario planning process could encourage regional teams of experts, facilitators, and stakeholders use the national/regional climate, environmental, and socioeconomic scenarios as background context to explore the potential implications of climate change for a small number of key objectives, systems, infrastructure, or other attributes important to the participants. Researchers, experts, stakeholders, and facilitators would interact in the scenario planning process and use available national/regional climate, environmental, and socioeconomic information to capture the range of potential change. From these scenarios participants can develop, analyze and evaluate possible adaptation actions. Examples of the types of information to be developed (not intended to confine the regional teams but simply to promote some comparability to aid in synthesis across the regions) include interactions with other development objectives, assumptions about resources developed locally or provided by the federal government or other jurisdictions, and descriptions of the possible adaptation actions.

The National Park Service process may be particularly useful for the pilot studies, since it takes only a few months from start to finish, can incorporate divergent missions and objectives of many jurisdictions, and can consider different sectoral concerns and non-climate scenarios. The NPS process focuses on efficiently identifying a small number of integrated scenarios, based on driving forces having both the highest uncertainty with the largest impacts on system response and then representing strongly divergent conditions for those variables. It has shifted the thinking of participants, to move beyond scenario analysis to actively and routinely plan for change and uncertainty, and has generated novel and innovative adaptation options.

IV. Long-term objectives: synthesis, evaluation, and development of resources for scenario planning

For the 2013 report process, the emphasis for regional and sectoral engagement might necessarily be on participatory scenario processes that are near completion or require little time from initiation to completion. For ongoing efforts, the NCADAC may wish to consider the following:

1. Identify how different participatory scenario processes fit together in the overall context of iterative adaptation planning and risk management.
2. Encourage development of new tools or extension of existing tools that support participatory scenario planning.
3. Use outcomes from the 2013 process as inputs to new and ongoing scenario planning processes.