Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress

R. B. Griffis, R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (editors)

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
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Preface

NOAA is committed to improving society's ability to plan for and respond to climate variability and change. This includes enhancing the conservation and management of living marine resources, coastal resources and coastal communities to meet economic, social, and environmental needs. Climate change is already having impacts on ocean/coastal resources and communities, and these impacts are expected to increase in scale and scope over time. The demand is high from multiple sectors for NOAA to provide increased information and services on (1) how climate change will impact marine life, coastal resources and the communities that depend on them, and (2) what can be done to mitigate and/or adapt to these impacts. Decision makers across the public and private sector are formulating strategies now and need tools and information to prepare, mitigate and adapt to impacts of climate change on ocean and coastal ecosystems.

As both a producer and user of climate information, NOAA can better meet its mandates by integrating climate, coastal, and marine ecosystem observations and predictions, improving delivery of regionally-focused climate information to ocean and coastal decision-makers, and providing tools to effectively use this information to assess risks and implement effective management strategies.

NOAA convened two internal workshops in 2008 to respond to a request from the NOAA Administrator for strategies to better incorporate climate change information in fulfilling NOAA's management responsibilities related to living marine resources, coastal resources and coastal communities. The workshops were also part of NOAA's commitment to "engage in consultations within the agency to identify climate information needs and capacities," as part of NOAA's response to a 2007 Government Accountability Office (GAO) report, *Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources*. GAO recommended that "the Secretaries of Agriculture, Commerce, and the Interior develop guidance incorporating agencies' best practices, which advises managers on how to address climate change effects on the resources they manage and gather the information needed to do so."

The two workshops focused on (1) climate information needed to fulfill NOAA's living marine resource management requirements, and (2) climate information and other tools needed to strengthen NOAA and its partners' capacity to address climate impacts on coastal communities and ecosystems. Representatives from all five of NOAA's Line Offices were present and included climate scientists, coastal and marine resource managers, mapping and geopositioning experts, biologists, ecologists, oceanographers, fishery scientists, meteorologists, social scientists, outreach coordinators, communicators, and senior NOAA leadership.

Workshop participants emphasized the need for additional climate data, improved understanding of how climate changes impact living marine resources and coastal communities, better internal communication and collaboration, improved mechanisms for delivering climate data to decision makers, enhanced models and projections (especially those scaled to regional and subregional levels), and increased capacity building for vulnerability assessments and adaptation planning. The workshops laid the foundation for a NOAA strategy to systematically incorporate climate

change into management of ocean and coastal areas, identify key gaps, and address those gaps. The workshops also identified opportunities for working across NOAA to better integrate climate change information into management of ocean and coastal resources by NOAA and partners. Workshop participants have initiated several joint activities to help fulfill these goals.

Increasing communication and collaboration between NOAA's climate, ocean and coastal activities offers significant benefits for addressing the impacts of climate change, both within NOAA and through our partners and stakeholders. NOAA is currently developing a strategic approach to integrate its coastal activities, with a specific focus on helping improve risk assessment and adaptation to climate change in coastal areas. Significant efforts are underway for improving the design, development, and delivery of effective climate services to NOAA and other stakeholders through a National Climate Service. These are important vehicles for development and implementation of an integrated, end-to-end suite of climate-related products and services for use in management of living marine resources and building hazard-resilient coastal communities and economies.

We believe implementing the recommendations from these workshops is critical to fulfilling NOAA's living marine resource and coastal mandates in a changing climate. These recommendations provide a solid framework for joint planning and action to address climate change impacts on NOAA's ocean and coastal stewardship missions.

To help move this forward, we suggest a number of near-term actions, including establishment of NOAA working groups to oversee implementation of the recommendations, engaging federal agencies and other stakeholders in planning and action, increasing access to climate data and decision-support tools, developing specific guidance for incorporating climate change into NOAA's living marine resource and coastal management activities, and organizing annual summits to assess needs, opportunities and progress towards our goals.

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Climate Goal Lead

Steve Murawski
Ecosystem Goal Lead

Acknowledgements

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Background

Climate change is expected to have significant impacts on ocean and coastal environments and the communities that depend on them.[1] Many of these impacts are already well documented. Key climate change impacts on living marine resources, coastal ecosystems and communities include:

- Changes to ocean physical and chemical properties (e.g., ocean temperature, ocean circulation, ocean acidification)
- Changes in sea level and coastal inundation (Note: this includes the Great Lakes, where the level is dropping)
- Loss of sea ice
- Changes in freshwater supply and quality
- Changes in frequency and/or severity of severe weather (including hurricanes and non-tropical storms)

These changes have a variety of subsequent impacts on ocean/coastal resources and communities for which NOAA has either direct or indirect stewardship responsibilities. NOAA needs to address these impacts in fulfilling its stewardship mandates for living marine resources, coastal resources and coastal communities including:

- Direct and indirect impacts of climate on living marine resources and the habitats they depend on (productivity, phenology, distribution)
- Food web impacts of changes to marine systems
- Socio-economic impacts
- Impacts on land use and transportation
- Reduced resilience of communities and natural systems
- Legal and policy implications
- Ocean and human health impacts

In 2008 NOAA's Climate Program Office worked with numerous NOAA offices to organize two workshops to assess capabilities and needs for NOAA to address impacts of climate change on its ocean and coastal stewardship missions. The workshops were motivated by internal and external calls for increased NOAA action to plan for and address climate change impacts on living marine resources and coastal communities and the ecosystems upon which they depend. The workshops had three primary objectives:

- Foster communication and coordination among NOAA offices responsible for producing climate information and those responsible for applying climate information in coastal and marine settings;
- Identify needs, gaps and priority actions for incorporating climate information into NOAA's ocean and coastal stewardship activities; and

[1] IPCC (Intergovernmental Panel on Climate Change), 2007: Summary for policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 7-22.

- Advance the development of a NOAA strategy for providing and applying climate information in NOAA's stewardship efforts related to coastal and marine resources.

The first workshop, addressing Climate and Living Marine Resources (LMR), was held May 14-15, 2008, at NOAA's Pacific Marine Environmental Laboratory in Seattle, Washington, with more than 50 people attending. The second workshop "Strengthening Capacity to Address the Impacts of Climate Change on Coastal Communities and Ecosystems" was held June 19-20, 2008, at the American Geophysical Union in Washington, DC, with approximately 100 attendees. Participants at both workshops were NOAA employees representing multiple headquarters and field offices. A small number of non-NOAA presenters provided management and science perspectives during a portion of each workshop.

NOAA has a variety of goals related to climate and ocean/coastal management including understanding and predicting how climate is changing; predicting the impacts these changes are having or will have on ocean and coastal resources and communities; assisting NOAA and non-NOAA customers with assessing risks and implementing mitigation and/or adaptation strategies; and monitoring and assessing impacts of climate change and our responses over time. Both workshops invited participants to review key challenges associated with these goals, as well as to discuss available resources (including knowledge, experience, data, data delivery, computational and other capacity, technology, and information systems) and important gaps. Workshop participants addressed three main questions:

1. What are the most critical impacts of climate change on living marine resources or coastal ecosystems and communities that NOAA should address?
2. What are the key gaps and needs for NOAA to address these climate impacts?
3. What key actions should NOAA take in the near (1-2 years) and long-term (3-5 years) to address these needs?

The workshops complemented each other and provided a solid framework for joint planning and action, including ongoing and evolving efforts within NOAA's climate and natural resource programs to address climate impacts and adaptation. Dialogues that occurred as a result of the workshops will contribute to the development of additional agency efforts for generating and applying climate information and services related to natural resource and risk management in marine and coastal regions. Needs assessments and potential strategies were discussed for both short and long term efforts.

Summary of Findings

Given the diversity of NOAA's mandates for living marine resource and coastal management, the two workshops had different focal areas. The Climate/Living Marine Resource workshop focused heavily on climate information and science needs required to fulfill NOAA's management responsibilities for fisheries, protected species, and place-based stewardship of important ocean areas. The Climate/Coastal Communities and Ecosystems workshop identified information and capacity needs of NOAA and the partners with whom NOAA works to manage the Nation's coastal areas. The workshops identified many common issues and validated the need to better incorporate climate change information in fulfilling NOAA's mandates. Many of the findings echoed the drivers and demands informing the proposed development of a National Climate Service within NOAA. The following is a summary of the key findings from the workshops (see Appendices for full workshop reports):

1. NOAA has unique capabilities and responsibilities for providing climate information and for managing climate impacts on living marine resources, coastal ecosystems and coastal communities. NOAA is unique in its mandates and abilities to provide observations for climate predictions and to help address impacts of climate change on LMRs, coastal ecosystems and communities. NOAA is both a producer and a consumer of ocean and coastal data used for climate assessments, as well as a boundary organization acting as a translator between producers (i.e., scientists) and users (i.e., resource managers), providing value-added and capacity building for a host of users beyond NOAA.

2. There is urgent need and high demand from internal and external customers/partners for NOAA to provide climate information and decision-support tools that can be used to assess risks and adaptation strategies for living marine resources, coastal resources and coastal communities. NOAA and its partners are making decisions now about climate-sensitive issues (e.g., coastal development, marine transportation, fisheries management and protected species listing and recovery). These stakeholders need climate predictions, risk assessments and management scenarios to evaluate the best possible solutions to address climate impacts at regional to local levels. Many states and other partners are already developing climate adaptation and mitigation plans and are looking to NOAA for climate services, information, tools and assistance in applying this information to reduce risk and increase resiliency of coastal communities and resources.

3. NOAA needs to do a better job of delivering the climate information it already has. NOAA has a responsibility to make it easier for stakeholders to identify and access what it has to offer, develop new ways of presenting this information, and recognize the importance of integrating physical, natural and socioeconomic information. NOAA should provide all available relevant data and information to those making decisions now. NOAA should also be working in a more integrated fashion to collect new data sets effectively and efficiently (e.g., through an Integrated Ocean and Coastal Mapping approach using topographic and bathymetric high-resolution Digital Elevation Models).

4. NOAA should provide better 'service' focused on user needs.
Both climate and coasts are "integrators" across NOAA. NOAA needs systematic and deliberate processes and dedicated funding to connect the communities of scientific knowledge and the service providers, decision makers and society. NOAA research should be responsive to formal needs assessments and prioritizations, and the transfer of information and tools should be accompanied by capacity building and technical support as necessary, so that our customers can use the tools and information that NOAA provides. Until NOAA makes these investments, it is not going to make the maximum use of the knowledge, information and expertise it has. Evaluation mechanisms should be used to track and improve the effectiveness of climate-related data delivery.

5. NOAA does not regularly and consistently apply climate information when developing predictions and adaptation plans for LMR management (some exceptions were highlighted).
Barriers to the use of climate information in LMR management include:

- Insufficient understanding of how climate changes impact LMRs
- Limited communication between the climate and ecosystem communities
- Lack of awareness about relevant climate information products
- Lack of support for multi-disciplinary, cross-office efforts
- Differences in the temporal scales of predictions and information needs
- Lack of synchronicity between observations (physical, chemical, and biological)
- Lack of a framework for integrating climate information into LMR management
- Lack of funding for multi-sector research and management that integrates climate, LMR, and coastal information

6. It is essential for NOAA's climate projections and scenarios to span the full range of possibilities and provide measures of probability.
There is a large range of uncertainty in the physical climate drivers. Ecological responses further magnify the uncertainty. For managers to make decisions on the best course of action for the resources they manage, they need to know the timescales, probabilities and bounds within which their decisions are being made.

7. The temporal and spatial scale of climate information provided must match the needs of managers.
The use of climate information by managers, to the extent it is available, is growing. LMR workshop participants noted that managers need information at annual or shorter time scales for seasonal and annual management decisions, but there is an emerging need for longer term (10-30 years) climate and climate impact projections for long range planning. Speakers and participants at the Climate/Coastal Communities and Ecosystems workshop highlighted the need for increased data resolution to meet planning needs at regional to local scales.

8. A mix of standard and custom products will be required.
There are a wide variety of problems and issues related to climate and management of ocean and coastal resources. Some can be addressed with standardized products while others will require customized research and development of more specialized products. Currently there is little

coordination among NOAA Line Offices in the development of climate-related products (e.g., sea level rise projections) for specific applications.

9. Establish and track environmental baselines to assess impacts of climate change.
There are legal and scientific reasons to establish environmental and other baselines with which to judge the implications of climate impacts on LMRs, coastal resources and coastal communities. Without adequate baselines, there are no standards for comparing current and future conditions and the effectiveness of management actions. This includes clear baselines for physical/chemical parameters such as coastal land elevation, ocean temperature and ocean acidification as well as other important variables such as productivity, phenology, distribution and abundance of species and habitats.

10. View climate in the context of other stressors.
The impacts of climate are overlaid on the impacts of other stressors (e.g., extreme events, pollution, land and resource use, and invasive species), and these multiple stressors sometimes have synergistic effects. For example, changing precipitation patterns will affect the delivery of land-based pollutants to coastal waters and changing water temperatures alter species distribution and ranges. NOAA research and management must adopt a system-level perspective that considers climate patterns, trends and episodes in the context of these other stressors.

11. Support a proactive approach for risk assessment and adaptation planning.
There is a need to address today's problems and high priority issues while planning for the future. Place-based information is essential to explore possible future scenarios, as well as options for adaptation. NOAA is in a position to take the leading role in a collaborative, participatory, and iterative planning and implementation process with our customers and partners. NOAA should strengthen capacity in communities and within government to take on this challenge in a proactive, not reactive manner.

12. Become an international leader in climate data, modeling, monitoring, research and service.
NOAA is uniquely positioned to help meet the urgent and growing demands from international partners for data, products and services to address climate impacts on ocean and coastal ecosystems and communities. NOAA should also seek out and learn from international efforts.

13. NOAA should expand development and delivery of state-of-the-art information and decision support tools on climate change and marine and coastal ecosystems.
As part of assessing NOAA capabilities, existing plans, and feedback from external and internal stakeholders, NOAA has developed proposals for expanding planned initiatives, building on current efforts, and filling important gaps to directly address many of the highest priority internal and external needs. Funding and implementation of these proposals would significantly increase the resilience of coastal and living marine resources, ecosystems, and communities to impacts of climate change.

14. There are key gaps in NOAA's ability to incorporate climate change in its ocean and coastal stewardship mandates, and additional investments are needed for NOAA to address the impacts of climate change on these resources.

The highest priorities for additional investments by NOAA identified at the workshops were 1) expanding integrated climate and ecosystem observations and studies, 2) downscaling climate predictions to the appropriate regional or local scale, and 3) expanding NOAA's products and services for assessing risks and implementing adaptation plans that increase community and ecosystem resilience to impacts of climate change. The following are some of the specific key needs identified at the workshops:

Observation Needs

- Observations and forecasts at relevant spatial and temporal scales
- Higher-resolution data
- Better information quality
- Integration of biological parameters into observing systems
- Baseline maps of ocean/coastal habitats and other environmental baseline data
- High Resolution Geospatial Framework (shoreline, bathymetry, etc.) and visualization tools
- Modernization/completion of monitoring networks, e.g., National Water Level Observation Network, National Spatial Reference System for accurate elevations, Global Ocean Observing Systems

Research and Modeling Needs

- Definition of critical thresholds and creation of early warning systems
- Improved ecological forecasts
- Research on ecological implications of climate change
- Research on feedbacks (e.g., biogenic feedbacks, ecosystem impacts on carbon fluxes)
- Research on adaptive capacity of species and ecosystems
- Measures and factors affecting resilience
- Models of economic and health impacts of projected changes
- Coupling of local monitoring and regional models
- Model evaluation and validation
- Research on chemical and physical changes to the oceans
- Infrastructure for community modeling
- Computing resources for downscaling models
- More robust models of the near-shore system
- Information about uncertainty/confidence, the probabilities of occurrence accompanying predictions, and the bounds within which the anticipated effects will fall

Integration and Capacity Needs

- Improved integration of climate, LMR, and coastal activities, planning and initiatives across and beyond NOAA
- Integrated Ocean and Coastal Mapping for shoreline and bathymetric data
- Training on how to interpret climate data and integrate them into products and services
- Improved access to and use of NOAA knowledge, information, and products and services through outreach and extension
- Improved awareness and utilization of existing data
- Enhanced data delivery and access

- Tools for risk assessment and scenario planning to evaluate management options
- Information and guidelines on adaptation options for decision makers
- Technical and financial assistance to implement adaptation plans
- Outreach materials and programs to build awareness in the community

Summary of Recommendations

The final breakout session at both workshops was devoted to identifying recommendations for priority short-term and long-term actions to improve NOAA's capacity to understand and address climate impacts on ecosystems and coastal communities. The following are major recommendations that call for improvements in: (a) observations and monitoring; (b) understanding, predictions and projections; and (c) risk assessment and adaptation (see Appendices for full set of recommendations from each workshop).

Major Recommendations (not prioritized)

1. Increase internal and external collaboration and communication.
The workshops brought together representatives of NOAA's climate, LMR, coastal and geospatial programs from around the country for the first time to discuss needs and intersections among these NOAA mission areas. There was significant benefit in raising awareness of others' expertise, activities, capabilities, products, and future goals. Enhancing the exchange of ideas between disciplines and regions will further the development of management tools and products. This dialog should be continued and coordinated with new and existing groups (including efforts to study establishment of a National Climate Service within NOAA, and to plan and implement the NOAA Coastal Enterprise) to increase integration, efficiency and effectiveness of efforts to incorporate climate change into fulfillment of NOAA's ocean and coastal stewardship mandates. The NOAA Climate and Ocean/Coastal Management seminar series should be continued and NOAA should organize regular workshops among scientists and managers from climate, ocean and coastal sectors to help identify key needs and enhance development and exchange of improved tools and information.

2. Establish regional approaches for working with our partners and addressing climate impacts.
Given the regional to local nature of climate impacts and issues, a regional approach should be used to work with our partners in addressing climate impacts. NOAA should establish and maintain nationally coordinated regional climate, coastal, and living marine resource research and management programs. Regional collaboration teams should include appropriate climate, coastal, ocean, living marine resource, social, and economic scientists, managers and regulators, and regional stakeholders. NOAA should support place-based projects at regional to local levels.

3. Improve Observations and Monitoring

- **Enhance delivery of and access to the best available climate data and information.** Coastal and living marine resource scientists and managers, the private sector and the public need easy access to credible, coordinated and high quality standardized data and information on climate variability and change (i.e., where appropriate climate information is located, how to access it, or which source to utilize). These constituencies are priority customers of NOAA's climate program. NOAA should work with these internal and external customers and partners to define and address their needs with the best available information through easily accessible vehicles such as a climate change web portal (clearinghouse for information).

- **Improve and integrate observations.** Improving the quality and comprehensiveness of the environmental, social and economic datasets that underpin NOAA decision support tools for climate risk assessment and mitigation is a top priority, given that the tools (and the decisions they generate) are only as good as the data they reference. In coastal areas, one of the most critical needs is a consistent high resolution geospatial framework as the foundation for measuring and predicting changes in sea level and other climate impacts. Collection of climate observations should be better integrated with collection of coastal and ecosystem observations to document responses to climate changes. Support of existing *in situ* and remotely sensed observations must continue with geographic, temporal, and technical expansion of simultaneous measurements. Supporting long-term monitoring at sentinel sites and habitats will facilitate the characterization of climate change impacts, the development of predictive models and their application to management scenarios, and risk/vulnerability assessments.

4. Enhance Understanding and Predictions

- **Increase understanding, predictions and assessments of climate change impacts on living marine resources and coastal ecosystems and communities.**
  NOAA and partners need information on how climate changes impact ocean and coastal ecosystems and the communities that depend on them. Additional research, observations and modeling are critical to predict possible future conditions and provide baselines for tracking changes. These studies are needed to better understand and plan for impacts of climate change on living marine resources and their habitats to fulfill NOAA's oceans and marine life management responsibilities.

- **Enhance environmental forecasts at regional and subregional levels.** Regional and subregional information is critical for successful management of coastal regions and living marine resources. Evaluation, expansion, enhanced resolution and downscaling of models are needed for long term projections and short term predictions of how climate change will impact specific places and resources. Key needs include decision support tools that can provide potential climate impact and management scenarios at appropriate scales (with probabilities and uncertainties) that help managers assess and determine the best course of action.

5. Facilitate Risk Assessments and Adaptation

- **Improve delivery and utilization of new and existing decision-support tools to reduce climate impacts.** Coastal and living marine resource managers need decision support tools and training to help them apply climate information in assessing risks and developing/implementing mitigation and/or adaptation strategies that address impacts of climate change. NOAA is uniquely positioned to develop and provide the necessary tools and training, including the development of guidelines to assist managers with incorporating climate impacts into NOAA's management plans for fisheries, protected species and the habitats they depend on. NOAA should also develop guidelines to assist partners at regional,

state and local levels in climate-related risk assessment and adaptation planning for coastal management.

- **Develop consistent procedures for evaluating climate impacts for inclusion in protected species and fisheries management.** The GAO report emphasizes the lack of standardized approaches for the inclusion of climate impacts assessment in NOAA's statutory mandates to protect living resources and habitats. Given the legal frameworks that apply to these stewardship requirements, it is imperative to develop and use standardized procedures and guidelines for evaluating the impacts of climate change and their implications for protected species, fisheries and habitat management. Developing these guidelines and procedures is a high priority for NOAA.

- **Improve indicators of climate risk and resilience for communities and ecosystems.** NOAA is uniquely positioned to help develop key indicators of climate vulnerability and resilience for coastal communities and ocean/coastal ecosystems. This effort, which could be conducted on a regional level, should build upon existing resilience work to develop indicators for quantitatively measuring risk and enabling communities and managers to work towards becoming climate-ready.

Next Steps

The following are some specific near term actions to continue to move this effort forward:

1. Improve access to and use of existing data and information through development of a web portal to provide a central place for climate data, models, information and inventories of relevant climate products for LMR and coastal management.

2. Establish NOAA working group(s) to oversee further development and implementation of these recommendations. Create cross-disciplinary working groups to foster dialogue across NOAA about climate impacts on coastal communities and on coastal and marine ecosystems, as well as to develop strategies to fill gaps identified at the workshops.

3. Develop guidance to help NOAA and partners use consistent, best practices in assessing risks and developing adaptation plans for climate impacts on protected species, fisheries, and coastal areas.

4. Continue a NOAA Climate and Ocean/Coastal Management seminar series and develop other mechanisms for training, education, capacity building, information exchange and dialog among NOAA and non-NOAA entities on these important issues.

5. Organize annual NOAA climate science and services summits to continue to identify key needs, gaps, and opportunities for better integration and effectiveness of NOAA climate, ocean and coastal efforts.

6. Identify process and venues (possible regional, sectoral and/or national workshops) for engaging NOAA stakeholders in discussions of key needs, gaps and NOAA products and services related to climate, oceans and coasts.

7. Engage other key federal agencies in discussion of NOAA climate services related to oceans and coasts to identify needs, gaps, roles and opportunities for integration and increased effectiveness.

8. Incorporate the findings and recommendations from this report into NOAA's planning and implementation of a National Climate Service within NOAA, an interagency national climate service partnership, NOAA's Coastal Enterprise and other efforts to deliver an "end-to-end" suite of climate-related products and services supporting NOAA's LMR and coastal mission requirements.

Summary

Workshop participants expressed strong interest in continuing the cross NOAA networking and strategic planning that was conducted at the two workshops. Implementing the recommendations from these workshops is critical to fulfilling NOAA's living marine resource and coastal mandates in a changing climate. These recommendations provide a solid framework for joint planning and action to address climate change impacts on NOAA's living marine resource and coastal stewardship missions.

Appendix A
Climate and LMR Workshop Report

NOAA Climate and Living Marine Resources Workshop

May 14-15, 2008
Pacific Marine Environmental Laboratory, Seattle, WA

Introduction, Context, and Background

NOAA conducted a Climate and Living Marine Resources workshop May 14-15, 2008, at the NOAA Pacific Marine Environmental Laboratory in Seattle, WA. The 54 participants included living marine resource biologists and ecologists, oceanographers, climate scientists, resource managers and regulators, and senior NOAA climate and ecosystem leadership.

The overall purpose of the workshop was to explore and enhance internal NOAA cooperation and integration in the development, communication, and application of information related to the impact of climate on NOAA's living marine resource (LMR) management responsibilities. Specifically, the intent was to advance the development of a strategy for addressing the impact of climate on NOAA-managed LMRs, through focused cooperation in research, assessments, and management applications within the agency and among our key partners.

This workshop was one of two related workshops conducted in 2008, with the second focused on climate and coastal impacts. The context for these workshops is laid out in the following sections.

I. The Challenge

NOAA currently faces two overarching challenges, the responses to which will shape the future of the agency for decades:

a) The design, development, delivery, and execution of effective climate services that provide applicable information relative to impacts and adaptation strategies; and

b) The effective management of natural resources in the marine and coastal environment, and the development of technical stewardship programs and decision support tools that foster hazard resilient coastal communities in the face of socio-economic, environmental, and climatic changes.

These efforts are not unrelated, and, in fact, could be enhanced through a purposeful strategy of integration and cooperation. The development of increased connectivity between the climate and coastal elements of NOAA offers significant benefits for multiple missions and programs within the agency, and, more importantly, for our external communities and constituents.

In addition, NOAA is increasingly called upon through existing and evolving legislation, interactions with stakeholders and government reports to integrate climate information in its natural resource management activities. Legislative drivers include the Magnuson Stevens Fishery Conservation and Management Reauthorization Act, the Endangered Species Act, the Marine Mammal Act, the Marine Sanctuaries Act, the Coastal Zone Management Act, and the Coral Reef Conservation Act. Stakeholders are organizing and articulating their desires to NOAA through means such as the Coastal States Organization's September 2007 Report on "The Role of Coastal Management Programs in Adaptation to Climate Change."

Finally, a 2007 Government Accountability Office (GAO) Report calls for Federal agencies to develop guidance for addressing the effects of climate change on Federal land and water resources. In response to this report, NOAA will consult with coastal and marine resource managers, both internally and within other federal agencies, to identify their needs for climate information and highlight the regional texture of climate and its related effects. By the end of 2008, NOAA expects to generate written materials to help foster the consideration of climate change in natural resource management.

II. Developing a NOAA Response to the Challenge

NOAA's two internal workshops were intended to advance the development of a strategy for ensuring the provision and application of climate information in natural resource management and the enhancement of coastal community resilience. These workshops were intended to complement and provide a larger framework for ongoing and evolving efforts within NOAA's climate and natural resource programs to address climate impacts and adaptation.

These workshops are contributing to the development of an overall agency strategy for generating and applying climate information related to natural resource and risk management in marine and coastal regions. They provide input and recommendations related to the development of guidelines for incorporating climate information in natural resource management, and for meeting these needs through climate services. Specifically, they address the needs and potential strategy for meeting these needs over the short and long term.

Case Studies

Four case studies were presented during the workshop to highlight current activities where climate and ecosystem information is being used to address management needs. These presentations defined the management goals and mandates for the studies, what climate and ecosystem information is required and how it is utilized, how living marine resource management is or may be improved, and who the user community is and what information they need.

In addition to the specific climate impacts on the living marine resources and the scientific knowledge gained on each topic and how it is being used, the case studies highlighted how climate and ecosystem scientists work together to address management priorities. The north Pacific fisheries case studies demonstrated the advantages of having climate and ecosystem scientists located geographically close to one another within institutions that frequently collaborate on projects of regional interest. These advantages include the facilitation of long-term working relationships, close coordination between climate and ecosystem scientists, the design of fully integrated climate and ecosystem studies, and frequent dialogue with regional living marine resource managers. The coral reef case study demonstrated the broad spectrum of developers and users of products to aid coral reef management in the face of climate change and the value of having many entities involved. Ocean acidification is a more recently recognized threat to living marine resources so this case study primarily focused on potential threats and topics that require more investigation. Abstracts of the four case study presentations are provided below.

Climate Considerations in the Management of Anadromous Fishes in the Pacific Northwest
Nathan Mantua – University of Washington

Pacific salmon have a complex life cycle, with portions spent in freshwater and ocean environments. Until relatively recently, management focused on factors affecting survival in the freshwater, even though the ocean phase composes most of a salmon's life and accounts for half the mortality and nearly all the growth of salmon. Salmon fisheries are managed at the level of individual stocks, and salmon hatcheries have contributed to increases in the number of salmon in the ocean. However, abundances of wild salmon along the west coast of the U.S. are now just a few percent of historic levels. For 2008 the Pacific Fishery Management Council adopted the most restrictive salmon fisheries catch limits ever for the West Coast, in response to the unprecedented collapse of Sacramento River fall Chinook and the exceptionally poor status of coho salmon from Oregon and California.

Short-term (3-6 month) salmon return forecasts produced for each river are based on assumptions about productivity trends and information about the number of spawning adults, jack returns, and juveniles produced in hatcheries. However forecast errors are frequently 50-100%. No climate information has been formally used, but many studies have looked to climate indicators for help in reducing forecast errors, as climate variations within the California Current system appear to influence the entire food web and are reflected by salmon survival. With relatively cool, less stratified waters, there is typically high salmon survival. Conversely, during warm periods with more stratified waters, there is typically low salmon survival in the ocean. Lessons learned for short-term forecasts include that the time and space scale of climate information provided must match the scale of management decisions in order to be useful. Basin-

scale research results are inappropriate for local scale management decisions like annual harvest planning. In addition, key aspects of ocean conditions for coho salmon are not likely predictable at seasonal-to-interannual timescales, highlighting the importance of monitoring.

On multi-year and longer time scales it is known that climate matters for Pacific salmon, but the lack of skillful forecasts limits the utility of this information. Skillful forecasts for the Pacific Decadal Oscillation, or other modes of Pacific decadal variability, are of great interest to salmon fisheries. Long-term salmon recovery and restoration planning also need to account for climate in decisions concerning where and how to invest efforts and in guiding freshwater management decisions. Finally, hatchery operations could benefit from climate information informing decisions on smolt release number and timing and optimal facility siting.

Climate Considerations in North Pacific Fisheries Management

Mike Sigler – NOAA/NMFS/Alaska Fisheries Science Center
Phyllis Stabeno – NOAA/OAR/Pacific Marine Environmental Laboratory

Alaskan marine ecosystems account for approximately half of the nation's seafood catch by weight. These fisheries have a value of $1.7B after initial processing and are used in a multitude of seafood products. NOAA is also charged with the protection of marine mammals, of which there are many that spend all or a portion of their lives in Alaskan waters. Tourism, much of which is based upon the natural resources that NOAA is responsible for, is very important to the economy, and many Alaskans depend upon the ocean for subsistence harvests. These ecosystems are experiencing rapid climate change as evidenced by decreases in sea ice and increases in ocean temperatures. An ecosystem approach to management, which takes into account climate variability and change, is a primary means of addressing the management needs for Alaskan living marine resources.

A number of studies contribute to the understanding of Alaskan marine ecosystems. These studies include resource and oceanographic surveys that provide living marine resource abundance and biological and oceanographic condition information, biophysical moorings that elucidate conditions throughout the year, short-term projects focused on specific processes, and modeling studies that help tie together the various components and explain and predict ecosystem responses. All these components contribute to an understanding of how ecosystems function, enabling predictions of how some components will respond if there is, e.g., more or less sea ice, relatively warm or cold water, weak or strong winds. Examples include impact on winter-spawning flatfish recruitment through effects of advection in the eastern Bering Sea on transport to nursery areas and impact of ocean conditions on spatial distributions of living marine resources and niche partitioning between species. In 2008, the North Pacific Fishery Management Council reduced the Bering Sea pollock quota by about 30% from 2007 levels. Climate information supplied by NOAA indicating relatively warm ocean conditions contributed to this decision, in combination with recruitment and ecosystem data.

Coral Reef Management in an Era of Warming Oceans

David Kennedy – NOAA/NOS/Ocean and Coastal Resource Management

Coral reefs are among the most diverse ecosystems on the Earth and have a large impact on the world's economy through their contributions to seafood, tourism and coastal protection. However U.S. coral reefs are imperiled due to increasing thermal stress and changes in ocean chemistry. Increases in temperature are causing more frequent and widespread bleaching events in which corals release their symbiotic algae. While corals can recover from brief or mild stress,

events of longer duration cause starvation and death. Reefs are deteriorating worldwide, with 2/3 of reefs already severely degraded. Much of this is due to thermal stress, bleaching and increased susceptibility to disease.

NOAA has produced a number of products to assist in warning coral reef managers of potential bleaching events via automated email alerts. These products include sea surface temperature (SST) data, SST anomalies, hotspots where SST is above the bleaching threshold, and a "degree heating week" product that accounts for accumulated thermal stress. NOAA, in association with outside partners, has also produced a Reef Manager's Guide to Coral Bleaching which lists long term actions managers can take before bleaching occurs and short term actions to be taken during bleaching events. These products have helped pave the way for community-based early warning systems, which derive from partnerships between NOAA, local scientists and managers, and the public.

Coral reefs are also susceptible to the changes in ocean chemistry caused by ocean acidification. The oceans absorb large portions of the anthropogenically produced CO_2 from the atmosphere. This is causing a decline in the pH of the ocean waters and a reduced availability of carbonate ions, which are needed by corals to build their skeletons. A number of experiments have shown a decline in the rate of coral calcification with increasing levels of ocean acidity. Other activities supported by NOAA that could improve our understanding of how a changing climate affects reefs include carbonate chemistry monitoring and surveys, as well as preliminary satellite based models designed to track changes in surface ocean chemistry.

Ocean Acidification and its Potential Impacts on NOAA-Managed Living Marine Resources

Richard Feely – NOAA/OAR/Pacific Marine Environmental Laboratory

Over the past 200 years, the pH and CO_2 chemistry of the oceans have been changing because of the uptake of anthropogenic CO_2 by the oceans. When CO_2 reacts with seawater, the pH of the water decreases (hence the term ocean acidification) and the availability of carbonate ions is depleted. The pH of ocean surface waters has already fallen by about 0.11 units, from an average of about 8.21 to 8.10, since the beginning of the industrial revolution. Estimates of future atmospheric and oceanic CO_2 concentrations indicate that by the end of this century the surface ocean pH will likely decrease another 0.4 units, making it lower than it has been for more than 20 million years. The carbonate saturation depths have also shoaled towards the surface of the oceans due to the penetration of anthropogenic CO_2 into the oceans. High latitude regions may be some of the first to become undersaturated with respect to carbonate, while calcification rates in the tropics may decrease by 30% over the next century. A 2007 survey cruise found water undersaturated with respect to aragonite (a form of carbonate) in upwelled water along the continental shelf of western North America.

Changes in pH and carbonate chemistry may have serious impacts on marine ecosystems. Carbonate is critical to shell formation for marine organisms such as corals, shellfish, zooplankton, and some phytoplankton. Exposure to lower pH levels can cause decreased respiration rates, changes in blood chemistry, and changes in enzymatic activity. Results from laboratory, field, and modeling studies, as well as evidence from the geological record, indicate that marine ecosystems are susceptible to the increase in oceanic CO_2 and the corresponding decreases in pH. Studies examining the impacts of ocean acidification on marine organisms have been conducted on many scales, from aquaria to large scale mesocosm experiments. However, much of our present knowledge comes from abrupt CO_2/pH perturbation experiments with single

species/strains, under short-term incubations, often with extreme pH changes. Therefore we know little about responses of genetically diverse populations, synergistic effects with other stress factors, physiological and micro-evolutionary adaptations, species replacements, and community to ecosystem responses. More research is needed to determine the temporal and spatial changes of the carbon system in the global oceans and their impacts on species and biological communities. This will enable a comprehensive characterization of the threat ocean acidification poses to marine ecosystems.

Breakout Sessions

Three breakout sessions, focused on topics and questions chosen to stimulate discussion around the important drivers for the workshop, generated much of the participant input during the workshop. For each breakout session, there were three breakout groups, all addressing the same topics and questions. Below are combined and condensed responses from the concurrent breakout groups for each of the breakout sessions and their respective questions. The responses in this section are relatively raw lists with specific answers to the questions. This information is provided here as it will be useful to those interested in specific issues. The overarching conclusions and recommendations resulting from the workshop, which were gleaned in large part from the breakout session discussions, are provided in the Summary section.

Breakout Session 1: The Implications of Climate Change for NOAA's LMR Portfolio

Question 1: What are the major climate change issues about which NOAA and its LMR management partners should be concerned?

Issues

- Physical/Chemical changes:
  - ocean properties (temperature, salinity, turbidity, nutrients, oxygen)
  - circulation, stratification, upwelling (changes to intensity and seasonal variability)
  - major climate cycles (e.g., ENSO, PDO, NAO, etc.)
  - storm tracks and intensity
  - frequency and magnitude of extreme events
  - wind patterns
  - cloudiness
- Loss of sea ice
  - loss of habitat
  - changes to stratification
  - changes in albedo
  - Arctic marine transportation, oil and gas development, fisheries development
- Sea level rise
  - changes in coastal habitat
  - saltwater intrusion
- Ocean acidification
- Altered freshwater systems (freshwater supply and quality)
  - precipitation timing, amount, and type (rain vs. snow)
  - freshwater temperatures
  - timing of freshwater delivery
  - allocation of freshwater
  - water quality (dissolved materials, sediment load)
- Other
  - climate change versus climate variability
  - unforeseen impacts

Responses

ocean productivity, distribution of organisms, migrations, transport, phenology, changes in community structure, species interactions and replacement, growth, reproduction, fitness, mortality, habitat impacts, unusual events

socioeconomic effects (fisheries, land use, water table, coastal erosion, tourism)

Question 2: Which LMR management processes need to be informed with climate change information? What are the temporal and spatial scales for these processes?

Processes:

Stock assessments for managed fish and protected species

Recovery plans for threatened and endangered species

Rebuilding plans for overexploited species

Regional Fishery Management Councils

Fishery Management Plans

Incidental Take authorizations for non-targeted species

Impacts on seafood safety and security

Ecosystem based management plans

Scales:

Information is routinely needed at annual or shorter time scales for management decisions (e.g., for total allowable catch decisions), whereas attribution between climate variability and climate change requires much longer time series.

Information is required for annual management decisions and long-term (10+ years) planning.

Different spatial and temporal scales are relevant depending upon the living marine resource being addressed.

Question 3: To what extent is climate information currently used in NOAA's LMR portfolio? What are the barriers (e.g., institutional, scientific, resource) to incorporating climate more fully in NOAA's LMR portfolio?

Use: Climate information is rarely applied in LMR management today. A few exceptions occur. These include:

Recovery planning for Pacific salmon

Total allowable catch for pollock

Ice seal listing determination

Coral management plans

Barriers:

Limited communication between climate and ecosystem communities

Disconnect between climate and living marine resource management communities - lack of understanding of the climate products needed or available

Inadequate incentives to facilitate collaboration between climate and ecosystem scientists

Insufficient understanding of how climate changes impact LMRs

Limited opportunities to support multidisciplinary activities as a single project between Line Offices

Lack of committed funding for long-term joint projects

Observing infrastructure – lack of synchronicity between physical, chemical, and biological observations

Gaps in environmental baselines

Time- and space-scale differences between management needs and climate predictions
Lack of an effective ecosystem framework within which to include climate information for LMR management
Some LMR managers see insufficient benefit in incorporating climate – the uncertainties are deemed too large such that there is not appreciable value added to LMR forecasts
Deficient data management and integration procedures and resources to effectively incorporate climate information

Question 4: Can priority be assigned to any of these issues and/or processes in the specific context of NOAA's LMR portfolio? If so, which are of greatest importance in terms of timeliness and impact?

Expand integrated climate and ecosystem observations
Develop regional and local scale climate predictions and validate with observations
Prioritize information needs based on impacts (i.e., based on immediacy of impact, degree of impact, and value of impacted resource)

Breakout Session 2: Key Decision Support Tool and Science Needs for Integrating Climate in LMR Management

Question 1: What are the key decision support resources, products, tools and capabilities needed to address climate and LMR management?

Observations (physical, chemical, biological data) are needed at the time and space scales pertinent to the ecosystem.
Ocean condition forecasts are required. For these forecasts to be used, NOAA needs to develop and demonstrate their benefit to LMR stock assessments.
Longer term (10-30 yrs) ocean condition projections with probabilities need to be developed.
Uncertainty, confidence, or probability of occurrence should be provided with any predictions.
Climate and ecosystem response scenarios based upon hypotheses that can be tested (conceptual models to "what if" scenarios) must be developed.
Coupled climate-ecosystem models are necessary.
Regional environmental forecasts and reanalysis, downscaled from global climate models, are required to support long term projections and short term predictions.
3-10 yr projections are needed to be useful for fishermen's business perspective, i.e., the timescale for which the fishing industry makes major industry investment decisions.
Critical environmental thresholds have to be defined.
An environmental early warning system across relevant time scales is requisite.
Ecological indicators should be developed in concert with modelers and managers. Include these and other required data in an integrated system of observations.
Probabilistic predictions of sea ice extent and remote sensing products are needed.
Predictive models of economic and health impacts need to be developed.
Models are required that integrate regional observations to better understand climate ecosystem impacts at management levels.
Information ought to be presented in formats (e.g., risk maps, red light/green light, numbers, probabilities) tailored to the users.

Question 2: What are the associated climate and living marine resource science issues that NOAA should address, and the current status of associated observations, modeling, process studies, impacts and adaptation research and assessment (e.g., well covered, in development, non-existent)?

- Forecasting physical/chemical changes – The general trend is predictable (useful in the long-term), but interannual and decadal variability is difficult to predict.
- Data needs and availability issues include:
  - Quality of baseline information is species and area dependent – information quality ranges from very good to very poor.
  - Paleo data is very non-uniform in its spatial coverage. There are some high quality datasets, including down to decadal timescales.
  - Biological parameters are underrepresented in large scale observing systems.
  - Satellite data – ocean sensors need to be maintained. Due to an aging infrastructure there is a high risk of data gaps.
- Little is known about abrupt climate change and its impacts. This needs development.
- Key issues to be resolved with respect to ecosystem responses to climate drivers include:
  - Food web alterations
  - Thresholds
  - Resiliency of different ecosystems (e.g., influences of diversity, anthropogenic footprint, fishing)
  - Definition of healthy populations - how to define when a population is impacted by climate, attribution of ecosystem changes to specific climate drivers
  - Species specific adaptability
- Socioeconomic impacts must be addressed and require substantial development.

Question 3: What ecosystem information is needed by the climate science community to assess and predict climate feedbacks from human-induced alterations (e.g., ocean acidification, iron fertilization)?

- Large anomalies (shifts) in long term ecosystem time series may provide guidance to climate scientists to identify key events.
- Determination of biogenic feedbacks (e.g., organic carbon ballasting, increased dimethylsulfide (DMS) production from coccolithophores).
- How are biofeedbacks affected by rapid vs. gradual climate change?
- How will carbon fluxes be impacted by changes in ecosystems, primary productivity, reef building, albedo, and coastal inundation?
- Determination of what fraction of primary production is deposited in the sediments.

Breakout Session 3: Future Directions and Next Steps

Question 1: How should NOAA's climate and LMR communities work together to address major needs and priorities identified on the first day?

- Have a framework of the major management questions to be addressed – prioritization of focused problems.

Create a forum to facilitate exchange between LMR managers and scientists, and climate scientists to better define their needs and capabilities.

Consider alternative approaches to funding collaborative research including: establishing and sustaining regional climate and LMR programs (explore cross-region synergy); and supporting proposal driven collaborations (broadly announce opportunities so bring in all interested parties and ideas).

Conduct integrated activities where appropriate (e.g., enhance physical studies with more ecosystem variables and vice versa).

Leverage existing capabilities of programs and expertise of people so efficiency is maximized.

Question 2: Which institutions/programs need to be involved to implement these actions?

Regionally focused and steered programs should be linked through a national ecosystem and climate program which has long-term, dedicated support.

Social and economic science sectors must be included.

Regional stakeholders must be involved from the beginning through regional teams.

Offices and programs whose mission is to observe, monitor, or model climate should be consulted with and informed of regional LMR priorities.

Take advantage of existing capabilities – NOAA laboratories, Cooperative institutes, the NOAA Regional Integrated Sciences and Assessments (RISA) program, academia, Sea Grant, and other federal agencies

Question 3: What are some short- and long-term steps that can be taken?

Develop regionally specific lists from LMR managers of what they need.

Develop lists of climate and ecosystem capabilities.

Evaluate adequacy of current observational systems.

Submit regular reports to regional Fishery Management Councils (FMCs) and get feedback.

Establish rotational assignments between climate and LMR programs. Have shared post docs.

Support regular, regional workshops.

Encourage cooperation with other national and international programs (within and outside of NOAA).

Develop a long term strategic plan and funding requirements.

Support an emphasis on climate applications (e.g., observations, monitoring, projections, predictions) in support of ecosystem approaches to management.

Standardize assessment and monitoring methodologies to permit intercomparisons.

Develop guidelines on how to incorporate climate into LMR management.

Consolidate and reconcile climate information from various sources into a central source.

Develop cross-training for climate and LMR personnel so they are aware of each others capabilities, needs, and limitations.

Develop climate scenarios for regional LMR issues.

Develop targeted LMR climate information products (including probabilities of predictions).

Release products early so they can be evaluated.

Develop approaches for climate predictions and projections relevant to regional and local scales.

Develop a NOAA climate/LMR website with names, pictures, presentations, etc. to help make connections.

Provide seed money, from existing funds, to begin to answer some of the questions identified.

Identify a few regions that would serve as mini-laboratories that provide a method to assess the reliability of ecosystem indicators as proxies for complex mechanisms.

Summary

Conclusions

- **NOAA has unique capabilities and responsibilities with regard to climate and living marine resources.** NOAA is unique in its mandates and abilities to provide observations and predictions of climate and to manage LMRs. The case studies presented demonstrated capabilities focused on climate prediction and ecosystem impacts, with some work on socioeconomic adaptation.

- **It is essential for NOAA's climate projections and scenarios to span the full range of possibilities and associated impacts and provide measures of probability.** There is a large range of uncertainty in the physical climate drivers. Ecological responses further magnify the uncertainty. For LMR managers to make decisions on the best course of action for the resources they manage, they need to know the timescales, probabilities and bounds within which their decisions are being made.

- **A mix of standard and custom products will be required.** There are a wide variety of climate-LMR problems and issues. Some can be addressed with standardized products while others will require customized research and development of products.

- **Climate quality environmental baselines are needed.** There are legal and scientific reasons to establish environmental baselines with which to judge the implications of climate impacts on LMRs. Without adequate baselines, there are no standards for comparing current and future conditions.

- **The workshop initiated an important dialog.** NOAA's climate and LMR scientists and managers from around the country were brought together for the workshop. Many of the people had never met. There is significant benefit in raising awareness of others' expertise, activities, capabilities, products, and future goals. A basic, yet valuable, result of the workshop was the initiation of a dialog between climate and LMR scientists and managers to inform one another of their capabilities and needs.

Recommendations

- **NOAA must develop predictions and adaptation plans for climate impacts on LMRs.** The legal and public policy implications for climate impacts on LMRs regulated by NOAA place the agency at the forefront of impacts and adaptation. Due to its unique mandates for management of living marine resources, NOAA is responsible for the development of predictions and adaptation plans for climate impacts on LMRs.

- **Make "best available climate information" available through a National Climate Service.** Most NOAA regional climate impact studies to date are the products of individuals or groups and do not necessarily use consistently obtained climate information. This approach takes advantage of the innovation at the regional level, but increases the risk that NOAA does not have a clear, coordinated definition of "best available science". A National Climate Service should provide standardized observations and predictions of coastal and marine physical and chemical conditions to support LMR management.

- **Improve utilization of what is known and available.** There are tremendous capabilities distributed across NOAA, its partners, and other collaborators to provide meaningful climate services relevant to management requirements for LMRs. An inventory of relevant NOAA climate data, products and services useful to LMR scientists and managers should be conducted. NOAA must ensure that available data and information are identified and made easily available. While NOAA capabilities regarding climate impacts on LMRs are underfunded, much can be done with current resources, including targeted increases in the understanding of climate impacts on LMRs.

- **Establish regional climate and LMR programs.** NOAA should establish and maintain regional climate and LMR research and management programs guided by regional collaboration teams that include climate, ocean, LMR, social, and economic scientists, LMR managers and regulators, and regional stakeholders. Regional efforts must be coordinated at a national scale to ensure that approaches between regions are consistent to the extent possible and priorities are addressed with minimal redundancy.

- **Establish a program for short-term (up to 5 year) integrated climate and LMR projects.** Sustained funding for regional efforts should be balanced by proposal based funding to enable collaborations, enhance regional efforts, target broader scale questions, and maintain flexibility to address emerging issues.

- **Integrate climate and ecosystem observations.** Integrated climate and ecosystem observations are necessary to document ecosystem responses to climate changes. Presently many ecosystem observations are made without adequate climate observations, and many climate observations are made without concurrent ecosystem observations. NOAA should ensure that climate and LMR measurements are coordinated when possible.

- **Develop and refine regional forecasts.** Regional environmental forecasts, downscaled from global climate models, should be developed in support of long term projections and short term predictions. Appropriate time horizons and spatial scales need to be defined depending upon the LMR and the question being addressed.

- **Establish an Endangered Species Act climate working group.** NOAA should establish guidelines for the incorporation of climate impacts into NOAA's mandated LMR management processes. As a first step, NOAA should convene a working group to develop standard operating procedures for incorporating climate information into Endangered Species Act actions.

- **Conduct regular climate – LMR workshops.** To facilitate communication between climate and LMR scientists and managers it would be beneficial to establish annual or alternate year climate – LMR workshops. These workshops would serve as a forum for the presentation of recent advances within the field of climate impacts on LMRs. They would also enhance the exchange of ideas between disciplines and regions, thereby furthering the development of management tools and products.

Appendix 1 – Workshop Agenda

NOAA Climate and Living Marine Resources Workshop
May 14-15, 2008
Pacific Marine Environmental Laboratory, Seattle, Washington

May 14, 2008

Plenary Session: Climate and Living Marine Resource Management (LMR) in NOAA

8:30 am	Welcome, Introductions, Context and Workshop Overview Moderator: Ned Cyr (Eddie Bernard, Steve Murawski, Chet Koblinsky)
9:10 am	An Overview of NOAA's Living Marine Resource Management Responsibilities (Steve Murawski)
9:30 am	Climate Change and Resource Management: The Legal Perspective (Ruth Ann Lowery)
9:50 am	NOAA's Climate Program and Service Directions (Chet Koblinsky)
10:20 am	Charge to Working Groups (Ned Cyr)
10:30 am	Break

Breakout Session 1: The Implications of Climate Change for NOAA's LMR Portfolio

10:40 am Working Group Discussions

Discussion Questions:

1) What are the major climate change issues about which NOAA and its LMR management partners should be concerned?

2) Which LMR management processes need to be informed with climate change information? What are the temporal and spatial scales for these processes?

3) To what extent is climate information currently used in NOAA's LMR portfolio? What are the barriers (e.g., institutional, scientific, resource) to incorporating climate more fully in NOAA's LMR portfolio?

4) Can priority be assigned to any of these issues and/or processes in the specific context of NOAA's LMR portfolio? If so, which are of greatest importance in terms of timeliness and impact?

12:00 noon Lunch and Guest Presentation: Climate considerations in the management of anadromous fishes in the Pacific Northwest (Nathan Mantua, University of Washington)

Plenary Session: The Implications of Climate Change for NOAA's LMR Portfolio

1:15 pm Breakout Groups Report Out, Followed by Plenary Discussion

2:15 pm Bringing climate and ecosystem science together to address management needs (Steve Murawski)

2:45 pm Break

Breakout Session 2: Key Decision Support Tool and Science Needs for Integrating Climate in LMR Management

3:00 pm Working Group Discussions

Discussion Questions:

1) What are the key decision support resources, products, tools and capabilities needed to address climate and LMR management?

2) What are the associated climate and living marine resource science issues that NOAA should address, and the current status of associated observations, modeling, process studies, impacts and adaptation research and assessment (well covered, in development, non-existent)?

3) What ecosystem information is needed by the climate science community to assess and predict climate feedbacks from human-induced alterations (e.g., ocean acidification, iron fertilization)?

Plenary Session: Key Decision Support Tool and Science Needs for Integrating Climate in LMR Management

4:40 pm Breakout Groups Report Out, Followed by Plenary Discussion

6:00 pm Adjourn

May 15, 2008

Plenary Session: Presentation and discussion of case studies for the successful integration of climate and ecosystem science for LMR management

8:30 am Introduction to Day Two of the Workshop (Moderator: Mete Uz)

8:40 am Remarks from the NMFS Perspective (Jim Balsiger)

8:50 am Climate considerations in North Pacific Fisheries Management (Mike Sigler/Phyllis Stabeno)

9:20 am Coral reef management in an era of warming oceans (David Kennedy)

9:50 am Discussion

10:00 am Break

Breakout Session 3: Future Directions and Next Steps

10:10 am Working Group Discussions

Discussion Questions:

1) How should NOAA's climate and LMR communities work together to address major needs and priorities identified on the first day?

2) Which institutions/programs need to be involved to implement these actions?

3) What are some short- and long-term steps that can be taken?

Plenary Session: Future Directions and Next Steps

12:00 noon Breakout groups report out, followed by discussion

1:00 pm Lunch and Presentation: Ocean acidification and its potential impacts on NOAA-managed LMRs (Richard Feely)

2:15 pm Discussion: Where do we go from here? Linking climate and LMR management in NOAA (Moderator: Steve Murawski)

4:00 pm Adjourn

Appendix 2 – List of Participants

(* denotes Organizing Committee member)
(NESDIS = National Environmental Satellite, Data, and Information Service;
NOS = National Ocean Service; NMFS = National Marine Fisheries Service;
NWS = National Weather Service; OAR = Office of Oceanic and Atmospheric Research)

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Appendix B
Climate and Coastal Management Workshop Report

Final Report

NOAA Workshop on Strengthening Capacity to Address the Impacts of Climate Change on Coastal Communities and Ecosystems

June 19-20, 2008
American Geophysical Union, Washington, DC

This internal NOAA workshop was initiated by the NOAA Climate Program Office (CPO), organized by a cross-NOAA committee,[2] and endorsed by the leads for NOAA's Climate, Ecosystem, Commerce and Transportation, and Weather and Water Goal Teams. Attendees included a mix of office level leaders and project staff working on climate and/or coastal management and planning activities, from both headquarters and field offices. For the full workshop agenda and a list of participants, see Appendices 1 and 2 respectively. The East-West Center in Honolulu, Hawaii, and the National Estuarine Research Reserve Association also provided financial support.

Background

The purpose of the workshop was to advance the creation of a NOAA-wide framework to address the impacts of climate change through: the application of science-based information; the development of decision support resources and tools; and the building of capacity to address climate impacts on coastal communities and the ecosystems they depend upon. The workshop was structured to address the following:

[2] Committee members include: Nancy Beller-Simms (OAR Climate Program Office (CPO)), Hannah Campbell (CPO), Ashley Chappell (NOS Office of Coast Survey (OCS)), Nell Codner (Coastal Services Center (CSC)), Mary Culver (CSC), Stephanie Fauver (CSC), Rebecca Feldman (CPO), Darlene Finch (CSC), Bess Gillelan (NMFS Office of Habitat Conservation (OHC)), Roger Griffis (OHC), Carrie Hall (NOS Ocean and Coastal Resource Management (OCRM)), Jim Hurley (OAR Sea Grant), Ruth Kelty (NOS National Centers for Coastal Ocean Science), Keelin Kuipers (CSC), Terence Lynch (OCS), Liz Moore (NOS Office of National Marine Sanctuaries (NMS)), Frank Niepold (CPO), Ken Pavelle (NWS Office of Hydrologic Development), Erica Seiden (OCRM), Eileen Shea (NESDIS National Climatic Data Center), Lisa Vaughan (CPO), and Vicki Wedell (NMS).

- *Key Challenges:* In the context of NOAA's mission, what are key coastal management challenges, drivers and customers for which climate information is relevant? Types of information that would be most useful for addressing these challenges were identified.

- *Current Resources:* What types of expertise, experience, knowledge, materials, technology, and information systems within and supported by NOAA can be used to generate and apply information relevant to addressing climate impacts in coastal regions? Key gaps in information, delivery methods, and tools needed by NOAA and our partners were highlighted.

- *Development of a NOAA Strategy for Addressing Climate Impacts in Coastal Regions:* This workshop will help inform development of a strategy to better integrate climate research, awareness and information into NOAA's stewardship activities for coastal communities and ecosystems. This will inform a variety of internal NOAA efforts, including planning for a National Climate Service, NOAA's Coastal Enterprise and NOAA's core programs.

Workshop Outcomes: The information from this workshop will be used to shape a strategy for using NOAA's authorities and expertise to address the impacts of climate change on coastal communities and the ecosystems they depend upon. The workshop fostered increased connectivity among NOAA offices with a role in producing and applying climate information in coastal regions.

Context: This workshop is the second of two workshops designed to shape NOAA's approach to providing climate information that supports the agency's management responsibilities for coastal communities, coastal ecosystems and living marine resources. The first occurred on May 14-15 and focused on climate and NOAA's living marine resource responsibilities. These two workshops complement each other and provide the foundation for a larger framework for ongoing and evolving efforts within NOAA's research and management programs to address climate impacts and adaptation. They were designed to increase the communication between climate researchers, information providers, and coastal, ocean and marine life resource managers that need climate information to fulfill their mandates. The information from both workshops will support NOAA's response to an August 2007 Government Accountability Office Report, which called on Federal agencies to develop guidance for addressing the effects of climate change on Federal land and water resources. The outcomes of this workshop will also be used respond to questions posed by Vice Admiral Lautenbacher and the NOAA Ocean Council. Finally, the workshop will be used to inform various NOAA-wide and external activities, including development of a National Climate Service and the Coastal Enterprise effort (a strategic framework which identifies three major coastal pressures as priorities: coastal hazards, particularly in the face of climate change; competing coastal uses, including both land and water uses; and coastal pollution, especially effects on human health and habitats).

Keynote Speaker: Dr. Denise Reed, professor in the Department of Geology and Geophysics at the University of New Orleans, gave the keynote address titled "Climate, Coast and Community in the 21st Century." Her remarks highlighted the interaction of humans and the environment in

the coastal zone and the complications to these interactions from the current and anticipated impacts of climate change. Among her main messages were:

- We should not wait for more detailed climate forecasts or more mature science; decision makers are already planning for the future and need the latest science.
- The science is too poorly linked to societal issues. We should focus on solving the problems that are defined by the people that live and work in the coastal zone. What people do is as important as what the natural system does.
- NOAA should develop an integrated approach to climate impacts that combines engineering and the natural, social and economic science components.
- Climate change impacts (e.g., to sea level, pH, and temperature) do not operate independently, and ecosystems respond collectively to these changes.
- NOAA personnel should collaborate across the agency and with other federal and non-governmental agencies, non-profits, academia, international organizations, and with local, state and regional governments.
- A NOAA framework could help others see how they could contribute. For example, in order for coastal managers to adequately plan for climate change, not only do they need to know what to do, they need to know what not to do.
- We should be proactive in our approach to climate change. (Planning is superior to reacting.)

Panel of Practitioners: A panel of practitioners provided context to workshop participants on the climate-related needs and practices of decision makers working on coastal management challenges. Each panelist was given time to address the following questions:

1. What is the focus of your current work related to climate change and coasts?
2. What tools and approaches are you using?
3. What are the gaps/needs/challenges that you face that NOAA can assist with?

A summary of their responses follows:

Robert Kafalenos (U.S. Department of Transportation) indicated a need for higher resolution near-shore models to provide better information on the synergies of storm surge, tides and other coastal processes and the anticipated impacts on the coastal zone. He suggested a probabilistic approach to forecasting climate impacts is needed, as well as a Saffir-Simpson-like scale for categorizing these impacts. His group is working on development of GIS-based sea level rise scenarios for the East Coast transportation infrastructure to assess impacts.

Jesse Schomberg (Minnesota Sea Grant) discussed the additional stress that human activities will place on coastal areas as a result of loss of streamside vegetation, paving of nearshore areas, sedimentation, water quality, and other impacts that result from development. Climate change will compound these challenges. He said that we are already seeing climate impacts, such as an increase in Great Lake water temperatures and '100-year' flood events becoming more frequent. As a result, there is a need to focus on implementing Smart Growth principles, such as developing in ways that preserve green spaces and reducing vehicle miles traveled. The Great Lakes Sea Grant and Great Lakes Environmental Research Laboratory (GLERL) are working on a project to help community planners, port managers, and other decision makers realize the importance of sustainable communities and the impact of long-term planning ordinances through

developing scenarios, tools and case studies. According to Mr. Schomberg, NOAA needs to address existing needs of decision makers instead of waiting for more data. He specifically mentioned the need for storm frequency forecasting tools, improved information on the effects of climate on whole ecosystems, and projections of water level changes in the Great Lakes.

David Carter (Delaware Coastal Program) reported that, for states to adequately address inundation, they need LIDAR elevation data, as well as state and federal coordination on standards for this data. He mentioned the importance of FEMA-approved storm surge model runs for early warning forecasting. Models need to be sufficiently robust to hold up if challenged in court. There is a substantial amount of data within NOAA; however, NOAA needs to put the data and tools together in ways that make them easy to use and accessible. He cited a recent Coastal States Organization survey to which most states responded that they are already working on or will begin intensively working on climate adaptation strategies, with plans expected within the next three years. They will be looking for guidance, including ways to streamline and share information between state programs and even internationally.

Skip Stiles (Wetlands Watch) spends much of his time speaking with local organizations to help them understand sea level rise impacts and discussing the importance of balancing the public good with the rights of property owners. He seeks data, good graphics and support to explain to local counties why they need to take climate change impacts into consideration, as the local level is where the land use decisions get made. Living shorelines may be a viable adaptation strategy, but a lack of local support and expertise makes them difficult to implement, in his experience.

Presentation by Chet Koblinsky: On the second day of the workshop, Chet Koblinksy, Director of the Climate Program Office and Climate Goal Lead, gave a presentation on the "Status of National Climate Service Development." Pending legislation in the Senate, S. 2307: Global Change Research Improvement Act of 2007, calls for the establishment a National Climate Service within NOAA. In September 2007, the NOAA Executive Council directed the agency "to take action to establish a National Climate Service." NOAA's proposed climate services strategy has two parts: to evaluate possible options for a National Climate Service within NOAA and to promote a national climate services partnership across external agencies, universities, non-governmental organizations and private-sector stakeholders. The partnership and the National Climate Service will work together to support a comprehensive system that monitors information on key climate indicators and develops credible, usable, accessible and timely assessments, projections, and predictions of climate and its impacts. These two entities would help user communities develop and transfer information for planning and decision-making, including decisions related to adaptation and mitigation. During the last week of June, the Climate Working Group, a standing committee of NOAA's Science Advisory Board (SAB), would be meeting, along with selected stakeholders, to discuss the draft strategic plan and to develop recommendations on the strategy. NOAA will take these recommendations under consideration and revisit its proposed strategy in light of them.

Workshop Process: Most of the rest of the workshop focused on breakout session discussions and report-outs. Participants were divided into groups by climate change stressor (i.e., sea level change, severe weather including hurricanes and non-tropical storms, freshwater quantity and quality, and ocean change including temperature and chemistry) and discussions were framed

around answering questions to address user needs, barriers, capabilities, and short-term (i.e., seasonal to five years) and long-term (i.e., over five years) opportunities. For a listing of breakout questions, see Appendix 3.

Workshop Outcomes: Eileen Shea of the National Climatic Data Center and the NOAA IDEA (Integrated Data and Environmental Applications) Center provided a summary of key points raised. She highlighted the significance of the challenges and the urgent need to assist coastal decision makers. Some overarching themes or principles that emerged throughout the workshop are identified below. For more detailed breakout group notes, see Appendix 4.

Overarching Workshop Themes:

- **Make better use of what we already know and have.** We need to make it easier for stakeholders to identify and access what NOAA has to offer, develop new ways of presenting this information and recognize the importance of integrating physical, natural and socioeconomic information. We should provide the data and information that we have now to those making decisions now.
- **Provide better 'service' focused on user needs.** Both climate and coasts are "integrators" across NOAA. We need people who can pull the natural and human components together, making the connections between the communities of scientific knowledge and the service providers, decision makers and society. NOAA needs to make investments by talking to customers to determine what they need, build their capacity, and help them use the tools and information that NOAA provides. Until NOAA makes these investments, we are not going to make the maximum use of the knowledge, information and expertise we have. Evaluation mechanisms should be used to ensure the effectiveness of climate services.
- **View climate in the context of other stressors**. We must recognize the interconnections across and among related issues. Climate variability and change information should be integrated into existing planning and decision-making frameworks. It is important to adopt a system-level perspective that considers climate patterns, trends and episodic events, as well as various consequences of multiple climate impacts on coastal communities and ecosystems.
- **Support a proactive approach.** We should address today's problems and high priority issues while planning for the future. Place-based information is essential to explore possible future scenarios, as well as options for adaptation. NOAA is in a position to take the leading role in a collaborative, participatory, and iterative planning and implementation process with our customers and partners. We must build capacity in communities and within NOAA to take on this challenge in a proactive, not reactive manner
- **Recognize that climate, ecosystems and human systems are dynamic.** Current and anticipated climate impacts bring both challenges and opportunities to natural and human systems. Changes on all timescales are relevant and must be addressed. Human and natural systems will adapt, but enhancing resilience is critical. Place, context, culture and history matter in determining how systems will respond.
- **Become an international leader in climate data, modeling, monitoring, research and service.**

Suggested Actions: Participants were asked to identify short term (1-2 years) and long term (3-5 years) steps for NOAA to undertake. The following list of proposed actions, spanning all discussion groups, for NOAA emerged:

- **Establish a NOAA-wide working group on climate and coastal communities.** This working group would continue to foster dialogue across NOAA and create implementation plans for the near term to address the gaps and recommendations highlighted in this workshop. This working group would facilitate accomplishing many of the actions listed below, including coordinating planning for products and services, as well as promoting cross-NOAA planning and execution to fill gaps in the coastal climate portfolio. Finally, this working group would enable continued internal communication on climate issues affecting coasts.
- **Inventory of NOAA Climate information related to coasts.** We need a NOAA-wide inventory of relevant climate data, products and services useful to coastal stakeholders to share within the NOAA community, with partners, and with users in the coastal community. This inventory should build on similar inventories initiated by the climate and living marine resources group and a 2007 Climate Services inventory.
- **Support development of a Climate Portal.** Customers need a portal for easy online access to new and existing resources (e.g., data, products, case studies, model outputs and projections) related to climate impacts with a user-friendly interface (including a call center).
- **Use existing mechanisms to integrate across NOAA.** NOAA should capitalize on existing mechanisms (e.g., goal teams, PATTs, regional teams and programs) and take advantage of these mechanisms in developing climate services.

Overarching Priority Needs for a National Climate Service (in no particular order):

- **Sustained and enhanced observations and time-series data.** Support of existing in situ and remotely sensed observations must continue with geographic, temporal, and technical expansion of simultaneous measurements and inclusion of new parameters (e.g., measurements of ecosystem and socioeconomic parameters) using consistent calibration, standards, datums and metadata. This should include a geospatial framework for access to the full suite of integrated observations. NOAA should use its network of sentinel sites and habitats to monitor and predict changes in coastal habitats along with the attendant impacts on adjacent communities. Stakeholders also need a continuous, iterative process of monitoring and assessing conditions to inform decisions.
- **Full coverage for bathymetry and LIDAR**. Improved collection frequency, resolution of and access to full coverage bathymetry and LIDAR, with a long term plan for standardization, in crucial for many applications.
- **Modeling and research enhancements.** Evaluation, expansion, enhanced resolution and downscaling of models are critical to the success of coastal climate efforts, as is the computer capacity to run these models. Models should be coupled with existing regional models. An expansion of the existing model suite (e.g., to include additional ecological modeling, ice-water-land-ecosystem interaction, and ocean acidification) is necessary. Models should address impacts on ecosystems and society, not just physical conditions. Improved expressions of uncertainty and frequency forecasts for severe weather are needed. An improved understanding of the large-scale climate regimes (e.g., El Niño Southern Oscillation (ENSO), the North Atlantic oscillation (NAO), and Pacific Decadal Oscillation (PDO)) is also critical to this process. Translation of forecasts, outlooks and projections is important for improved user understanding of the limitations and vulnerabilities associated

with these models. The predictive tools developed need to be synthesized, disseminated, and incorporated into threat assessment, management, and hazard resiliency planning.

- **Coastal management guidebook covering approaches to integrating climate change into state and federal planning.** States and federal resource management agencies have a critical need for guidance materials about how to reduce human influences contributing to climate change and how to incorporate climate change impacts into their long-term plans. A guidebook would set out national guidelines for how to conduct and what to include in an adaptation strategy to provide consistency, but allow for differences, across states. A guidebook would include a compilation of lessons learned and best practices. Examples of effective state and federal plans and pilot projects to demonstrate and test a variety of practices should be widely available. Place-based pilots at the watershed scale are also critical. This guidebook should include tools to assist with identification and assessment of societal climate vulnerabilities and resilience.
- **Consistent NOAA message and single voice.** It is critical for NOAA to have a clear and unified voice on climate issues. NOAA should be groomed to become the authoritative source, in collaboration with partners. Resources should be developed as cross-NOAA efforts to fully incorporate all NOAA resources that address a climate change problem and should feed the Climate Portal.
- **Cross-agency coastal climate team for education, outreach and training.** This team would build on existing capabilities, teams, and programs to lead, coordinate, and train NOAA's place-based extension and outreach providers and field-office personnel to identify and address priority climate issues. This team would contribute to the revamp of the new NOAA climate 'roadshow,' as well development of educational materials for a variety of media to improve internal and external knowledge. Climate change and general risk communication approaches to messaging should be established and should address uncertainty. Social science should be incorporated to help determine how messages could most effectively reach various audiences.
- **Interdisciplinary, integrated analytical tools and resources.** NOAA should support a systems approach to assessing climate science impacts and adaptation. Pilot projects to demonstrate the integration of data and predictive models into tools for decision-making should be implemented. Socioeconomic, physical and biological systems are related and need to be integrated for a more complete picture of community and ecosystem mitigation of and adaptation to climate change. Evaluation of management scenarios and options should be a component of these tools, to fulfill NOAA's responsibility to provide support to coastal managers and its own stewardship responsibilities related to the coasts and oceans. Temporal integration is also necessary to blend short-term warnings associated with extreme events with long-term planning and efforts to affect policy decisions.
- **Regional approaches to working with our partners.** Given the regional nature of climate impacts and issues and existing regional activities (e.g., NOAA regional teams and Regional Integrated Sciences and Assessments (RISA) programs), a regional approach should be used to develop strategies to work with other agencies, academia, local and state governments, non-profits, and businesses to maximize effectiveness of collaboration. Roundtable discussions should be used to understand needs and communicate current products. NOAA should promote cross-regional communication and coordination. Place-based regional pilot projects with community engagement components should be used as demonstration projects to foster and promote working together on climate issues.

- **Modified NOAA policies and processes to allow for more effective climate services.** A new process with leadership commitment to execution and resource allocation is necessary within NOAA to affect change, develop priorities and improve effectiveness of our products and services. NOAA should identify any arenas in which we might need to reduce our emphasis to accommodate the focus on climate services. NOAA should formalize policies and memoranda of understanding (MOUs) with other agencies contributing to and using climate service data and products. We should also assess NOAA legislative mandates related to our roles and needs associated with climate change. Further, we need a process to develop priorities for getting data out to communities.
- **Indicators of climate risk and resilience for communities and ecosystems.** This effort, which could be conducted on a regional level, could build upon existing resilience work to develop indicators for quantitatively measuring risk and enabling communities and managers to work towards becoming climate-ready. Supporting long-term monitoring at sentinel sites and habitats will facilitate the characterization of climate change impacts, the development of predictive models and their application to management scenarios, and risk/vulnerability assessments.

Final Note: At a wrap-up session with the conference organizers held right after the last session, there was a general consensus that there was a collective enthusiasm for working together on these issues and a hope that this workshop would be the first in a series of steps to hold a dialogue among different offices engaged in work that relates to climate impacts on coasts.

Appendix 1: Workshop Agenda

NOAA Workshop on Strengthening Capacity to Address the Impacts of Climate Change on Coastal Communities and Ecosystems

June 19-20, 2008
at the
American Geophysical Union
2000 Florida Avenue N.W.
Washington, DC 20009

Agenda

The purpose of the workshop is to advance the creation of a NOAA-wide framework to address the impacts of climate change through the application of science-based information, the development of decision support resources and tools, and the building of capacity to address climate impacts on coastal communities and the ecosystems they depend upon. Toward this end, the workshop will address the following:

- *Review Key Challenges:* In the context of NOAA's mission, consider key coastal management challenges, drivers and customers for which climate information is relevant. Identify the types of information that would be most useful for addressing these challenges.

- *Consider and Assess Current Resources:* Identify expertise, experience, knowledge, technology, and information systems within and supported by NOAA that can be used to generate and apply information relevant to addressing climate impacts in coastal regions. Identify key gaps in information, delivery methods, and tools needed by NOAA and our partners.

- *Advance the Development of a NOAA Strategy for Addressing Climate Impacts in Coastal Regions:* Outline a strategy to better integrate climate research, awareness and information into NOAA's stewardship activities for coastal communities and ecosystems. This will inform a National Climate Service, NOAA's coastal enterprise and NOAA's core programs.

Workshop Outcomes: This workshop will produce information that can be used to develop a strategy for using NOAA's authorities and expertise to address the impacts of climate change on coastal communities and the ecosystems they depend upon. The workshop will foster increased connectivity among NOAA activities with a current and potential role in producing and applying climate information in coastal regions.

Context: This workshop is the second in a series designed to advance the development of NOAA's approach to providing climate information that supports the agency's management responsibilities for coastal communities, coastal ecosystems and living marine resources. The first occurred on May 14-15 and focused on climate and living marine resources. These two

workshops complement each other and provide the foundation for a larger framework for ongoing and evolving efforts within NOAA's research and management programs to address climate impacts and adaptation. They were designed to increase the communication between climate researchers, information providers, and coastal and ocean resource managers that need climate information to fulfill their mandates. Both workshops support NOAA's response to an August 2007 Government Accountability Office Report, which called on all Federal agencies to develop guidance for addressing the effects of climate change on Federal land and water resources. The material generated at these workshops will help address these needs over the short- and long-term.

Workshop Attendees: A mix of office level leadership and project staff working on climate and/or coastal management and planning activities, from both headquarters and field offices.

Workshop Organizers: NOAA's Climate Program Office had overall responsibility for planning and organizing this workshop, with support from staff in the following offices:

Office of Atmospheric Research
- National Sea Grant College Program

National Ocean Service
- Coastal Services Center
- National Centers for Coastal Ocean Science
- Office of Coast Survey
- Office of National Marine Sanctuaries
- Office of Ocean and Coastal Resource Management

National Environmental Satellite and Data Information Services
- National Climatic Data Center
- Integrated Data and Environmental Applications Center

National Marine Fisheries Service
- Office of Habitat Conservation

National Weather Service
- Office of Hydrologic Development

Sponsors: NOAA gratefully acknowledges the support provided by the East-West Center in Honolulu, HI, the National Estuarine Research Reserve Association.

Thursday, 19 June

Time	Session
8:30 - 9:00 am	**Registration**
9:00 - 9:30 am	**Welcome and Goals of Workshop** – ▪ Dr. Chet Koblinsky , Climate Goal Team Lead ▪ Dr. Steve Murawski, Ecosystem Goal Team Lead ▪ CAPT Steve Barnum, Commerce and Transportation Goal Team Lead ▪ Dr. George Smith, Weather and Water Goal Team Lead
9:30 - 9:45 am	**Overview of the Agenda and Meeting Logistics** – Nancy Beller-Simms**,** Climate Program Office
9:45 - 10:30 am	**Presentation on major climate change impacts with a focus on coastal communities and ecosystems** – Dr. Denise Reed, Ph.D., Professor, University of New Orleans
10:30 - 10:45 am	**Discussion** – Nancy Beller-Simms
10:45 -11:00 am	**Break**
11:00 - 12:00 pm	**Panel of Practitioners: Key challenges and examples of solutions for coastal communities and ecosystems** (Moderator: David Kennedy, Director, NOS Office of Ocean and Coastal Resource Management) ▪ Dave Carter, Delaware Coastal Program ▪ Jesse Schomberg, Minnesota Sea Grant ▪ Skip Stiles, Wetlands Watch ▪ Robert Kafalenos, Department of Transportation
12:00 - 12:15 pm	**Discussion with Panel –** David Kennedy
12:15 - 1:15 pm	**Lunch** (on your own, restaurant listing provided separately)
1:15 -1:45 pm	**Introduction of major pressures of climate change on coastal communities and ecosystems** – Darlene Finch, NOAA Coastal Services Center
1:45 - 3:15 pm	**Understanding Impacts and the Needs for Climate Information:** Break into small groups according to major climate change pressures of : ▪ Sea Level Change ▪ Severe Weather, including Hurricanes and Non-Tropical Storms ▪ Freshwater Quantity and Quality ▪ Ocean Changes, including Temperature and Chemistry Each small group will address the following questions: ▪ *What are the most critical impacts that NOAA needs to address?* ▪ *What kind of climate information and tools do managers need from NOAA to address these impacts? Please prioritize.* **Outcome**: Prioritized list of impacts that NOAA "should" address and associated tools and information that NOAA is capable of providing.
3:15 - 3:30 pm	**Break**
3:30 - 4:45 pm	**Report back from the Small Groups** on major impacts, needs and gaps – Eileen Shea, Director, NOAA Integrated Data and Environmental Applications Center

	▪ Sea Level Change ▪ Severe Weather, including Hurricanes and Non-Tropical Storms ▪ Freshwater Quantity and Quality ▪ Ocean Changes, including Temperature and Chemistry
4:45 - 5:00 pm	**Recap of the first day** and review of what participants should be prepared to discuss on the second day – Nancy Beller-Simms
5:15 - 7:30 pm	**Reception** at AGU

Friday, 20 July

Time	Session
9:00 - 9:15 am	**Recap of first day**. Charge for the second day – Nancy Beller-Simms and Eileen Shea
9:15 - 10:30 am	**Understanding our Capabilities and Gaps**/Small Group discussions. Each small group will address the following questions: ▪ *What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities?* ▪ *What additional research, data, information, and delivery methods do we need?* **Outcome**: Using the tools and information lists developed yesterday, identify how NOAA is currently working towards those outputs and the barriers to developing/improving those products. Identify key capabilities and what capabilities need to be strengthened.
10:30 - 10:45 am	**Break**
10:45 – 12:00 pm	**Report out from Small Groups** - Eileen Shea ▪ Sea Level Change ▪ Severe Weather, including Hurricanes and Non-Tropical Storms ▪ Freshwater Quantity and Quality ▪ Ocean Changes, including Temperature and Chemistry
12:00 – 1:00 pm	**Lunch** (on your own, restaurant listing provided separately)
1:00 - 1:30 pm	**National Climate Service** - Chet Koblinsky
1:30 - 1:45 pm	**Charge to the Small Groups** - Nancy Beller-Simms
1:45 - 3:00 pm	**Identifying Solutions**/Small Group discussions. Each small group will address the following core questions: ▪ *What should NOAA be doing in the next 1-2 years to address the impacts of climate change to our coastal community and associated ecosystems responsibilities? Next 5 to 10 years?* ▪ *How do we work more effectively across NOAA to address major needs and priorities?* **Outcome**: A list of short- and long-term steps to developing products that address critical impacts.
3:00 - 3:15 pm	**Break**

3:15 - 4:15 pm	**Report out from Small Groups** – Eileen Shea ▪ Sea Level Change ▪ Severe Weather, including Hurricanes and Non-Tropical Storms ▪ Freshwater Quantity and Quality ▪ Ocean Changes, including Temperature and Chemistry
4:15 - 4:45 pm	**Observations and Synthesis of the Material Developed During the Workshop** – Eileen Shea
4:45 - 5:00 pm	**Next Steps and Adjournment –** Nancy Beller-Simms

Appendix 2: List of Participants

NOAA Workshop on Strengthening Capacity to Address the Impacts of Climate Change on Coastal Communities and Ecosystems
June 19-20, 2008

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Appendix 3: Breakout Questions

Understanding Impacts and the Needs for Climate Information:

- What are the most critical impacts of this pressure that need to be addressed? Which of these are within NOAA's mission?
- What kind of climate information do managers need to address these impacts? What are the temporal and spatial scales for this information?
- What are the key decision support resources, information resources, products, tools and capabilities needed to address climate and coastal resource (communities and ecosystems) management?
- Can priority be assigned to any of these issues and/or processes? If so, which are of greatest importance in terms of timeliness and impact?

Understanding our Capabilities and Gaps

- To what extent is climate information currently used to address these coastal responsibilities? What are the current barriers to incorporating climate information into efforts to manage coastal communities and the ecosystems they depend on? How will these challenges and barriers affect our ability to implement management efforts for coastal communities and ecosystems?
- What is the current status of research related to climate-related coastal issues and associated observations, modeling, process studies, and impacts and adaptation research and assessment (well covered, in development, non-existent)?
- How effectively is this information being delivered to the managers who need it, and how can delivery be improved?
- What additional coastal communities and ecosystems information is needed by the climate science community to assess and predict climate feedbacks from human-induced alterations (e.g., ocean acidification)?

Identifying Solutions

- How should NOAA work across the agency to address major needs and priorities that have been identified?
- Which institutions/programs need to be involved to implement these actions? What partners will be critical?
- What are some short- and long-term steps that can be taken? What are the priorities?

Appendix 4: Breakout Group Notes

Breakout Session I

Freshwater Quantity and Quality

What kind of climate information and tools do managers need from NOAA to address these impacts?

For a coastal freshwater budget, needs include:

- accurate data
- modeling capacity and scenario forecasting
- spatial and temporal scale identification
- ability to connect to coastal managers and
- appropriate decision-making, i.e., tech transfer

Oceanic Changes – A

What are the most critical impacts that NOAA needs to address?

- Melting land ice and sea ice
- Ocean acidification
- Temperature change
- Ocean circulation
- Water quality and quantity

What kind of climate information and tools do managers need from NOAA to address these impacts?

Melting ice

- Forecasting – projections and predictions of ice extent
- Transportation: Remote sensing information for shipping lanes, safety for ships (search and rescue), science for spill response, bathymetry
- Synthesis/analysis of existing observations and data "archaeology"
- Measurements/observations – salinity, productivity
- Ecological forecasting of shifts due to melting ice

Ocean acidification

- Observations – CO_2, pH, salinity, etc.
- Carbon chemistry (inorganic [CO_2, bicarbonate] and organic)
- Predictive tools for depth and latitude
- Biological monitoring, indicator species, coastal observations
- Significant research needs

Temperature changes

- More information at spatial and temporal scales relative to ecosystem monitoring
- Full water column temperature (and other components) profiles
- Link of above to fisheries production, corals, etc.

Water quantity and quality

- Products to address changes and effects on estuaries, especially salinity
- Flow data
- Circulation info nearshore/estuaries

Ocean Circulation

- Upwelling information
- Information on ENSO/PDO affecting fish production
- Monitoring currents

Sea Level Change – A

What are the most critical impacts that NOAA needs to address?

- Ecosystems, habitats, species impacts
- Communities, land use impacts
- Economic impacts
- Marine Transportation System impacts
- Legal, policy impacts

What kind of climate information and tools do managers need from NOAA to address these impacts?

Cross – Impact Tools

- Bathymetry/topography (LiDAR), VDatum to forecast and understand shoreline change
- Baseline data and change analysis to understand impacts of future changes
- Integrated Ecosystem Assessments, including assessments of actions, costs and benefits for management options, etc.
- Prediction system for sea level rise to understand changes at all scales

Additional thoughts

- Standardization as NOAA's role
- Roles and coordination with federal partners
- Products need to be responsive to managers needs
- Peer review process

Sea Level Change – B

What are the most critical impacts that NOAA needs to address?

Impacts

- Changes to coastal habitats – salt marshes, habitat, species, degradation of human response (12)
- Loss/change in property values, use
- Flooding of infrastructure -- roads, rail, transit, transportation (10)
- Residential impacts
- Impacts on water quality – saltwater intrusion, e.g. (6)

- Freshwater resources, e.g., saltwater intrusion
- water treatment facilities flooding
- dumps currently sealed/capped
- septic fields
- toxic contaminant sites
- diseases, waterborne pathogen threats to human health
- Reduced resilience as a result of confounding processes
- Synergy w/other changes (coastal processes impacted by SLR, water temp, salinity, etc.) (11)

What kind of climate information and tools do managers need from NOAA to address these impacts?

For changes to coastal habitats as result of sea level change or human response – salt marshes, habitat, species, degradation because of human response

Need consistent, basic info on:

- extent/rate of Sea Level Change
- Nested scales
- Habitat-specific – how they will respond
- Regional to local
- Need for refined information on ecosystem/human impacts for possible responses
- Baseline data – seamless geospatial framework
- Monitoring
- Assessments
- Forecasts, projections/future scenarios – worst case, potential
- Management options

What kind of climate information and tools do managers need from NOAA to address these impacts?

- Capacity for pro-active actions
- Identify priority habitats/areas
- Maps for Sea Level change
- LIDAR data, geospatial framework to build decisions on
- Development plans – "Green prints" – growth and planning tool that designates important resource identification of priority habitats, cultural, economic areas, etc.
- Resources – investing capacity to protect and restore habitat, infrastructure

<u>Oceanic Changes – B</u>

What are the most critical impacts that NOAA needs to address?

<u>Pressures</u>

- Acidification
- Precipitation (can effect stratification)
- Temperature

Impacts

- Ecosystem
  - Change/loss of habitat,
  - Change/loss of productivity and species
  - Nuisance Species
- Socio-Economic – Impact on communities
  - Jobs
  - subsistence
- Health
  - Increased disease in humans
  - Increased disease within ecosystems

What kind of climate information and tools do managers need from NOAA to address these impacts?

Information, Tools and Outreach Needed

- Common data standards
- Address satellite observation gaps
- Education – understanding of data – limitations/probabilities
- What can I say right now about climate? i.e., current best available information.
- Downscaled regional information on acidification, temperature, and productivity – "Downscaled Tool Kit"
- One stop shopping for information
- Better information exchange within NOAA

Breakout Session 2

Freshwater Quantity and Quality

What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities? What additional research, data, information, and delivery methods do we need? NOAA does replicable pilots that integrate water budget and hydrology information at watershed scales.

Coastal Freshwater Budget for use in scenario and ecological forecasting

- Weather–integrated information to use at local scale
- Groundwater–corporate commitment to integrate and execute
- Water quality–transferability of pilots
- Bathymetry–user needs assessments (internal/external) need
- Sedimentation–involvement from beginning
- Land Cover
- Data mining and historical data
- Stream flow

What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities? What additional research, data, information, and delivery methods do we need?

GAPS

- Quantify benefits to users
- Expanded coverage for watersheds for nutrients and contaminants
- Snow melt and permafrost data
- Disease agents
- Diversion and withdrawal information
- Operational capacity
- Process, leadership, and resources to integrate assets in/out of NOAA
- Community modeling infrastructure
- Summit to sea modeling – coupled hydrology and ocean models
- Use assets to deliver to users

Severe Weather

What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities? What additional research, data, information, and delivery methods do we need?

Things we really care about (but these aren't prioritized!!):

- Overarching
- Integrate/blending short term warnings and long term planning
- Mission of NOAA vs. other feds
- Web site to provide integrated access to NOAA climate information for a variety of audiences
- Improved frequency, resolution and access for bathymetry and LIDAR
- Need improved frequency forecasts (e.g., seasonal outlooks, hazardous weather)
- Climate regimes (ENSO, NAO, PDO, Pacific/North American Oscillation (PNA)) forecasts/improved prediction for climate variability and long term change
- Education
- Develop materials (video, tutorials)
- Working with TV, teachers, realtors
- Links to social science
- Frequency forecasts and uncertainty information
- Evaluating and validating climate prediction models, including quantitative uncertainty
- NOAA taking the lead on long term time series

What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities? What additional research, data, information, and delivery methods do we need?

Funding needed for everything:

- Observations
- Calibrate and validate time series
- Continuity of monitoring
- Ocean acidification – Need more information
- Ecosystem thresholds relative to acidification including why regional differences
- Upscaling of coastal observation with global process
- Harvest/mine other data sets into NOAA data
- Calibrate/integrate data sets
- Fund IOOS
- Tracking of contaminants in atmosphere and deposition – changes due to climate change

Oceanic Changes – B

What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities? What additional research, data, information, and delivery methods do we need?

Research and Assessments

- Models need to be coupled across land/sea/air
- Need to develop and improve ecological models and forecasting
- Baseline mapping of ocean habitats – continue coordination across federal government
- Couple regional models with local scale monitoring
- Improve ecological forecast capability
- Downscaled modeling of snowpack and streamflow (viable just need to add topography to models)

What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities? What additional research, data, information, and delivery methods do we need?

Decision Support Tools

- Ecosystem impacts of climate change needs to be an ESSENTIAL component in NOAA Climate Services
- Regional ocean acidification, temperature, phenology, ocean productivity, ocean currents, and upwelling monitoring and forecasts
- Tools to evaluate management options, temp forecasting in short term
- One place to find information
- Need to prioritize climate efforts
- Build on existing efforts
- Integrate local data with regional models

Sea Level – B

Major Impacts of Sea Level Change	Loss/Change in Coastal Habitats	Flooding & Inundation of Built Infrastructure	Degraded Water Supplies/ Quality	Increased Threats to Human Health	Other?
Tools Categories	**Observation Gaps**				
Observations & Monitoring	**1) Geospatial Framework** ▪ Map topography and bathymetry of coasts ▪ Long-term geodetic (CORS) ▪ Shore to shore bathymetry ▪ Water level network completed ▪ U.S. & Global contribution (ITRF) **2) Coastal Change mapping & baseline maps** ▪ High resolution standards **3) Climate Info** ▪ Historical baseline ▪ Sea-level measures ▪ Temperature etc. monitoring ▪ Repeated measures **4) Habitat Observation** ▪ Surface elevation tables ▪ Coastal education changes (high resolution coastal change info.) **5) Need high-resolution Satellite capacity** ▪ Habitat characterization inventory ▪ Monitor habitat change over time ▪ Standards ▪ Coordination w/partners ▪ Reference & restored sites	**1) Geospatial Framework** **2) Infrastructure** ▪ Data layers **3) Demographic data layers** **4) Hazard data buyers**	**Coordinated & cohesive assessment/ observations** **Contaminant levels & sites?**	**Harmful Algal Blooms (HABS)?** **Disease observa-tions?**	**Socio-economic Response**

Research Assessments & Projections **Modeling**	**1. Integrated assessments of geospatial & ecosystem information** **2. Coastal elevation early warning system** **3. Model ecological impacts of SLR** **4. Assess impacts, cost & benefits of predicated ecological change on people/built** **5. Research to better understand SLC change at regional/local** **6. Research tipping points for ecosystem responses** **7. Downscaling of information**	**1. Vulnerability assessment tools** ▪ **Infrastructure/ hazards** ▪ **People** ▪ **Visualization tools** ▪ **Risk assessment/ scenario planning** ▪ **Coastal flood modeling** **2. Management options & scenarios** ▪ **Data, models**	**1. Vulnerability assessment & support** ▪ **Data** ▪ **Visualiza-tion tools** ▪ **Models** ▪ **Training**
Management Capacity **Plans & Implementation/ Education/ Outreach**	**1. Clearinghouse for adaptation planning tools & information** **2. Capacity building for adaptation planning (training & tools)** **3. Provide framework of tools & approaches (training & guidelines)** **4. Tools & resources for coordinated conservation (plans & implementation)-RISA** **5. Education outreach** ▪ **change scenarios** ▪ **basic concepts** ▪ **options** ▪ **cost & benefits**	**1. Guidelines/ framework for policy/reg. changes ~coastal zoning/use** **2. Tools/capacity for adaptation plans including "green infrastructure"** **3. Clearinghouse in adaptation plans** **4. Proactive planning w/ private sector** **5. More robust warning systems** **6. Education outreach** ▪ **Basic understanding** ▪ **Cost benefits** ▪ **Uncertainty** **7. Influence policy on other agencies** ▪ **Flood insurance**	

Breakout Session 3

Oceanic Changes – A

What should NOAA be doing in the next 1-2 years to address the impacts of climate change to our coastal community and associated ecosystems responsibilities? 2-5 years?

Goal: Make better ecological forecasts and vulnerability assessments for managers

- NEEDS ASSESSMENTS
- INVENTORIES
- INTEGRATION AND MATCHING
- DELIVERY OF PRODUCTS

Goal: Make better ecological forecasts and vulnerability assessments for managers

1. NEEDS ASSESSMENTS (Start within 0-2 years; continuous)
1A. Internal Needs Assessment.
Where are gaps and problems and where should we address climate? To what extent do we need to use climate in our day-to-day work?

- Observations and monitoring
- Research and modeling
- Management
- Education/Outreach

1B. External Needs Assessment (Start within 0-2 years)
Use existing NOAA structure, advisory councils and extension groups to determine needs of coastal stakeholders.
- Builds stakeholder support from the "bottom up"

2. INVENTORY of Capabilities within NOAA (Start within 0-2 years)
Capabilities and products
Gap analysis
Provides better communication and integration across NOAA

3. INTEGRATION and MATCHING of capabilities at NOAA
Integration of existing information across NOAA
Develop/research

4. DELIVERY
Delivery of Forecasts – Biological, chemical, physical
Sustained approach. Feedback necessary.
Providing information
Developing and implementing a climate portal

FEEDBACK LOOPS – Continual communications both internal and external

Sea Level Change – A

What should NOAA be doing in the next 1-2 years to address the impacts of climate change to our coastal community and associated ecosystems responsibilities?

Short-term steps (and what they will accomplish)

- Inreach on existing climate products and services to better understand what is currently being produced
- Establish a workgroup to identify and develop materials, programs, etc.
- One-pager on SLR products and services
- CO-OPS with CPO and regional
- Work with regional teams to identify capabilities and gaps – region-specific
- Scope/develop an outreach program for the public (with Public Affairs) include communication of uncertainty
- Identify/inventory observations, modeling, requirements, etc. to develop an SLR predictive capability
- Focused effort to identify a short-term SLR product we can provide now (GIS-friendly format) designed to address communication of uncertainty
- Scope a 1–2 year regionally-based pilot project to demonstrate integration of data, prediction models, etc. for decision-making (implementation may be long-term)
- Detail NOAA personnel to CEQ to understand/influence policy issues and to elevate visibility of NOAA role
- Identify/develop standards/guidelines for planning
- Needs assessments – planned regional assessments should include acceptable uncertainty and observing systems gaps

What should NOAA be doing in the next 5-10 years to address the impacts of climate change to our coastal community and associated ecosystems responsibilities?

Long-term steps

- Explore opportunities to include SLR data and issues into Integrated Ecosystem Assessments
- Develop/implement a SLR prediction system
- Address modeling and observation gaps
- Coordinate across NOAA to speak with one voice
- Create derived products to address specific management needs
- Develop performance measures
- Communicate error and uncertainty
- Develop a strategy to integrate data into our core mission capabilities
- Develop tools to identify societal vulnerability/resilience (MTS, fisheries, contaminants, etc.) – "Don't analyze, think!"
- Accelerate research on climate
- Accelerate multi-disciplinary integration to address climate

Sea Level Change – B

What should NOAA be doing in the next 1-2 years to address the impacts of climate change to our coastal community and associated ecosystems responsibilities?
Short-term steps (and what they will accomplish)

- SLC: Create NOAA Team to promote coordination & delivery of key messages
- Climate-Coast "Tiger Teams" that share consistent messages
- NOAA web-portal on climate-coasts:
  - Messages
  - Info/data
  - Products
  - Case studies
  - Call center
  - Customer friendly
  - Cross NOAA
  - Serves multiple customers
  - Access to range of products/resources
- Regional round tables to understand needs & communicate current products
  - Maximize existing fora
  - Promote cross regional communication, coordination
  - Federal, State, Local governments
  - Non government interests
- Shape key policies, actions for other Federal agencies
  - USGS, ACOE, NASA, FERC, EPA, FEMA
  - MOUs
  - Guidelines
  - Products/Services
  - Increased collaboration
  - Leverage resources
  - Key Topics: Energy Development
- Guidelines for/with coastal states for adaptation plans
- Prioritize and focus FY09-10 budgets to fill key gaps (e,g., geospatial infrastructure)
- Prioritize "end to end" initiatives for FY11-15
- Implement pilot projects to demonstrate/test adaptation strategies
  - Partnerships
  - Green infrastructure
  - Contaminants
- Lead design/development of coastal habitat assessments
  - Cross NOAA
  - Cross government
- Improve/expand coastal vulnerability indices
- Broaden NOAA efforts on modeling ecological impacts of SLR/Climate Change
- Assess NOAA legislative mandates for role/needs in climate change context (strong/clear NOAA roles and support changes where needed)

What should NOAA be doing in the <u>next 5-10 years</u> to address the impacts of climate change to our coastal community and associated ecosystems responsibilities?
<u>Long-term steps (and what they will accomplish)</u>

- SLC "Tiger Team"
  - Cross NOAA
  - Coordinate planning for products/services
- Promote Cross-NOAA planning & execution to fill gaps in climate/coastal portfolio
- Fill key gaps
  - Geospatial framework
  - Priority research
- Build partner capacity to assess and act

<u>Severe Weather</u>

What capabilities and gaps exist in NOAA's current efforts to address the impacts of climate change to our coastal community and associated ecosystem management responsibilities? What additional research, data, information, and delivery methods do we need?
Overall barriers:

- prioritization at all levels (supervisors to leads of agencies)
- we may not have data yet
- resources, including dollars and people
- behavior/political will

Overarching

- Integrating/blending short term warnings and long term planning
  - Short term because states needs this information now and are having to make decision
  - Long term for really affecting building code changes and other land use decisions
- Mission of NOAA vs. other feds
  - Long term and problem specific
  - Web site to provide integrated access to NOAA climate information for a variety of audiences
- Short term because climate services portal is under development
- Long term – maximize the opportunity this affords
  - Improved frequency, resolution and access for bathymetry and LIDAR
- Short term because an underlying need for inundation/storm surge work
- Short term need to figure out the specific needs
- Long term is working across the federal family to get the resources and standardized coverage
  - Integrated Funding announcements
  - Need improved frequency forecasts (e.g., seasonal outlooks, hazardous weather)
- Short term because we have the climatology and have started to characterize uncertainty for hurricanes
- Long term is characterizing the uncertainty for other severe weather

    - Climate regimes (ENSO, NAO, PNA, PDO) forecasts/improved prediction for climate variability and long term change
- Short term for ENSO
- Long term for NAO, PNA, PDO, etc.
    - Education
- Develop materials (video, tutorials) working with TV, teachers, realtors
- Link to social science
    - Short term is incorporating social science so we improve the delivery
    - Long term to get into education systems
- Evaluation and validation of climate prediction models including quantitative uncertainty
    - Short term
- NOAA takes lead on long term time series
    - Short term is conducting a needs analysis
    - Long term to put into place
- Translation
    - Work with users to define tool/resource needs
    - Short and long term, start now but continue as iterative process

Oceanic Changes – B

What should NOAA be doing in the next 1-2 years to address the impacts of climate change to our coastal community and associated ecosystems responsibilities?

- Get out information we know now to users
- Designing and implementing a process to bring together users and researchers, ex. PaCIS, CIG (NW RISA) at regional level
- Education/Outreach/Training for decision-makers – build user base
- Support for regional climate center in Alaska
- Reach out to news media – Alaska worked w/PBS to develop information segments – reaching out to public and using programs in school
- Promoting NOAA work within NOAA – replicate good examples
- Education – Public
- Education – K-12 – develop climate curricula
- Branding NOAA as the lead on climate (investigate non-competitive issues) "fair and balanced information provider"
- It should be decided what outlets NOAA will use to gets out information
- Downscaled modeling in coastal and great lakes areas. Great Lakes Environmental Lab, Alaska (UAF), etc.
- Define toolkit for downscaling so groups don't have to reinvent
- Assessment of what data capabilities are, a gap analysis, and prioritization of data collection. Includes reaching out to international groups and other external partners
- Interdisciplinary workgroups to synthesize information targeted at specific users. Bringing together socio-economic, physical, and biological.
- Develop interdisciplinary budget proposals for research
- NOAA budget process needs to be modified to allow for cross-goal projects to have success

- External review of Climate Services Development, for example, NSF
- Develop plan for developing models (non climate change models) – leverage global capabilities and link to regional etc. so there can be tie in.
- Plan for better observation NOW.
- Improved research lab cooperation
- Shared computer resources between labs
- Put coastal into the RISAs

Three to Five Years

- Interdisciplinary research conducted.
- GFDL Higher Resolution Models - Reconfigure existing models (going to 25km is a funding issue, beyond that is a research issue)
- Enhance computer capabilities (NASA and Navy have the systems)
- Development of indicators and warning system for Climate Risk for communities – pick limited number of impacts, regionalize (possibly build on community resilience indicators)
- Climate Ready Communities program (ex., tsunami ready communities)
- Development of ecological impact models, includes economics
- Begin executing improved in-situ observation. Leverage existing NWS buoys. NDBC needs to work with other parts of NOAA to execute.
- Climate quality time series
- Develop capacity to work with satellite salinity measurements (will directly support ocean acidification)
- Apply NOAA resources to work with NASA Orbital Carbon Observatory. Will give total atmospheric column CO_2. We need boundary layer CO_2 content for measuring ocean uptake.
- Development and implement Ice-Ocean-Ecosystem model and monitoring
- NEST Policy Directive within 1-2 years to look at water availability model situation under different scenarios including water quality, water quantity, etc., ACOE, USGS, NOAA, DOI.
- Issues with water quality – brings in 16 agencies, each measure water quality a different way

Freshwater

Short Term Actions

- Initiate an internal competition to support integration between offices
- Lead, coordinate, and train NOAA's place-based extension, outreach, field-office personnel to identify and address priority climate service issues
- Capitalize on existing pilot projects and adapt them to address climate issues
- Identify what we will stop doing to accommodate the focus on climate services.
- Improve internal communication - Who is doing and planning what? What data sets exist?
- Quantify benefits of products and data derivatives

- Apply research on risk communication to climate. How do we convey uncertainty associated with data and forecasts?
- Better measure uncertainty and variability in hydrology models
- Formalize policies/MOUs with agencies contributing to and using climate service data and products
- Standardization and coupling of datums, etc. Convergence on shared standards.
- Improve remote sensing for water quality
- Identify and address internal inconsistencies and redundancies at the intersections of Climate, Coasts and Water
- Expand the utility and use of NOAA's existing freshwater forecast services

Longer Term Actions

- Become an international leader in climate research and service.

Appendix C
Climate/Ecosystems Observation Needs Assessment

[The following document was prepared in April 2008 by a cross-NOAA team (led by Steve Murawski) under the auspices of the NOAA Ocean Council to respond to request from NOAA's VADM Lautenbacher for a summary of requirements to fulfill NOAA ocean and coastal stewardship mandates in a changing climate]

Climate and Ecosystems
Observation, Research and Management Requirements

NOAA has direct responsibility for understanding and incorporating climate impacts in meeting its living marine resource and coastal management obligations. The NOAA Ecosystem and Climate Goal Teams and the NOAA Ocean Council have identified six high priority climate change issues involving ecological and coastal resources. A cross-NOAA group was assembled under the auspices of the NOAA Ocean Council to populate a list of observational requirements (scientific parameters to be measured on a continuing basis) needed to address these six specific issues. For all of these theme areas there is a need for climate forecasts and scenarios (projections) at appropriate scales involving these and other issues. The NOAA Climate/Ecosystems Working Group is currently developing a more thorough plan for incorporation of climate issues into ecosystem management efforts, which include workshops in May and June, followed by a final more complete report in summer 2008. The summary below and in the attached table highlight the specific observational requirements for NOAA in the climate/ecosystems realm. There are additional research requirements and management outcomes required to meet these increasingly important obligations.

NOAA's Observational Requirements Necessary to Meet Emerging Climate/Ecosystems Obligations:

<u>Ocean Acidification</u>

NOAA is responsible for managing living marine resources supporting the Nation's commercial and recreational fishing industry and its protected marine species and marine managed areas. Native peoples also depend upon these resources for subsistence, and vast numbers of people use these resources for tourism and recreation. Accounting for ocean acidification effects on these living marine resources requires the capability to monitor the pace of changes in ocean carbon and pH, as well as to forecast their impacts on species abundance, distribution and various lethal and sub-lethal impacts. Ocean acidification may have significant detrimental effects on the living marine resources and the social and economic activities dependent upon them, but there are significant unknowns regarding physical and chemical oceanography and physiological impacts on biota. The following measurements represent priority monitoring parameters:

- Coastal and ocean carbon, pCO_2, pH, temperature, salinity
- Ocean surface winds, circulation at depth, and CTD measurements for hydrodynamic models

- Monitoring of pH-sensitive species (including phytoplankton, zooplankton, deep and shallow water corals, bivalves, crustaceans) and associated impacts on food web-dependent species, habitats and community structure
- Physiology experiments to understand the capacity for adaptation to lower pH and carbonate ion conditions
- Monitoring of the economic and societal value of pH-sensitive biota, and the ancillary ecosystem services, in appropriate valuation terms

Sea Level Rise

Sea level rise will have significant impacts on the condition and distribution of coastal habitats and human interactions with these habitats (i.e. coastal development), effecting living marine resources, coastal communities and economies that depend on them. To meet its management responsibilities for these coastal regions and habitats, the dependent living marine resources and the effected coastal zone, NOAA will need additional observations and models on the actual and potential impacts of sea level rise. Many fisheries for which NOAA has management responsibilities utilize coastal habitats (e.g., wetlands, estuaries, riverine) as nursery areas. Pinnipeds and marine turtles use low-lying coastal regions as resting, pupping, or nesting areas. Shallow water coral reefs are also susceptible to sea level rise due to their light requirement. Changes in sea level may alter the services habitats provide to buffer coastal communities from storms, floods and other hazards. Coastal communities and built infrastructure will become more vulnerable to inundation, storm surge and erosion stimulated by sea level rise and in some areas sea floor sinking. Following are the priority measurements required to monitor sea level rise and its impacts on ecosystems and coastal built infrastructure and communities:

- High resolution bathymetry and geodesy for sensitive coastal regions
- High resolution satellite altimetry and ground-truth from tide gauge monitoring
- Down-scaled climate model results allowing regionally-appropriate estimates of the rate and impacts of sea level rise
- Monitoring of the abundance and productivity of species in relation to habitats sensitive to sea level rise
- Periodic mapping and characterization of coastal habitats that are threatened by sea water inundation (e.g., coastal wetlands, shorelines estuaries, riverine floodplains)
- Observations of shoreline and habitat change over time, including inventories of built infrastructure in sensitive areas.
- Observations and forecasts on the economic and societal value of sensitive biota and habitats (and the ancillary ecosystem services and community profiles in appropriate valuation terms)

Loss of Sea Ice

NOAA is responsible for providing management advice for Arctic and Antarctic fisheries, marine mammals and related ecosystem components. Additionally, communities and villages are sensitive to sea ice loss because of impacts on storm resiliency, inundation and effects of sea level rise. NOAA provides ongoing advice to domestic fishery management councils, ESA and MMPA managers and is also responsible for upholding the U.S. obligation to the Arctic Fisheries Convention and the Convention on the Conservation of Antarctic Marine Living

Resources. In both these regions sea ice is diminishing and has a major influence on the structure and function of the ecosystems and the status of regulated species, as well as communities. Below are the priority monitoring requirements to understand the impacts of sea ice loss on managed species, ecosystems and associated communities:

- Annual and seasonal monitoring of sea ice extent, thickness and related ocean physics (satellite monitoring and in situ measurements)
- Surveys of the distribution and productivity of key trophic levels and species in relation to sea ice loss
- Monitoring of fisheries and other economic activities and culturally significant activities (e.g., aboriginal hunting of sea mammals) in relation to sea ice extent
- Monitoring of sea ice loss in relation to coastal community resilience

Freshwater Supply and Quality

Many marine and anadromous species for which NOAA has primary management responsibilities utilize coastal areas that are influenced by freshwater inputs or coastal currents driven by freshwater inputs. Salmon, some of which are listed under the ESA, utilize freshwater ecosystems as spawning and nursery areas. By combining predictions of freshwater conditions and flows with ecological information relevant to species and populations of interest, NOAA will have an improved ability to assure the sustainability of affected populations, or at least to frame the difficult choices that will arise between competition for increasingly scarce fresh water flows for domestic, agricultural and industrial uses, and fish and wildlife habitat protection. The critical observational priorities are:

- Regional precipitation, freshwater flows in surface and subsurface waters, water quality, temperature characteristics
- Atmospheric water vapor content
- Monitoring of anadromous and estuarine-dependent species (and the species they depend upon) by appropriate life stage
- Monitoring of freshwater and estuarine flows, water quality, salinity and other sensitive habitat parameters
- Monitoring of economic and social values of fresh-water and estuarine dependent fisheries and protected species and habitats

Attribution of Ocean and Coastal Ecological Phenomena to Long-term Global Change vs. Natural Variation

Living marine resources (LMR) vary in abundance and distribution over a variety of scales due to naturally-occurring cycles such as the Pacific Decadal Oscillation (PDO), the North Atlantic Oscillation (NAO), El Niño events, and other sources of low-frequency interannual variation. Managers increasingly need to know if changes observed in LMR populations are driven in part by these variable, but stationary processes or, increasingly, are being influenced by long-term directional change being forced by global change. Management targets and measures are likely very different, especially in the long term, depending on the sources of observed variation. In order to inform resource managers about the source and frequency of these climate-driven changes in productivity, the following are observational priorities:

- Observations of weather and ocean physical parameters on space and time scales pertinent to biological resources of management or ecological importance
- Observations of living marine resource productivity in relation to appropriate scales of natural variability (e.g., annual to decadal) and longer-term climate trends
- Observations of socioeconomic outcomes in relation to variation and trends in climate-related changes in natural resources

Ocean Physical Changes, (e.g., warming impacts) on distribution, productivity, and phenology (i.e., the seasonal timing and distribution of biological phenomena)

Long-term warming of the oceans has had and is projected to have significant impacts on the abundance, productivity and geographic distributions of LMRs. For example, for many species of interest, poleward migrations of the maximum range and the centers of distribution are a likely outcome, based on historical information. As these phenomena occur, changes in fisheries and protected species outcomes will ensue. Also, NOAA manages fixed sites of ecological and cultural significance which will be influenced by these warming trends. Understanding what threats to these managed locations will arise required treating them as sentinel sites for global warming and prediction. In order to meet NOAA's LMR requirements, the following observations are considered high priority:

- Monitoring of key oceanographic parameters (temperature, salinity, density, upwelling) and meteorological conditions (air temperatures, surface winds, etc.) at appropriate spatial and temporal scales to determine the impacts of global and regional warming and variability on biological processes and phenology
- Monitoring of key biological parameters (abundance, distribution, vital rates) for species sensitive to climate-induced shifts in distribution and productivity, at regional scales and in NOAA's marine managed areas
- Monitor changes in biodiversity in relation to key ocean and coastal environmental variables
- Survey for invasive species abundance and distribution in relation to climate change variables
- Monitor coral bleaching and related environmental variables

Research and Management Needs:

Apart from these observational requirements, NOAA has a number of high priority research and management needs in order to implement an integrated approach to effectively incorporate impacts of the above six climate/ecosystem themes into its management responsibilities. Below is a comprehensive summary of these requirements:

Summary of key requirements to incorporate climate change information into NOAA living marine resource and coastal management responsibilities and decision making

CLIMATE-ECOSYSTEM THEMATIC AREA	NOAA STEWARDSHIP REQUIREMENT (SUMMARY OF POTENTIAL RELEVANCE/IMPACT TO NOAA STEWARDSHIP RESPONSIBILITIES)	CLIMATE-ECOSYSTEM SUB-THEME	REQUIREMENTS TO ADDRESS CLIMATE-RELATED STEWARDSHIP NEEDS			STEWARDSHIP STATUTORY DRIVERS	KEY OBSERVATIONS & VARIABLES REQUIRED
			Observations & Monitoring	Research & Assessment	Management and Decision Support Resources		
Ocean Acidification	NOAA is responsible for providing living marine resource assessments required to manage the Nation's commercial and recreational fishing industry and protected marine species. These resources are also depended upon by native peoples for subsistence and help attract vast numbers of people to coastal regions for tourism and recreation. If NOAA does not account for OA effects on these living marine resources, there is an increased potential for inaccurate assessments and mismanagement of the resources. This would have detrimental effects on the living marine resources and the social and economic activities dependent upon them.	Chemical Oceanography	Coastal OA Survey, Oceanic OA monitoring Network	Development of oceanic carbonate sensing technology			Coastal carbon, pCO2, pH, temperature, salinity
			Deployment of carbonate system sensors in likely vulnerable areas.	Regional predictions of calcite and aragonite saturation state as a function of time; the frequency and magnitude of extremes due to upwelling, etc	Forecasts of the rate of OA by appropriate water bodies in relation to species specific threats. Managers implement mitigation strategies or reduce coincident stressors		Oceanic carbon, pCO_2, pH, temperature, salinity
				Coastal hydrodynamic modeling necessary for meeting geochemical modeling requirements. Calibration of models requires coastal ocean observations.			Ocean surface winds, circulation at depth, and CTD measurements for hydrodynamic models
			Include OA sensitive plankton samples in	Community-scale change detection from hyper spectral	Forecasts of OA impacts on the marine food web	MSRA, MMPA, ESA, CRCA	Monitoring of pH-sensitive species including

Ocean Acidification (cont.)			surveys such as CalCOFI, AMLR, FOCI and Repeat Hydrography Program, Coral Reef Ecosystem OA Monitoring Network	imaging	and NOAA-managed resources. Managers develop mitigation and other strategies to reduce other simultaneous stressors		phytoplankton, zooplankton, deep and shallow water corals, bivalves, crustaceans, and associated food web-dependent species
		Ecological Impacts	Determine organism responses to varying carbonate chemistry and ability to adapt to a declining pH environment	Experimental physiology studies to determine impacts of OA on growth, survivorship, and productivity of phytoplankton, zooplankton, bivalves, crustacean and vertebrate species		MSRA, MMPA, ESA, CRCA	Physiology experiments to understand the capacity for adaptation to lower pH and carbonate ion conditions
				Develop consistent protocols for impact and exposure studies to project OA effects on biota	Peer-reviewed outreach materials describing the potential impacts of OA on valued resources. Predictions of OA impacts on NOAA-managed species.	MSRA, MMPA, ESA, CRCA	
		Socio-economic impacts	Monitoring and valuation of the ecosystem goods and services provided by pH-sensitive ecosystems and species	Vulnerability assessments of the resources most susceptible to OA, and their socio-economic value	Vulnerability assessment (which are the resources most susceptible to OA, and what is their socio-economic value?)	MSRA, MMPA, ESA, CRCA	Monitoring of the economic and societal value of pH-sensitive biota, and the ancillary ecosystem services, in appropriate valuation terms

				Incorporate impacts of OA into stock assessments, population viability analyses and jeopardy decisions by NOAA	Forecasts of the socioeconomic consequences of OA. NOAA's social scientists will link trophic model outputs to economic models to forecast how loss of resource populations would affect human communities.	MSRA, MMPA, ESA, CRCA	
Sea Level Rise	By impacting coastal habitat, sea level rise impacts NOAA's coastal zone management responsibilities as well as its responsibilities for management of living marine resources that utilize shallow waters or low elevation coastal land. Many marine fisheries for which NOAA has management responsibilities utilize shallow water regions as nursery areas. Pinnipeds and marine turtles use low-lying coastal regions as resting, pupping, or nesting areas. Shallow water coral reefs are also susceptible to sea level rise due to their light requirement.	Rates of Sea Level Rise	High resolution observations of coastal topography and nearshore bathymetry. Sea level observations.	Models of regional sea level rise and shoreline evolution.			High resolution bathymetry and geodesy for sensitive coastal regions
			Continued documentation of SL variation by gauges and remote sensing	Investigations into gap-filling & optimizing of gauge ground-truthing data			
			Satellite Altimeter and Ocean Island Tide gauge Networks	Integration of the effects of ocean acidification and sea level rise and regional ocean "freshening"	Integrated information and evaluation of the stress factors on coral reef communities world-wide		High resolution satellite altimetry and ground truth from tide gauge monitoring
			1) Accurate vertical heights on tide gauges to monitor "true" sea level rise" 2) High Accuracy Surveys for elevation monitoring of coastal habitats	1) Develop GIS tools for helping habitat restoration projects plan for sea level changes. 2) Develop guidelines and specifications for obtaining high accuracy			

Sea Level Rise (cont.)				elevations for all climate change related activities.			
			Improved comprehensive downscaled modeling of sea level to incorporate local and regional impacts on sea level changes, in relation to IPCC forecasts of global change, appropriately disaggregated to local conditions	Peer-reviewed outreach materials describing the potential impacts of ice sheet melting on SLR, Scenarios of rates of SLR geospatially represented and incorporating locally/regionally relevant contributions to sea level changes, Guidance for best practices for scenario use for planning and decision making 3)Communication of uncertainty associated with sea level rise scenarios to managers			Down-scaled climate model results allowing regionally-appropriate estimates of the rate and impacts of sea level rise
		Ecological Impacts of SLR	Monitoring of key ecosystems in sentinel sites. Detailed observations to quantify impacts of habitat changes on populations.	Research on the effects of SLR on specific ecosystem types and high priority species (e.g., sea turtles). Studies and models to examine impact of habitat changes on populations. Develop production models for key species and parameterize the models for different coastal	Incorporate impacts of SLR into stock assessments, population viability analyses and jeopardy decisions by NOAA Ecosystem-specific guidance for adaptation. Mitigation strategies. Prioritized regions and habitat types for preservation or restoration.	MSRA, MMPA, ESA, CZMA, MPRSA, CRCA	Monitoring of the abundance and productivity of species in relation to habitats sensitive to sea level rise

				systems.			
Sea Level Rise (cont.)			Monitoring of key ecosystems in sentinel sites	Research on the effects of SLR on specific ecosystem types and high priority species that depend on shoreline environments (e.g., sea turtles, monk seals, etc.)	Ecosystem-specific guidance for adaptation and use of Sanctuary and Research reserve managers		
				Integration of GIS layers for elevation and scenario mapping.	Inundation maps showing SLR projections		
				Development of coastal elevation early warning system			
					Delineation of SLR controlled habitats using High Resolution Topographic and Bathymetric data. Ecosystem-specific guidance for adaptation Geospatial tools to evaluate and prioritize habitat for conservation/restoration/hazard resilience	Clean Water Act, Water Resource Development Act, National Flood Insurance Act, CZMA (NERRS)	
			Monitor changes in habitat and production rates	Flooding and sediment transport models to predict SLR and ecological models for each habitat (subtidal-benthic,inter-tidal, SAV oyster refs, sand, wetland, coastal forest and	Mapping and modeling tools to help land use managers and resource managers enabling future survival of essential habitats	MSRA	Periodic mapping and characterization of coastal habitats that are threatened by sea water inundation (e.g., coastal wetlands, shorelines used as breeding areas)

Sea Level Rise (cont.)				integration into a landscape change model)			
		Socio-economic Impacts of SLR		Regional and local scale vulnerability assessments, including the interaction of SLR with human stressors (e.g., land use)	Maps and interactive decision support tools to illustrate SLR impacts on ecosystems and resulting impacts on human communities on a scale appropriate for decision making.	MSRA	
				Appropriate ways to determine value of living marine and coastal resources in a context of changing climate	Updating penalty schedules and NRDA support	NMSA, MMPA, ESA, MSFMA, OPA	Observations and forecasts of the economic and societal value of sensitive biota and habitats (and the ancillary ecosystem services and community profiles in appropriate valuation terms)
					Review of coastal and marine development to protect public and private property (e.g., seawalls for homes, roads, and other structural development.	NMSA, CZMA	Observations of shoreline and habitat change over time, including inventories of built infrastructure in sensitive areas.
Loss of Sea Ice	NOAA is responsible for providing management advice for Arctic and Antarctic fisheries, marine mammals and related ecosystem components. NOAA provides ongoing advice to domestic fishery management councils,	Ice Physics & Forecasts	Sea ice extent and thickness, Ocean physical parameters	Development of regional climate/sea ice models			Annual and seasonal monitoring of sea ice extent, thickness and related ocean physics
				Models to forecast ice loss scenarios and to assess the potential impacts of sea ice on		CZMA, Hydrographic Services Improvement Act	

Loss of Sea Ice (cont.)	ESA and MMPA statutes and is also responsible for upholding the U.S. obligation to the Antarctic Fisheries Convention and the Convention on the Conservation of Antarctic Marine Living Resources. In both these regions sea ice is diminishing and has a major influence on the structure and function of the ecosystems and the status of regulated species.			coastal communities (i.e., increased erosion)			
		Ecological Effects	Expand fishery and ecosystem surveys. Initiate routine whale & ice seal monitoring	Assess impacts on vital rates (growth, maturity, & feeding) of managed species and impacts on food webs.	Forecast distribution & abundance of managed species (including endangered species and mammals) and the economic and sociological impacts on the commercial and subsistence fisheries.	MSRA, MMPA, ESA, CCAMLR	Surveys of the distribution and productivity of key trophic levels and species in relation to sea ice loss
				Improved models to forecast sea ice coverage and the impacts to coastal ecosystems	Incorporate impacts of Loss of Sea Ice into stock assessments, population viability analyses and jeopardy decisions by NOAA Adaptation guidance and best practices including potential mitigation of impacts to threatened and endangered species	MMPA, ESA	
		Socio-economic impacts			Loss of sea ice studies provide: assessments & predictions to improve management of Arctic fisheries and management of native harvests of marine mammals and management of protected resources.	MSRA, MMPA, ESA	Monitoring of fisheries and other economic activities and culturally significant activities (e.g., aboriginal hunting of sea mammals) in relation to sea ice extent
					Assessments of the socio-economic	CZMA, Hydrographic	

					impacts of sea ice loss- both positive and negative- on coastal communities Best practices guidance for adapting to potential socio-economic impacts	Services Improvement Act	
Freshwater Supply and Quality	Many marine and anadromous species for which NOAA has management responsibilities utilize coastal areas that are influenced by freshwater inputs or coastal currents driven by freshwater inputs. Salmon, some of which are listed under the ESA, utilize freshwater systems as spawning and nursery areas. By combining predictions of freshwater conditions and flows with ecological information relevant to species of interest, NOAA will have an improved ability to assure the sustainability of affected populations.	Regional Precipitation Forecasts	Precipitation, Freshwater temperature, & flow measurements		Freshwater temperature & flow forecasts		Regional precipitation, freshwater flows in surface and subsurface waters, water quality and temperature characteristics
			Monitor precipitable water vapor content in the atmosphere.		Informational guides/guidance on adapting to drought/flooding conditions		Atmospheric water vapor content
		Ecological Impacts	Monitor anadromous species migrations and changes in coastal and freshwater ecosystems.	Assess impacts on growth, spawning, survival. Identify populations most sensitive to climate change.	Long-term strategies to recover/maintain populations	MSRA, ESA	Monitoring of anadromous and estuarine-dependent species monitoring by appropriate life stage
					Incorporate impacts of fresh water changes due to climate change into stock assessments, population viability analyses and jeopardy decisions by NOAA. Decision support tools to identify and account for impacts of water	MSRA, ESA	

					flow changes to ecosystems		
				Run-off and sheet flow modeling	Estuarine impacts - salinity regime changes		
Freshwater Supply and Quality (cont.)		Socio-economic impacts			Products to ensure the sustainability of economically and culturally important west coast salmon populations and other living marine resources influenced by freshwater input.	MSRA, ESA	Monitoring of economic and social values of fresh-water dependent fisheries and protected species and habitats
				Estimates of flow and circulation for large estuarine systems (i.e. those used in Everglade and Louisiana wetland restoration planning)	Peer-reviewed outreach materials describing the potential of water flow changes on valued resources and habitats	Water Resource Development Act, NIDIS legislation	
				Better modeling and allocation tools to develop strategies to evaluate the impacts of water projects on agriculture, forestry, and living marine resource outcomes			
Attribution of Ocean and Coastal Phenomena to Long-term Global Change vs. Natural	Living marine resources vary in abundance and distribution over a variety of scales due to naturally-occurring cycles such as the Pacific Decadal Oscillation (PDO), the North Atlantic Oscillation (NAO), El Nino events, and other	Variation in Physical Forcing	Requires improved observations of environmental changes	Research to understand attribution of observed variability in to anthropogenic and natural causes		MSRA, ESA, MMPA, CZMA, CRCA	Observations of weather and ocean physical parameters on space and time scales pertinent to biological resources of management or ecological

Variation	sources of inter-annual variation. Managers increasingly need to know if changes observed in LMR populations are driven in part to these variable but stationary process or, increasingly, being influenced by long-term directional change being forced by global change. Management targets and measures are likely very different, especially in the long term, depending on the sources of observed variation.						importance
		Detecting Regime Shifts	Requires improved observations of environmental changes	Modeling efforts to understand human versus natural signals in the climate record			
		Predicting future conditions	Requires improved observations of environmental changes	Modeling efforts to understand future changes in both physical and ecosystem properties	Incorporate variation in ocean climate conditions affecting marine animal survival into stock assessments, population viability analyses and jeopardy decisions by NOAA. Management of living marine resources and coasts incorporates predictions of the impacts of climate variation and trends on productivity		Observations of living marine resource productivity in relation to scales of natural variability (e.g., annual to decadal) and longer-term climate trends
		Socio-economic impacts					Observations of socioeconomic outcomes in relation to variation and trends in climate-related changes in natural resources
Ocean Physical Changes, (e.g., warming impacts) on distribution, productivity, and phenology (i.e., the seasonal timing and distribution of biological	NOAA is responsible for providing living marine resource assessments required to manage the Nation's commercial and recreational fishing industry and protected marine species. These resources are also depended upon by native peoples for subsistence and help attract vast numbers of people to coastal regions for tourism	Determine Variation & Trend in ocean conditions influencing the productivity and distribution of living marine resources	Observations of weather and ocean physical parameters on scales pertinent to organisms. Maintenance of climate data records.	Development of regional climate prediction models and coupled atmosphere-ocean models.	Regional predictions of long term climate trends and changes in climate variability. Predictions of changes in ocean physical properties (temperature, salinity, currents, eddies, fronts, stratification, upwelling).	MSRA, MMPA, ESA, CZMA, MPRSA, CRCA	Monitoring of key oceanographic parameters (temperature, salinity, density, upwelling) and meteorological conditions (air temperatures, surface winds, etc.) at appropriate spatial and temporal

phenomena)	and recreation. If NOAA does not account for the effects changing ocean conditions on these living marine resources, there is an increased potential for inaccurate assessments and mismanagement of the resources. This would have detrimental effects on the living marine resources and the social and economic activities dependent upon them.						scales to determine the impacts of climate change and variability on biological processes of interest
		Determine Variation & Trend (cont.)	Rescue (data archaeology) of historical in situ physical and ecosystem observations; Satellite-based Climate Data Records for SST, Ocean Color, Marine Winds, and Sea Surface Topography (sea level)	Research to create improved algorithms resulting in more accurate, stable, and consistent Climate Data Records	Ocean climate summaries for specific ecosystems and marine managed areas		
		Ecological Impacts	Living marine resource and ecosystem surveys, biological samples, satellite ocean color observations.	Quantify impact of environmental forcing on vital rates, movements, and interactions of species. Develop coupled climate/ecosystem modes - incorporate mechanistic understanding of climate impacts into ecosystem and population models.	For different climate scenarios: predictions of growth, maturity schedule, reproductive success and distribution of living marine resources. For input into stock assessment models, setting fishing areas, and developing management strategies for protected species.	MSRA, MMPA, ESA, CZMA, MPRSA, CRCA	Monitoring of key biological parameters (abundance, distribution, vital rates) for species sensitive to climate-induced shifts in distribution and productivity, at regional scales and in NOAA's marine managed areas
				Research to better understand ecosystem interactions with physical environment	Management plans that take climate-induced variability in distribution and productivity into account in setting targets and thresholds	MSRA, MMPA, ESA, CRCA, CZMA, NMSP	

Ocean Physical Changes (cont.)		Ecological Impacts (cont.)	Evidence of changing distributions of key species caused by temperature changes	Models of effects on food webs resulting from changes in temperature	Changes in monitoring approaches and priorities; public education and outreach materials	MSRA, MMPA, ESA, CRCA, CZMA, NMSP	
			Identify indicator species and assess changes in their distribution pattern and phenology	Relate changes in physical environment and climate indices to changes in the distribution pattern and phenology of indicator species	Peer-reviewed outreach materials describing the potential impacts of physical changes on valued resources	MSRA, MMPA, ESA, CRCA, CZMA, NMSP	Monitor changes in biodiversity in relation to key ocean and coastal environmental variables
		Invasive Species Vulnerability	Mapping of invasive species locations and habitat ranges	Research to better understand invasive species' tolerance to changes in the physical environment	Interactive maps with capability to provide current and possible future invasive species habitat ranges	Invasive Species Act, Non-indigenous Aquatic Nuisance Prevention and Control Act, Lacey Act, ESA	Survey for invasive species abundance and distribution in relation to climate change variables
			Changing distributions of invasives and affected species	Models of vulnerability based on temperature change	Update vulnerability ratings, impact assessment, public outreach materials, and mitigation and prevention measures	Invasive Species Act, Non-indigenous Aquatic Nuisance Prevention and Control Act, Lacey Act, ESA	
					Outreach materials describing the potential impact of invasive species spread due to changes in temperature and salinities		
		Socio-economic impacts				MSRA, ESA, MMPA	
					Improved management of the living marine resources which		

					support: a $60 billion per year seafood industry; recreational fisheries that contribute $12 billion per year to the economy; native peoples dependent upon subsistence harvests; major coastal recreation and tourism activities.		
			Climate change impacts on coral bleaching and human uses of coral reef ecosystems.	Integrated assessment of the amount of coral reefs available under different management strategies and preferences and values for trade-offs between global strategies to reduce greenhouse gases versus local management strategies that can increase coral reef systems to withstand or recover from climate change coral bleaching	Socioeconomic impacts of climate change on coral bleaching, including economic impacts CRCA, NMSA on local economies and value of management strategies to protect coral reef ecosystems. How much to invest in global versus local management strategies for coral reef ecosystems.	CRCA, NMSA	Monitor coral bleaching and related environmental variables
					Peer-reviewed outreach materials describing the synergistic effect of land use and changes in environmental stressors on ecosystem function. Decision support tools to identify and	CZMA	

					minimize the effects of land use decisions on ecosystems		

Appendix D
Climate/Transportation/Communities Needs Assessment

[The following document was prepared in May 2008 by a cross-NOAA team under the auspices of the NOAA Ocean Council to respond to request from NOAA's VADM Lautenbacher for a summary of requirements to fulfill NOAA ocean and coastal stewardship mandates in a changing climate]

Climate Observation, Research and Management Requirements for Transportation and other Human Environment Concerns

Climate change is now and will continue to affect the U.S. transportation system, communities and industries both coastal and inland. Coastal areas are home to over 50% of the U.S. population, with the requisite supporting infrastructure – roads, rail, airports, ports, utilities – extremely vulnerable to climate change impacts such as sea level rise and increased storm intensity. Inland areas are threatened by greater flooding potential and drought. Following on a similar exercise developed for Climate and Ecosystems requirements, the NOAA Strategic Goals for Weather and Water, Ecosystem, and Commerce and Transportation undertook a preliminary assessment of the need for climate information to better meet NOAA programmatic responsibilities in the arena of the human environment. The summary below and the attached table serve to highlight climate requirements specific to transportation, coastal zone management and land use decisions, marine pollution incident management and other human-related infrastructure needs. A NOAA Climate Service delivering climate information, forecasts and models at appropriate scales for a number of key variables would be of great utility to these customers.

NOAA's Observational Requirements Necessary to Meet Climate/Human Environment Obligations:

Sea Level Rise

Sea level rise will have significant impacts on transportation and other built infrastructure in the coastal zone, exacerbating flooding, storm surge, and permanent inundation. 60,000 miles of coastal highway are already exposed to periodic storms and flooding; sea level rise will compound the problem for road maintenance and evacuation route planning. Major U.S. airports sited within coastal zones are also vulnerable to higher water levels. Marine transportation may see both threats and benefits from sea level rise: landside facilities will require raising or relocating, while at the same time channels could either become deeper and more navigable, or silted and closed to traffic. Changes in sea level may alter the services habitats provide to buffer coastal communities from storms, floods and other hazards. Coastal communities, agricultural areas, and other built infrastructure such as water treatment plants will become more vulnerable to inundation, storm surge and erosion stimulated by sea level rise and in some areas sea floor sinking. To meet stakeholder needs and NOAA responsibilities in coastal regions, NOAA will need additional observations and models on the actual and potential impacts of sea level rise.

Following are the priority measurements required to monitor sea level rise and its impacts on coastal built infrastructure and communities:

- High resolution bathymetry and geodesy for coastal regions
- High resolution satellite altimetry and ground-truth from tide gauge monitoring
- Down-scaled climate model results allowing regionally-appropriate estimates of the rate and impacts of sea level rise
- Periodic mapping and characterization of coastal habitats that are threatened by sea water inundation (e.g., coastal wetlands, shorelines estuaries, riverine floodplains)
- Observations of shoreline and habitat change over time, including inventories of built infrastructure in sensitive areas.
- Accurate coastal and inland elevations and continuous vertical velocities for coastal areas (includes built physical infrastructure and adjacent coastal environments)
- Regional and local rate of sea level rise scenarios based on model projects
- Regional decision support tools (including inundation maps, integration of GIS layers for elevation mapping) to analyze impacts of sea level rise scenarios on coastal resources and human communities.
- Adaptation guidebooks that provide examples of best practices for planning that incorporate SLR projections

Precipitation Changes/Extremes

Rainfall (and other precipitation) or the lack thereof can be both a boon and a bane to transportation, industry, physical infrastructure and communities. Increased flooding due to more intense rainfall will affect ports, roads, rails, runways, pipelines, homeowners, regional/local public utilities, etc… in all parts of the country. Low-lying bridge and tunnel entrances and culverts are extremely susceptible to flash floods, and flooding also causes erosion, subsidence and scouring of road/runway beds, rail and pipelines, and bridge supports. Service interruptions across all modes will become more common. Changes in seasonal precipitation levels and types can also be problematic; for example more rain rather than snow leads to immediate runoff and landslides. Periodic droughts will also have impacts, whether to maritime transport on reduced-flow rivers and lakes, or decreased visibility for airports/roads located in drought susceptible areas due to increased wildfires. NOAA information needed on precipitation includes:

- Observations of surface moisture and rainfall to support models
- Frequency, intensity, and duration of precipitation to support models
- Probabilistic estimates of rainfall intensities for a range of durations and recurrence intervals of 20, 50, and 100+ years
- Projected increases in intense precipitation
- Model trends of drought conditions

Temperature Changes/Extremes

Warming temperatures and heat extremes will affect all modes of transportation. Rising temperatures in Alaska are already causing permafrost to thaw, impacting surface transport with slumping and buckling of roadways and pipelines, impeding access to remote communities and commerce with shorter ice road seasons, and endangering coastal and native communities.

Northern states in the lower 48 will likely see benefits from reduced expense on salt and chemicals for icing, as well as reduced adverse environmental impacts from icing treatments. Surface infrastructure, though, will experience more freeze-thaw conditions, with heaves and holes occurring on bridges, roads and runway foundations, and warmer temperatures affecting pavement and rail integrity. Excessive heat periods will augment drought conditions, increasing wildfires, threatening communities and infrastructure directly and causing air, road and rail service interruptions. Warming temperatures are also likely to provide longer shipping seasons for Alaskan ports and the Great Lakes, but reduced lake levels from heat and evaporation will impact cargo carriage. Information requirements include:

- Observational temperature records
- Models of temperature trends
- Climate outlooks of temperature and case studies to support models

Loss of Sea Ice

Loss of sea ice as a result of warming temperatures poses a unique set of challenges for the U.S. transportation industry and the infrastructure supporting communities in ice-prevalent regions. In particular Alaska and the Arctic are experiencing unprecedented change, with loss of sea ice, rising sea levels and eroding coasts all occurring faster than forecast. Sea ice melt is also causing the very real potential for at least a seasonal, if not permanent, oceanic trade route across the Arctic that could cut existing oceanic transport by an estimated 5,000 nautical miles (one week). These changes have implications for a host of activities such as shipping, oil/resource development, fishing, ecotourism, subsistence livelihoods and scientific exploration – all in an ecologically fragile region lacking the security and safety infrastructure necessary to handle this rapid change effectively. Additionally, communities and villages are sensitive to sea ice loss because of impacts on storm resiliency, inundation and effects of sea level rise. Services needed by users to plan for sea ice melt impacts include:

- Annual and seasonal monitoring of sea ice extent, thickness and related ocean physics (satellite monitoring and in situ measurements)
- Monitoring of sea ice loss in relation to coastal community resilience

Storms

Climate change may also generate more intense storms, which will lead to greater impacts on infrastructure and communities from precipitation, winds, and wind-induced storm surge. Global warming will likely increase the intensity of hurricanes making landfall, a particular concern in the Gulf Coast because of its heavy coastal population and critical oil and gas industries. Pipelines, drilling platforms, and refineries are all vulnerable to storm forces, endangering not only the environment but also the economy and other regions critically dependent on the Gulf for oil and gas. Storm surge and wave action can also damage homes, roadways and bridge decks, destroy signals and signs, and leave dangerous debris on highways, runways and in waterways. Severe storms also disrupt shipping and aircraft operations. Evacuation route planning, particularly in coastal areas, is made more difficult by the likelihood of road inundation as a result of flooding and storm surge.

- How climate may affect hazardous weather (frequency and intensity)

- Model trends of increased intensity of tropical cyclones
- Storm frequency/intensity predictions
- Improved projections of the link between extreme events and climate variability and change (including, flooding and drought events, El Niño scale changes in precipitation and temperature and tropical cyclone impacts at a regional/local scale)
- Assessments to spatially and temporally examine the impacts of extreme weather events on coastal communities suitable for decision making

Freshwater Supply and Quality

Coastal zone management, land use decisions and decision support tools such as the National Integrated Drought Information System (NIDIS) need freshwater supply information to inform regional drought early warning systems. NIDIS, for example, is designed as a user-based drought information system that assesses potential drought indicators and impacts in order to provide tools for anticipating, preparing for and mitigating the effects of drought. Decision makers at the regional and local level need the following climate services to inform scenarios on water supply and partnerships to share resources between communities in times of water shortage.

- Increased network of groundwater and stream gauge monitoring stations
- Regional precipitation, freshwater flows in surface and subsurface waters, water quality, temperature characteristics
- Atmospheric water vapor content
- Monitoring of freshwater and estuarine flows, water quality, salinity and other parameters
- Water sustainability projections under variable community growth and water supply scenarios
- Improved hydrological and meteorological modeling under climate change influences to anticipate water supply issues.