Strengthening NOAA Science

Findings from the NOAA Science Workshop

April 20-22, 2010

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Executive Summary

The April 2010 Workshop on Strengthening NOAA Science brought together 70 participants, principally NOAA scientists and science managers, to provide their perspectives on the grand science challenges facing NOAA and on opportunities to improve how NOAA conducts its science. This Workshop was the first of its kind for NOAA in which such a broad group of active scientists and science managers from across the agency was asked to consider and articulate their views on these critical issues. There was a strong consensus on an overarching grand science challenge of developing and applying an integrated approach to connecting geophysical, natural, and human components to provide a holistic understanding of the interactions between human activities and the Earth system. In addition, several topic-specific grand challenges were identified. These were to:

- Acquire and incorporate knowledge of human behavior to enhance our understanding of the interaction between human activities and the Earth system
- Understand and quantify the interactions between atmospheric composition and climate variations and change
- Understand and characterize the role of the oceans in climate change and variability and the effects of climate change on the ocean and coasts
- Assess and understand the roles of ecosystem processes and biodiversity in sustaining ecosystem services
- Improve understanding and predictions of the water cycle at global to local scales
- Develop and evaluate approaches to substantially reduce environmental degradation
- Sustain and enhance atmosphere-ocean-land-biology and human observing systems

Two crosscutting challenges associated with uncertainty were to:

- Characterize the uncertainties associated with scientific information
- Communicate scientific information and its associated uncertainties accurately and effectively to policy makers, the media, and the public at large.

Workshop participants identified several areas where new or altered practices could strengthen NOAA science. Three issues of broad agreement were identified. These included needs for (i) better-defined science career paths to attract and retain the best quality staff and to ensure a motivating research environment, (ii) corporate services that facilitate the conduct and advancement of science, and (iii) more efficient and timely funding processes for sustaining the research structure. The participants recommended that additional meetings be convened with scientists and NOAA leadership to develop solutions.

Introduction

The Workshop on Strengthening NOAA Science was initiated to address the central role of science in NOAA within the broad context defined by the agency's mission and Administration and NOAA science priorities as enunciated by Dr. Jane Lubchenco, Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator. This first-of–its-kind meeting sought to engage active scientists and science managers from across NOAA to assist in identifying grand science challenges for NOAA over the next five to twenty years and to recommend practices for improving how NOAA conducts science. As such, the Workshop was intended to be the initial step in a larger and ongoing effort being undertaken at the direction of Dr. Lubchenco to strengthen science throughout NOAA. The Workshop's main findings are summarized below, with more detailed information provided in the Appendices.

Workshop participants were asked to address two broad questions: (1) What are the grand science challenges facing NOAA, and (2) What are the opportunities for improving how NOAA conducts its science? Workshop findings provide direct input from working scientists and science managers for use within the agency in the development of science objectives of the Next Generation Strategic Plan (NGSP), the FY12 NOAA budget, materials for the Senior Executive Service (SES) Summit Science Day, and for updates of the NOAA 5- and 20-year Research Plans.

Background: Dr. Rick Rosen, the NOAA Research Council (NRC) Vice-Chair, led the initial drafting of the workshop charge. Dr. Paul Sandifer (Senior Science Advisor to the NOAA Administrator) and Dr. Randy Dole (Deputy Director for Research in the Physical Science Division of NOAA's Earth System Research Laboratory) were invited to co-chair the Workshop and, working with the NRC, further refined the charge. The intended audiences for Workshop outputs were identified as:

1) Dr. Lubchenco and other NOAA senior leadership
2) NOAA Research Council
3) NOAA Program Planning and Integration (PPI) for Next Generation Strategic Plan (NGSP)
4) NOAA Budget Office
5) SES Summit planners
6) NOAA Science Advisory Board
7) Science colleagues throughout NOAA and in the external community

The Workshop co-chairs convened a small group of leading scientists, science managers and leaders from across the agency to serve on the Workshop program committee (Appendix B). This program committee played a crucial role in refining the key questions to be considered at the workshop and developing a program intended to address the interests of both participants and the intended audiences. The program committee and co-chairs wish to thank the many NOAA staff who contributed so effectively to the Workshop (Appendix C), and especially wish to recognize the exceptional contributions by the NOAA Research Council Executive Secretary, Derek Parks, and AAAS Fellow Gabrielle Dreyfus. The Workshop organizers also wish to thank NOAA's Office of Oceanic and Atmospheric Research and the Office of the Deputy Undersecretary for Oceans and Atmosphere for sponsorship of the event.

The general organization of the Workshop consisted of plenary sessions with overview presentations on each question followed by detailed discussions in breakout groups. Each of the five breakout groups consisted of approximately 10-15 participants organized to include scientists from all NOAA line organizations, including the proposed NOAA Climate Service. To encourage breakout group participants to address the issues as they felt appropriate, the Program Committee did not provide additional detailed questions to constrain their deliberations. Following the breakout sessions, the groups reconvened in plenary to summarize their findings and identify areas of common agreement. Appendix A provides the agenda and Appendix C lists the participants and their affiliations. More detailed information from the presentations and breakout groups is included in appendices corresponding to the sessions.

Chapter 1: Identifying Critical Science Challenges for NOAA

The focus of Workshop Day 1 was the question: "What are the grand science challenges for NOAA over the next five to twenty years?" As background for discussions, Dr. Paul Doremus (Acting Deputy Assistant Administrator and Director of Strategic Planning) provided a synopsis of the draft NGSP (version 2.0) and Dr. Lubchenco presented her visions for strengthening science in NOAA. Dr. Lubchenco's remarks set the stage for leading NOAA scientists who presented their perspectives on science grand challenges in topical areas central to NOAA's mission: Dr. Isaac Held (NOAA Geophysical Fluid Dynamics Laboratory) on Climate, Dr. Marty Ralph (NOAA Earth Systems Research Laboratory) on Weather and Water, Dr. Steve Murawski (NOAA National Marine Fisheries Service) on Resource Management, and Dr. Mary Ruckelshaus (NOAA National Marine Fisheries Service) on Ecosystem Science. Appendix D provides summaries of these presentations. Following the morning sessions, breakout groups convened to discuss grand science challenges facing NOAA. The following major themes were identified through the breakout groups and in subsequent plenary discussions.

Overarching Grand Challenge: *Develop and apply holistic, integrated Earth system approaches to understand the processes that connect changes in the atmosphere, ocean, space, land surface, and cryosphere with ecosystems, organisms and humans over different scales.*

- All breakout groups recognized the vital importance of developing a more holistic understanding of the connections between changes in the physical Earth system and its biological components, including human interactions. Developing this understanding will be vital to addressing the societal grand challenge proposed by Dr. Lubchenco: "to improve human well-being while restoring the planet's life support system," as well as to achieving NOAA's long-term vision of "healthy ecosystems, communities, and economies that are resilient in the face of change."

- Achieving the above is critical to NOAA's mission and mandates and will require many partners, both nationally and internationally. At the same time, the agency has unmatched and distinguished capabilities in its core areas of science expertise. NOAA is thus uniquely positioned to lead crucial scientific advances toward understanding connections among areas such as climate, weather and water, and coastal and marine ecosystems. NOAA has tremendous capabilities and potential to improve understanding of the relationships between the physical, chemical, and biological sciences and humans in areas such as: marine resource management, risk assessment and response for both natural and numerous human-caused hazards, climate change adaptation and mitigation, development of sustainable and healthy coastal communities, and promotion of human well being. In short, workshop participants regarded this overarching grand challenge as an exciting goal that would help integrate collective capabilities across NOAA to achieve major scientific advances for the benefit of society and the environment.

Cross-cutting challenge: The workshop participants also identified two crosscutting challenges associated with uncertainty that are intimately related to the overarching grand challenge and the other grand challenges discussed below:

- Characterize the uncertainties associated with scientific information,
- Communicate scientific information and associated uncertainties accurately and effectively to policy makers, the media, and the public at large.

In addition, there was broad agreement on the importance of addressing the following seven major science challenges (in no priority order) for NOAA to meet its overarching grand challenge.

1. ***Acquire and incorporate knowledge of human behavior****, societal values, and economics into our weather, climate, and ecosystem assessments to enhance our understanding of the interaction between human activities and the Earth system.*

   - For NOAA to meet its mission to understand and predict changes in weather, climate, oceans and coasts, to share that knowledge with others and use it, and to improve society's conservation and management of marine resources, we must develop a much better understanding of the human dimensions of these issues. In addition, improving the human condition of current and future generations is a central part of NOAA's quest for better understanding of an integrated Earth system. Woven throughout the discussion of the grand challenges below is the recognition that an active, innovative, and integrated natural and social science enterprise can improve human well-being. Societal values and needs should help shape scientific priorities. Better understanding of how people respond to information should inform the production and communication of information. The future of our communities and livelihoods depends on our ability to adapt and respond to changing weather and climate. Sustaining the capacity of ecosystems to provide vital services will depend on our ability to identify and effectively communicate their economic and societal benefits as well as ecological importance.

2. ***Understand and quantify the interactions between atmospheric composition and climate variations and change***

- To achieve NOAA's overarching grand challenge, NOAA science must improve understanding of the causes and consequences of climate variations and change, including the interactions between atmospheric composition and climate, and the physical, chemical, biological and ecological impacts. A rigorous scientific foundation built upon NOAA's strengths that includes observations, models and analysis is essential for integrative understanding of the processes involved in the climate system and how they explain specific phenomena and their consequences. Such detailed understanding of climate processes and their impacts will lead to more credible predictive capabilities that include characterization and quantification of associated uncertainties. Understanding the manner in which atmospheric composition affects climate and vice versa, the physical and biogeochemical climate feedbacks governing climate change, and the resulting impacts on the Earth system are integral requirements for NOAA to accomplish its mission. A key thrust is determining the impacts due to natural variations of the system and those caused by human activities on all space and time scales. The scientific outcomes of the interactions involving atmospheric composition and climate are relevant to many sectors of societal concern including adaptation and mitigation decisions and linkages to social science, e.g., tradeoffs involving air quality and climate, contrasting effects of greenhouse gases and aerosols, effects on ecosystems, implications of climate change for sustainability in the water, energy, transportation and health sectors.

3. ***Understand and characterize the role of the oceans in climate change and variability*** *and the effects of climate change on the ocean and coasts, including biological, chemical, and geophysical effects (e.g., sea level rise, ocean acidification, living marine resources).*

- As the Nation's oceans and atmospheric agency, NOAA is responsible for advancing the acquisition of scientific knowledge on the oceans, coasts and Great Lakes, and for taking on the newer challenges arising in the context of the changing climate. A critical research challenge for NOAA is to understand the role of the oceans in climate change and variability, including implications for predictability of regional climate, as well as to anticipate impacts of climate change on the ocean and coasts, including chemical, biological and geophysical effects. Among the phenomena that need to be addressed through observations and modeling are the meridional overturning circulation, natural fluctuations (e.g., ENSO) and long-term trends in the coupled ocean-atmosphere system, transformation of ocean ecosystems (e.g., ocean acidification, biodiversity loss and shifts, alterations in species' distribution and ranges), and the manner in which changes in polar climate may affect climate and ecosystems elsewhere. Models need to be developed, based on a strong science foundation, to support regional decision-making including sea level rise, regional impacts on coasts, and development of coastal resources, e.g., aquaculture, energy, habitat restoration, capture fisheries. Coastal community adaptation to climate change should benefit from the scientific developments. Climate and carbon cycle feedback mechanisms involving marine and terrestrial ecosystems and anthropogenic impacts, including marine pollution, also constitute key science areas where advancements by NOAA will be essential. Determination of vulnerability thresholds, effects of humans on ecosystems and ecosystem effects on humans, and the response of humans to ecosystem changes represent an intertwining problem where NOAA's collective capabilities can make major contributions in support of our mission.

4. ***Assess and understand the roles of ecosystem processes and biodiversity in sustaining ecosystem services*** *and the connections among ecosystem condition, resilience, and the health of marine organisms, humans, and communities.*

- One of the primary aims of NOAA science is to provide information that will help improve human well-being while sustaining and, where necessary, restoring the planet's life support system. Maintenance of natural biodiversity is a crucial part of sustaining healthy ecosystems and the essential goods and services they provide. We need to understand how human activities change biodiversity and natural system functions, and how those changes in turn affect the ability of ecosystems to provide benefits for humans. NOAA science should identify vulnerabilities, possible thresholds, and the nature of relationships between ecosystem components, ecosystem resilience, and the value of services provided. Science focal areas include: (1) understanding connections between ocean condition and human health, including a strong focus on long-term stressors; (2) developing system models to elucidate the cumulative consequences of changes in multiple ecosystem components on continued provision of ecosystem services; (3) consequences of changes in biodiversity and habitats for the stability and magnitude of critical ecosystem services such as fishery landings, shoreline protection, recreation value, and the resulting socio-economic condition of nature-dependent economies; (4)

understanding how human communities respond to ecosystem changes; and (5) market and non-market valuation of ecosystem benefits.

5. ***Improve understanding of the water cycle*** *at global to local scales to improve our ability to forecast weather, climate, water resources and ecosystem health.*

- According to the projections by the Intergovernmental Panel on Climate Change (IPCC), while the globally averaged precipitation may increase only by a few percent per degree of global average temperature increase, in many places precipitation intensity and drought frequency will both increase. Such changes are expected to further stress already over-strained water supply and flood control systems, making it even more critical to improve the efficiency of water resource management throughout the US and in many other parts of the world. This problem poses a considerable challenge because with current technology it is impossible to determine the composition, structure and physical properties of the subsurface (both soil and bedrock), and therefore, to develop models that accurately predict the movement of water below the Earth's surface. As the nation's agency responsible for forecasting fresh water flows, from droughts to floods, NOAA is uniquely aligned to address this challenge in cooperation with its partners for subsurface hydrology. Further, water fluxes in the atmosphere, on land and in the subsurface affect weather, climate, and hydrology, and are a key component for maintaining healthy ecosystems, fisheries, and transportation on rivers and estuaries. It is therefore imperative that NOAA emphasize improving understanding of the water cycle, across all spatial and temporal scales, and from observations to forecasts. Water managers critically need reliable short- and long-term forecasts, and developing these forecasts requires detailed understanding of water cycle processes and their implications for water resources in a changing environment.

6. ***Develop and evaluate approaches to substantially reduce environmental degradation****, overfishing, and climate change in ways that maximize benefits and minimize adverse impacts.*

- Understanding the consequences of human activities and natural factors on ecosystem conditions will help NOAA provide science-based guidance on approaches for managing or coping with environmental change. NOAA has adopted Integrated Ecosystem Assessments (IEAs) as a decision analytical framework for combining what we know about system-level biophysical processes with social system responses to support ecosystem approaches to management such as Coastal and Marine Spatial Planning. System-modeling approaches that incorporate quantitative, tactical level information with quantitative or semi-quantitative, strategic information are needed to support these policy and decision frameworks and to provide information for evaluating likely effects of management decisions. Specific science needs include: (1) identifying a set of indicators and thresholds (or limits, boundaries, or tipping points) that track sustainability and illuminate trade-offs for shared objectives for marine ecosystems; (2) learning from protection and restoration actions (e.g., protected areas, coastal restoration) and their effectiveness in sustaining ecological function and other social goals; (3) linking the cumulative effects of human actions and climate to changes in habitats, water quality, and species status; (4) developing a capability to evaluate proposed responses to the challenges of climate change, including a broad range of potential mitigation and adaptation actions; and (5) developing integrated ecosystem forecasting/early warning capabilities for both predicting and anticipating natural and human-caused ecosystem changes and their implications for ecological and human health.

7. ***Sustain and enhance atmosphere-ocean-land-biology and human observing systems****, and their long-term data sets, and develop and transition new observing technologies.*

- Workshop participants emphasized that addressing this challenge is fundamental to achieving NOAA's mission. Discussions in this area highlighted similar points made on Days 1 and 2 of the Workshop. Observations provide the foundation for all of NOAA science and, indeed, science in general. NOAA plays a vital role in this area both nationally and internationally, especially in providing and sustaining long-term observations of the atmosphere, ocean, coasts, Great Lakes, fisheries and marine ecosystems. Observations within NOAA are derived from many sources, from in-situ to remote, including extensive satellite observations. These observations encompass an extraordinarily broad range of space and time scales and types from microscopic biological observations to global satellite data used for weather and climate. The numbers and diversity of needed observations of Earth system components will continue to grow rapidly. NOAA will play a core role in obtaining, quality-controlling, organizing and distributing these diverse data internally and externally, as well as providing the long-term data stewardship required to preserve and protect the data for this and future generations. NOAA also will play a major role in developing innovative new techniques to help fill key gaps in our observing systems. Sustaining existing observations, enhancing future observations and performing analyses of observations to enhance Earth system understanding will be essential to address the overarching grand challenge identified at this Workshop.

The first part of the Workshop focused on identifying grand science challenge questions for NOAA over the next five to twenty years, but did not address questions of how to do the science required to meet these challenges. **In plenary discussions and comments numerous participants voiced support for follow-on workshops focused on specific topics that would be aimed at identifying actions NOAA could take to address these science grand challenges.**

Chapter 2: Improving How NOAA Conducts Science

Four invited panelists opened this plenary session with short presentations on issues related to scientific integrity (Dr. Dian Seidel, NOAA Air Resources Laboratory), scientific literacy (Louisa Koch, Director, Office of Education), partnerships (Dr. Frances Van Dolah, NOAA National Centers for Coastal Ocean Science), and science management (Dr. A. R. Ravishankara, NOAA Earth Systems Research Laboratory). The following are examples of issues that reached consensus in multiple breakout groups. A few suggested practical steps for improvement that are expected to have little or no net cost to NOAA are presented in Box 1. Appendix E provides a summary list of the issues identified and discussed by the participants.

Management/Business Practices

An overarching point of discussion was how NOAA prioritizes science in its management practices. This was addressed on many levels, from the pragmatic to the philosophical. At the most basic level, there was an overwhelming consensus among participants that the relationship between NOAA's administrative service providers and those charged with carrying out NOAA's core science mission need to be realigned to ensure that the primary focus of service providers is to facilitate NOAA's science and related activities. The general perception was that centralization of services (human resources, grants and acquisitions, etc.) has led to deterioration in service, impacting NOAA's ability to fulfill its scientific mandates. For example, budgets are often not received until mid-year, while some line offices cutoff purchasing by July 31. This process can leave our scientific enterprises essentially without funds for seven out of twelve months and have serious impacts on the core science functions.

Other variables in the current financial process also impede scientific excellence. All five working groups expressed the need to foster an environment where scientists can focus on science. In this regard, steps should be taken to address administrative challenges that may substantially limit scientific progress. For instance, inter-agency transfers of funding have been stymied by delays in getting requisite Memoranda of Understanding (MOU) in place. NOAA's administrative services need to be responsive to the needs of a versatile organization and should not act as "gate-keepers" that prevent or discourage collaboration. Difficulties and the time required for MOU and fund transfer processes can discourage NOAA and external partners from developing or conducting collaborative scientific projects.

A second major topic discussed was how NOAA could more effectively direct resources to support and sustain scientific excellence, especially in high-risk areas. To enable scientists to respond more effectively to short-term (<2 yr) rapid response issues of national concern, a suggestion was made for NOAA to establish readily accessible and flexible funding pools to increase responsiveness and adaptability. Secondly, it was widely recognized that NOAA must conduct long-term, high-risk research with the potential to lead to transformational advances in understanding and development of vital information, products and services. Such innovative research is a critical component of NOAA's overall science portfolio, yet it is often incompatible with milestone-driven performance metrics, and should be evaluated by other means. One example of important high-risk research is the need to incorporate aerosol feedbacks into climate models.

NOAA science requires high capacity, cutting edge computing capabilities to remain a global scientific leader. There was a general feeling that NOAA's information technology support for scientific computing is insufficient and that the needs of scientific computing are subordinate to IT security measures.

Extensive discussion was dedicated to the need for NOAA to improve communication of its science-based outcomes, and to quantify the benefits of NOAA to society. For example, NOAA needs to be better able to communicate the differences between forecasts and scenario-based projections, and to be better recognized as an authoritative source of scientific information. To aid in communications, NOAA requires a stronger science/policy interface. Additionally, most of the breakout groups recommended the establishment of a single, enterprise-wide NOAA science dictionary for ecosystems, earth system, climate, weather, variability, uncertainty, social science and its subcategories to improve communication and collaborations among scientists from different disciplines and backgrounds.

Box 1. Examples of low- or no-cost practical steps to improve NOAA science.

- Create a business environment that acknowledges science as our product
  - Develop a service attitude in acquisitions, information technology, and human resources
  - Expedite MOU process
- Develop sabbaticals, increase use of IPAs and cross-office rotation opportunities for scientists
- Develop a searchable NOAA-wide project database to facilitate collaboration
- Develop rational guidelines that are not demoralizing to visiting foreign scientists
- Enable high risk transformational research not subject to milestone performance measures

Many of these issues require little or no additional funding to address. These solutions would benefit both internal and external partners by removing administratively imposed barriers.

Scientific Integrity and Outcomes

Workshop participants recognized that, although ensuring the integrity of scientific information is a constant requirement for all NOAA personnel, including e.g. public information officers and managers as well as scientists, it is rarely discussed until problems arise. Formal ethics training typically available to Federal workers is not directly relevant to issues of scientific integrity or professional ethics. Ethical issues are not limited to personal choices, but are also institutional. For example, management choices required by mandates may be perceived as in conflict with available scientific information. Any such conflicts should be openly and carefully addressed to ensure the integrity of NOAA's overall enterprise. NOAA should develop a scientific integrity/ethics training program for its personnel.

Integrity of NOAA's science also could be enhanced through development of a formal NOAA-wide policy for internal peer reviews of manuscripts. Such policy should ensure a consistent and timely process, free of internal or external politics, and consider only scientific quality. Similarly, NOAA should provide formal guidelines for its scientists and managers with regard to public presentations and when it is, or is not, proper for a scientist or manager to speak in his or her official capacity as a NOAA employee. Such guidelines should help define the special roles and responsibilities of NOAA personnel as they relate to the at times conflicting concerns of individual freedom of speech and the need for public servants to earn and maintain the public trust.

Workforce

NOAA's core science mission addresses a very broad range of problems, requiring a diverse workforce that is enthusiastic, knowledgeable, and flexible. There was substantial discussion regarding a perception that government scientists are second tier to academics, and how that perception might be overcome. In order to acquire and retain the best scientific talent in the agency, it was widely agreed that a science career path needs to be supported so that NOAA scientists interested in staying in science do not have to move into management positions to advance professionally. In particular, it should be made clear that there are opportunities for stepwise career advancement for scientists, and a clear pathway should be codified and available from early career to successive levels of responsibility, independence, and seniority. Broader use and availability of Senior Scientist (ST) or Senior Level (SL) classification positions will help, but will not be sufficient. Workshop participants further identified the practice of recruiting junior, typically younger non-FTE-scientists by NOAA-affiliated institutions as a workforce issue needing attention. These young scientists invested in NOAA are often not available to replace FTEs who leave for retirement or other reasons. Regardless, where this cannot be rectified, rewards and acknowledgements need to encompass non-FTE scientists, in addition to direct hires, to ensure their continued enthusiasm for engagement with NOAA.

NOAA hiring is severely impaired by bureaucratic processes, and even after a person is hired, workforce procedures can continue to be onerous, especially for foreign personnel. Science is a creative endeavor, but current human resource processes are based on a production-style atmosphere. For the mid-grade and senior scientists, a continuing education capacity needs to be developed, including the potential for sabbaticals and IPA assignments, standard practices in the academic scientific community. NOAA should also consider broader use of inter-line-office science rotations to encourage scientific “cross-fertilization” and strengthening of a multi-disciplinary science workforce.

Many working groups cited the “deemed export requirements” as a major impediment for recruitment, collaborative research with visiting foreign scientists, and the maintenance of international collaborations. NOAA needs to promote a healthy and open collaborative atmosphere that enhances scientific growth and recruitment while engaging the external community. The way NOAA science centers and laboratories are required to implement “deemed export” is completely contrary to such an open and collaborative atmosphere and demeaning to foreign visiting scientists, students, post-docs, and potential recruits.

A written policy outlining the proper balance of personal vs. institutional gains from intellectual property could be developed. If applicable, the ingenuity of NOAA scientists and engineers would be rewarded with intellectual property rights, highlighting the diversity of rewards possible for the diversity of NOAA personnel.

Infrastructure

It was generally agreed that a key to NOAA’s ability to address the grand challenges lies in investments in sustained observations. NOAA needs to be able to implement new technologies for an enhanced system of earth-ocean-atmosphere-land and human observations. In addition, there is a need to optimize and integrate observations across disciplines rather than independently, and to ensure that a wide range of observing platforms, sensors, and other assets are part of a long term system of observations.

Investment in high performance computing is urgently needed in order to remain at the cutting edge of modeling and molecular sciences. This need was expressed across all line offices represented at the workshop. The vast quantities of data generated from sustained observing systems and modern biological science (e.g., genomics) require continually-improved data management capacity.

NOAA Centers and Laboratories are critical to achieving the grand challenges laid out in this workshop. NOAA needs to develop a plan for maintaining modern scientific facilities, and planning and providing for instrumentation replacement in order to remain at the cutting edge of technology.

Given the holistic goals of its future activities, NOAA must develop a process that enables prototype products and applications that are generated by integrating disparate data sources and to readily cross traditional line office boundaries to be transitioned to services. One model that has been successfully employed on several key problems is the use of test-beds to accelerate development and testing of new technologies and their transition into products for services.

It was noted that the search engines on the NOAA websites need improvement to enable internal NOAA staff to access data that are currently unobtainable. This workshop highlighted the diversity of NOAA science conducted and also illustrated that there are few internal mechanisms to assist scientists from one discipline or area of research to connect with those in other areas to explore opportunities for collaboration. It was suggested that a searchable NOAA-wide database of all research projects would enable better collaboration and coordination of scientists, both internally and externally to NOAA.

There was strong support for the NOAA library system, including both its holdings and the services of its professional staff, and the importance of continued investment in the library by the agency. A review of the NOAA Library process was suggested, as electronic access to journals and other library resources appears to vary across the agency.

External Partnering

NOAA needs to engage a wide array of partners to effectively achieve its goals, including private enterprise, non-government organizations, academia, local and state governments, and other federal agencies. NOAA has had significant successes when partners are brought to the table during the planning stages of projects dealing with regional and local issues. However, NOAA's success is often hampered by erratic funding processes, inability to make long-term funding commitments, and the administrative burden of MOUs that make NOAA an unattractive partner for collaboration.

Miscommunication between NOAA and its partners can also lead to tension and mistrust. NOAA, therefore, needs to develop a culture of open and transparent communication of its science prioritization and budgeting processes to eliminate sources of tension and to build trust with its partners.

Chapter 3: Expanding the Discussion on Strengthening NOAA Science: Broadening Engagement of Internal & External Science Communities

By design, this initial Workshop on Strengthening NOAA Science was kept small and all participants were from within NOAA. However, participants fully agreed that, given the complex and difficult nature of the grand challenges discussed in Chapter 1 and NOAA's ongoing responsibilities, it is imperative that NOAA take full advantage of input from both the internal and external science communities. To make substantial progress toward these challenges, NOAA will need to strengthen and expand science relationships internally and between NOAA and its partners. In particular, the group recognized the critical role that our contractors, partners in academia, other federal agencies, and in the private sector play in advancing NOAA's science mission. Further, better integration across the scientific disciplines is required to support significant scientific progress on topics that are at the core of NOAA's mission.

A continuing internal science conversation is essential for NOAA, just as it is for academic institutions and other organizations, but an ongoing dialog between NOAA and the external science community is equally important. Participants recommended the inclusion of external partners in future science workshops, with the caveat that some discussions of internal NOAA practices should remain NOAA-only. They also suggested that, while NOAA-only meetings are appropriate at the early stages of strategic planning, we should engage our partners as fully as practical in the development of science plans and implementation approaches. As part of ongoing internal and external science discussions, workshop participants strongly supported planning of a larger NOAA science conference, but on a longer timescale (e.g., 12-months out) and with clearly articulated goals and participation by external partners. The NOAA Science Advisory Board should be involved in helping NOAA improve its interactions with the external community including planning for a potentially larger science conference.

Some near-term specific opportunities for engagement of the external community in development of NOAA research plans include the agency's next Five-Year Research Plan and 20-Year Research Vision. This Workshop identified high-level science challenges for NOAA (Chapter 1) that will inform development of the next versions of these plans. The NOAA Research Council has lead responsibility for these documents and typically has engaged the external community in their development. As in the past, the Council will again need to identify the relevant external research communities and develop an engagement strategy, including goals. Such engagement could take numerous forms, including but not limited to public review, one or more directed workshops, a single larger conference, joint planning exercises with cooperative institutes, and others.

The option or combination of options chosen by the Council and NOAA leadership will depend on the goals determined for engagement and on logistical considerations. Among the latter are: (a) the relative ease/costs of convening a series of workshops versus a large conference, (b) competition between a potential NOAA Science Conference and other conferences on the calendar, and (c) the best means to encourage effective communication among participants, a key element in the current Workshop. An additional consideration, of course, is the degree of visibility and breadth of community involvement sought.

In order to address the grand challenges described in Chapter 1, NOAA must support and facilitate its internal scientific community and leverage its relationship to existing and potential partners. This Workshop was a vital and necessary first step in achieving these goals. But it was only a first step. It is essential for NOAA to continue and expand its internal science discussions and extend the conversation to include the external science community in regular and meaningful ways. Future workshops/conferences should be organized to take the next step and understand how we can fully engage our internal and external scientific communities.

Conclusions and Recommendations

The 2010 Workshop on Strengthening NOAA Science was remarkable in several aspects. For the first time, it brought together a broad group of scientists and active science managers from across NOAA to consider and discuss questions of critical importance to the agency and its future. Scientists from across all line organizations participated, and ranged from senior scientists to those who were relatively early in their scientific careers. Scientists in the breakout groups actively considered and discussed key crosscutting science challenges for NOAA that connected different NOAA goals in the current NOAA Strategic Plan, helping to inform thinking for NOAA's Next Generation Strategic Plan. The extent of this crosscutting thinking went well beyond what typically occurs in planning meetings organized around either conventional goal or line office structures. Outputs of the Workshop include identification of science challenges of high priority to the entire agency that will require engagement and integration of all of NOAA's science assets and strong participation by the external science community. They also included frank discussion and identification of practical measures NOAA could take to improve day-to-day science operations.

Workshop participants were enthusiastic and quite constructive in their contributions. In a post-meeting evaluation (Appendix F), all respondents indicated that the workshop was a good use of their time, and almost all found it enjoyable. All respondents also indicated that similar meetings should be held in the future, and a significant number volunteered to help in organizing future meetings. Major benefits of the meeting included the opportunity to interact with scientists from across NOAA and to be exposed to, and discuss, a diversity of new ideas. In this respect, the Workshop served as a very useful educational experience for participants, while also helping to inform NOAA.

As the first of its kind, this Workshop was an experiment. Although in many ways the above results alone could justify identifying this Workshop as successful, this meeting should be viewed as only the beginning of what should be a longer-term process. A number of comments suggested areas where future meetings could be improved. While all participants expressed enthusiasm for holding similar future meetings or cross-NOAA workshops, several also noted that in the end assessing the success of this workshop will depend on whether NOAA leadership acts upon the challenges, issues and recommendations that were identified and whether leadership is committed to continue and broaden the participation of NOAA's scientists in discussions of the agency's science goals and research priorities.

In this regard, the following steps have been taken or are now in progress. At the conclusion of the Workshop, PPI received the initial Workshop outputs (e.g., draft grand science challenges and other presentations and workshop notes), and has already incorporated key Workshop findings into a revised draft Next Generation Strategic Plan. The day following the Workshop, the co-chairs briefed the NOAA Research Council on the Workshop outcomes, with the entire meeting devoted to this topic. The present document was prepared to serve as input for the SES Summit "Science Day" held June 3, 2010 and to provide input for the revised NOAA Research 5-year and 20-year plans and the FY12 and ongoing budgets. In addition, the science challenges identified should lay the foundation for discussions with both internal and external scientists regarding science action plans.

The following further steps are recommended. As needed, additional briefings can be provided to NOAA Senior leadership, e.g., at a NEP/NEC meeting, as well as to the NOAA Science Advisory Board. This white paper will be distributed to all Science Workshop participants, and consideration should be given to broader NOAA as well as external distribution, perhaps through a NOAA web site. Already, some participants have given briefings on the Workshop outcomes at their home offices, centers, or labs. More such presentations should be encouraged, as they are an excellent way to strengthen science communication across NOAA. Further, NOAA leadership should ensure that this first step leads to many more that will result in a regular process of consultation with and involvement of active scientists in identifying the agency's science priorities and ensuring development of effective science action plans. Such efforts should also emphasize opportunities to acquaint NOAA scientists with other researchers and research activities across the agency. Consistent with participant recommendations, additional Science Workshops should be held that involve cross-NOAA participation, perhaps focused on specific questions and possible implementation steps. The external community should be engaged in topic-oriented workshops and in any larger-scale Science Conference. However, before this occurs there should be careful planning to identify specific objectives of the larger Conference and whether this approach is the best means for achieving those objectives.

Appendices

A. Workshop Agenda

Day 1: April 20, 2010

0815-0900: Registration, coffee and informal discussions
0900-0915: Introduction to Workshop: Paul Sandifer and Randy Dole
0915-1000: Next Generation Strategic Plan- Paul Doremus
1000-1015: Break
1015-1130: Keynote Presentation- Dr. Jane Lubchenco – Q/A and discussion
1130-1230: Science Grand Challenges Panel

- Grand Challenges in Climate: Isaac Held
- Grand Challenges in Water & Weather: Marty Ralph
- Grand Challenges in Resource Management: Steve Murawski
- Grand Challenges in Ecosystem Science: Mary Ruckelshaus

1230-1330: Lunch
1330-1415: Plenary discussion & Instructions for Breakout 1
1415-1430: Reconvene in breakouts
1430-1600: Breakout 1: What are the grand science challenges for NOAA over the next 5-20 years?

- Group 1 - Chris Barnet (facilitator)
- Group 2 – V. Ramaswamy (facilitator)
- Group 3 - Mary Ruckelshaus (facilitator)
- Group 4 - Dian Seidel (facilitator)
- Group 5 - Fran Van Dolah (facilitator)

1600-1615: Break
1615-1715: Breakout 1 cont'd
1730-1930: Reception with Dr. Lubchenco and NOAA Leadership (HCHB main lobby)

Adjourn

Day 2: April 21, 2010

0800-0830: Coffee
0830-1030: Breakout 1 Reports and Plenary Discussion
1030-1045: Break
1045-11:45: Panel on Opportunities for Strengthening NOAA Science

- Professional ethics/scientific integrity: Dian Seidel
- Role of NOAA scientists in enhancing Public scientific literacy: Louisa Koch
- Building strong NOAA-University –private sector connections: Frances Van Dolah
- Managing science in an agency environment: A. Ravishankara

11:45-12:30: Plenary discussion and instructions for Breakout 2:
1230-1330: Lunch
1330-1500: Breakout 2 What are opportunities and practical steps for strengthening NOAA science?

- Group 1 - Chris Barnet
- Group 2 – V. Ramaswamy
- Group 3 - Mary Ruckelshaus
- Group 4 - Dian Seidel
- Group 5 - Fran Van Dolah

1500-1515: Break
1515-1630: Breakout 2 cont'd
1630-1700: Reconvene in plenary – Recap Day 2 preview Day 3
1700: Adjourn for the day: Dinner on your own

Day 3: April 22. 2010

0800-0830: Coffee
0830-1030: Plenary for Breakout 2
1030-1045: Break
1045-1300: General Plenary Discussion

- Workshop Summary
- White Paper
- Options for a larger NOAA Science Conference
- Opportunities for engaging broader community

1300: Adjourn Workshop
1330-1500: Program Committee Working Session

B. Program Committee Members

- Paul Sandifer (USEC)-Co-Chair
- Randall Dole (NCS)-Co-Chair
- Chris Barnet (NESDIS)
- Paul Doremus (PPI)
- Beth Lumsden (NMFS)
- V. Ramaswamy (NCS)
- Pedro Restrepo (NWS)
- Rick Rosen (NRC)
- Mary Ruckelshaus (NMFS)
- Dian Seidel (OAR)
- Susan Solomon (NCS)
- Frances Van Dolah (NOS)
- John Adler (OMAO)

C. List of Participants & Affiliations

NESDIS:

1. Chris Barnet	STAR	Physical Scientist
2. Chris Brown	STAR	Oceanographer
3. Ivan Csiszar	STAR	Supervisory Physical Scientist
4. Eric Leuliette	STAR	Oceanographer
5. Chris Elvidge	NGDC	Physical Scientist
6. Thomas Peterson	NCDC	Chief Scientist
7. Scott Cross	NCDDC	Regional Science Officer
8. Paul Chang	OPPT	Remote Sensing
9. Eric J. Bayler	JCSDA	Remote Sensing

NWS:

10. Bob Glahn	MDL	Director
11. Paula Davidson	OST	Asst Dept Administrator
12. Jiayu Zhou	OST	Climate Services Division
13. David Green	OCWWS	Physical Science Manager
14. Pedro Restrepo	OHD	Senior Scientist for Special Projects
15. William Lapenta	EMC	Deputy Director
16. Terry Onsager	NCEP	Space Weather
17. David Novak	NCEP/HPC	Science Operations Officer
18. Yan Xue	CPC	Meteorologist
19. Jon Gottschalck	CPC	Meteorologist
20. Wayne Higgins	CPC	Director

OAR:

21. Jim Overland	PMEL	Oceanographer
22. Frank Marks	AOML	Supervisory Meteorologist
23. Silvia Garzoli	AOML	Supervisory Oceanographer
24. Dusan Zrnic	NSSL	Senior Scientist
25. Dian Seidel	ARL	Research Meteorologist
26. Stan Benjamin	ESRL/GSD	Branch Chief
27. Dick Feely	PMEL	Supervisory Oceanographer
28. Marie Colton	GLERL	Director
29. John McDonough	OER	Deputy Director

NCS:

30. V. Ramaswamy	GFDL	Director
31. A.R. Ravishankara	ESRL/CSD	Director

32. Ron Stouffer	GFDL	Physical Scientist
33. Marty Hoerling	ESRL/PSD	Meteorologist
34. Marty Ralph	ESRL	Program Manager, WxW ST&I
35. Isaac Held	GFDL	Senior Scientist
36. Gabriel Vecchi	NCS/GFDL	Research Oceanographer
37. Steven S. Brown	ESRL/CSD	Research Chemist

NMFS:

38. Mary Ruckelshaus	NWFSC	Program Manager, Ecologist
39. Sam Pooley	PIFSC	Science Director, Economist
40. Lisa Ballance	SWFSC	Division Director
41. Michael Vecchione	Systematics	Zoologist/Lab Director
42. Rick Methot	OST	Research Fish Biologist
43. Tom Minello	SEFSC	Supervisory Research Fish Biologist
44. Rusty Brainard	PIFSC	Supervisory Oceanographer
45. Paul Rago	NEFSC	Supervisory Research Fish Biologist
46. Doug Demaster	AKFSC	Science and Research Director
47. Phil Levin	NWFSC	Program Manager
48. Rita Curtis	OST	Director, Econ & Social Analysis Prgrm
49. Dana Hanselman	AKFSC	Stock Assessment Scientist

OMAO:

50. CDR John Adler		Emerging Technologies Officer

NOS:

51. Frances Van Dolah	NCCOS	Research Biochemist
52. George Sedberry	ONMS	Superintendent, Gray's Reef NMS
53. Theresa Goedeke	NCCOS	Social Scientist
54. Mary Culver	CSC	Acting CLS Program Manager
55. Dru Smith	NGS	Chief Geodesist
56. Mary Erickson	OCS	Supervisory Physical Scientist
57. Mark Monaco	NCCOS	Acting Director, CCMA
58. Andy Armstrong	OCS	Physical Scientist
59. Shawn McLaughlin	NOS NCCOS	Research Microbiologist
60. Dwight Trueblood	CICEET	NOAA Co-Director

Other Attendees:

61. Paul Sandifer	Co-Chair	NOAA Science Advisor
62. Randy Dole	Co-chair	Supervisory Meteorologist
63. Steve Murawski		Director of Scientific Programs

64. Leon Cammen		Sea Grant Director
65. Gary Matlock		RC Monitoring Research Committee Chair/PPI
66. Jamie Kruse		NOAA Chief Economist
67. Ned Cyr		Research Council NMFS
68. Paul Doremus		PPI Deputy Assistant Administrator
69. Rick Rosen		Research Council Vice
70. Chet Koblinsky		Research Council/Climate Program Office

Special Guests:

71. Jane Lubchenco		NOAA Administrator
72. Louisa Koch		Director, Office of Education

Staff:

73. Derek Parks	OAR	Research Council Exec Sec
74. Gabrielle Dreyfus	USEC	AAAS Fellow
75. Roger Pierce	OAR	Meteorologist
76. Chris Smallcomb	NWS	Meteorologist
77. Shelby Walker	OAR	Chemist
78. Frank Parker	OAR	Marine Biologist
79. Nathalie Valette-Silver	OAR	Planning Director/Oceanographer

D. Summary of Presentations

Next Generation Strategic Plan – Paul Doremus

- Long term trends and stakeholder views
    - Regional-scale climate trends
    - Understanding and predicting non-climate ecosystem impacts
    - Continuity and effectiveness of observations, data, monitoring, forecasts, and predictions
    - Delivery of scientific information
    - Environmental literacy
- NOAA's Mission, Vision, and Goals
    - Mission: Science, Service, and Stewardship – To understand and predict changes in weather, climate, oceans, and coasts. To share that knowledge and information with others. To use the information to manage natural and marine resources.
    - Vision: Thriving communities and economies within ecosystems that are resilient in the face of change
    - Goals
        - Climate Adaptation and Mitigation
        - Weather Ready Nation
        - Sustainable Ocean Ecosystems
        - Sustainable Coastal Communities
- Strategic Questions for NOAA Science: what is the science that underlies our goals?
    - Reliable, accurate, and integrated Earth observations
    - An integrated environmental modeling network
    - A holistic understanding of oceanic and atmospheric systems

Keynote Presentation: Science Serving Society – Dr. Jane Lubchenco

- Strengthening NOAA Science – A continuous process that involves engaging NOAA's scientists and science managers and our external partners to address four key questions:
    - What are the *grand challenges* for NOAA Science?
    - What are the *best practices* for encouraging promoting, and protecting healthy science at NOAA?
    - What is the *optimal alignment* to address those challenges?
    - How can NOAA ensure *continual evaluation, enhancement, and celebration* of its science?
- Science Serving Society – science provides the foundation for credible decision-making
- Grand Societal Challenges – How to improve human well-being while restoring the planet's life support system?

  - Millennium Ecosystem Assessment – loss of services, drivers for degradation are constant or increasing, and reversing degradation while meeting increasing demands will require significant changes
  - Key Indicators
    - World population growth
    - Species extinction rates
    - Planetary boundaries - "tipping points"
    - Global fishing trends
    - Millennium development goals – Environmental Sustainability
- What is NOAA's role?
  - Environmental sustainability and resilience
  - Disaster risk reduction
  - Providing enabling capabilities – Earth observations, models, assessments, ecosystems based management, coastal and marine spatial planning
- Integrating natural and social sciences – scientists should:
  - Address the most urgent needs of society
  - Communicate their knowledge and understanding widely
  - Exercise good judgment, wisdom, and humility

Grand Challenges in Climate – Dr. Isaac Held

- Mitigation – uncertainty in the overall magnitude of the climate response is important. Critical uncertainties:
  - Cloud feedbacks
  - Aerosol forcing
  - Multi-decadal variability
  - Land and ocean carbon update
  - Stability of the polar ice sheets
- Attribution – a necessary first step towards decadal prediction. Are emerging trends forced signal or internal variability?
- Adaptation – the difficulty of regional forecasts on decadal scales should not be underestimated. What is the best open, transparent framework for connecting regional projections to impacts?
- Monitoring – monitoring of key indices will make a profound difference to our understanding of climate change
  - Land and ocean surface temperatures
  - Energy balance at the top of the atmosphere
  - Ocean heat content
  - Sea level
  - Mass balances of the polar ice sheets
  - Carbon sources and sinks

Grand Challenges in Weather and Water – Dr. Marty Ralph

- Warn-on-Forecast –including Multi-Function Phased Array Radar
- Precision forecasts for air travel – NextGen and 4 dimensional weather cube
- National imperatives on fresh water
  - Protect lives and property – floods and droughts
  - Support economic security
  - Protect health and environment
  - Mitigate escalating risk – scarcity, floods, climate change, aging infrastructure
- Understand, monitor and predict atmospheric rivers – a key to extreme precipitation, water supply and the global water cycle
- Hurricane forecast improvement – track, intensity, and storm surge forecast reliability
- A Global "super" model with statistical post processing – could it outperform ensembles?
- Weather-driven renewable energy
- Overarching Challenges:
  - Maintain a culture of innovation
    - Engineering and scientific support thriving in an operational environment
    - Transitions to operations rewarded
  - Understand key physical processes for weather and water
  - Regional optimization and integration of observation networks
  - High resolution numerical models for aerosols coupled with ocean models

Accelerate innovation through testbeds

Grand Challenges in Resource Management – Dr. Steve Murawski

- Primary science goals for the iron triangle of people, environment, and animals
  - Understand and predict how people effect and are affected by interactions with the environment
  - Comprehend how conditions in the marine environment and their variability influence natural ecosystems and human communities
  - Quantify and predict the relative effects of human interactions and fluctuations in the environment on the abundance, recruitment, and biodiversity of animal populations, communities, and ecosystems
- How to enumerate marine animal populations – cooperative research and new technologies, more precise and spatially resolved information needed.
- Grand challenges for environmental sustainability
  - Many indicators, but no agreed-upon definition
  - Relationship between indicators and adaptive environmental management
  - Defining cumulative impacts and "tipping points"
  - Connectivity of offshore and near-shore ecosystems and the role of protected areas
  - Prioritization of coastal habitats for protection

- Understanding long-term trends in environmental forcing
    - Attribution of climate signals impacting ecosystems
    - Impacts of Ocean warming
    - Impacts of loss of sea ice
    - Impacts of ocean acidification
    - Freshwater supply
    - Sea level rise
- Need for transformational research
    - Advancing technology for quantifying and observing – high resolution mapping
    - Robust forecasting of bioeconomic conditions under various management scenarios

Grand Challenges in Ecosystem Science – Dr. Mary Ruckelshaus

- Observing ecosystem phenomena
    - Deep ocean
    - Species tracking
- Forecasting ecosystem events
    - HABs, sea nettles, seafood safety/mortality
- Analytical support for ecosystem-based management – what is needed?
    - EBM as a policy directive
    - Marine spatial planning as a component of EBM
    - Integrated ecosystem assessments for decision support
        - System models - synthesize available data, determine key interactions, generate hypotheses, and identify gaps for strategic decision making
        - Quantifying and valuing ecosystem services
        - Learning from protection and restoration actions

Professional Ethics and Scientific Integrity – Dr. Dian Seidel

- Premise: All worthwhile human endeavors are strengthened when they are carried out in an ethical manner and with integrity
- We do not discuss these issues enough in NOAA
- Public service is a public trust, and we must always be worthy of that trust
- Current training and resources are not particularly useful. Instead, look to On Being a Scientist: A Guide to Responsible Conduct in Research, and to values statements from AGU and AMS – focus on the enterprise, not the individual
- Discussion Topics
    - Being honest about uncertainty – what is our moral obligation?
    - Differing scientific perspectives – use these to strengthen, not weaken science
    - When science and stewardship conflict – will need to be addressed sooner rather than later

  - Transparency in science – should there be any expectation of privacy for federal work products?
  - Freedom of speech for Federal scientists – communicating our science is the only way to make it useful to society, but conflicts can and do arise
- What do we stand to gain?
  - Self respect
  - Respect of our scientific colleagues
  - Confidence of the public we serve

The Role of NOAA Scientists in Enhancing Public Scientific Literacy – Dr. Louisa Koch

- Recruiting the next generation of NOAA scientists
  - Scholarships, LCDP, ELDP
  - Increased usage of Post-Docs
- Nurturing NOAA's future senior science executives
  - Create better incentives and a career path for senior scientists in NOAA
- Role of NOAA scientists in promoting science literacy
  - Take advantage of pipelines to the public – Science on a Sphere, Ocean Today Kiosk

Building Strong NOAA-University-Private Sector Connections – Dr. Frances Van Dolah

Now is the time...for NOAA to spur the creation of new jobs and industries, revive our fisheries and the economies and communities they support, improve weather forecasting and disaster warnings, provide credible information about climate change and ocean acidification to Americans, and protect and restore our coastal waters [and] ecosystems."

Dr. Jane Lubchenco, Message to NOAA staff, March 20, 2009

NOAA's challenge to address the diverse science needed to fulfill our strategic goals in climate adaptation and mitigation, weather resilience, and sustainable fisheries and communities cannot be met without engagement with partners at universities, private enterprise, and every level of government.

University Partnerships play several critical roles in NOAA's science enterprise, including maintaining NOAA's capacity in transformational research and rapidly evolving technologies, bridging NOAA's national objectives at regional and local needs, and furthering NOAA's mandate for a public literate in environmental and climate science. NOAA currently uses a number of formal mechanisms through which it engages universities: Cooperative Institutes, Regional Integrated Sciences and Assessments, Cooperative Science Centers, partnership labs, the Sea Grant College Program, and targeted extramural grants programs. NOAA's largest investment in university partnerships resides in eighteen Cooperative Institutes that link NOAA research labs in long-term partnerships (oldest now 43 years) with major universities or non-profit research institutes. In addition to collaborative research, CIs provide training of students and postdocs who represent the next generation of scientists, access to vessels and high performance computers, and advocacy for NOAA science. Another model resides in NOAA's Hollings Marine Laboratory, established under a 50 year Joint Project Agreement, which brings five federal, state, and academic partners together in one building. In this model, NOAA provides administration and infrastructure, while each partner institution brings unique expertise to joint research initiatives. Cooperative Science Centers fulfill a different role in partnering with minority serving institutions to increase NOAA-relevant scientific capacity as well as environmental and climate literacy to these communities. Regional Integrated Sciences and Assessments (RISAs) utilize university partnerships to align NOAA's climate research with a new paradigm of stakeholder-driven climate research. The NOAA Sea Grant College Program's similarly engages region-specific knowledge and expertise to fulfill NOAA's national commitment to conserve coastal resources and enhance coastal economies at the local level. In addition, numerous NOAA line offices utilize targeted, competitive extramural research grants programs to fulfill mission-specific research needs.

Federal, State, Local, and Private Sector Partnerships NOAA is dependent upon partnerships at all levels of government and the private sector to meet its emerging science challenges. For example, meeting the unique needs of different regions for ecosystem-based management of ocean resources or the development of region-specific climate tools requires collaboration and information sharing with state and local governments and stakeholders whose culture and economies are dependent upon these resources. Nationally and internationally, NOAA must leverage multilateral partnerships to obtain the best science to support climate assessments, the development of integrated observing systems, and to inform climate predictions. Every NOAA strategic goal requires the engagement of a network of partners to address a myriad of complex challenges.

Managing Science in an Agency Environment – Dr. A.R. Ravishankara

I. Mission focused science – the concept of science in this setting and the utility in thinking about Pasteur's quadrant (key outcome- help mission and "create science" that furthers mission + others aspects)

II. Resources and their acquisition and allocations: the compulsories- dealing with money, personnel, etc.

III. Many pathways for better results that do not involve money: Optional but important- how can we at NOAA strengthen science without money increases?

-Setting scientific Goals by managers with scientists

-Maintaining and enhancing depth when there is constant pressure for breadth, integration, etc.

-Empowering and "liberating" scientists to be "scientists"

-How to measure success? Does a performance measure really measure performance? How can we better measure success?

E. Summary of Breakout Group Discussions

Day 2 - Report Outs by Breakout Group:

Group 1:

- Science vs research definition ahead of time would be good
- Discussion led quickly to generic recommendations, which leads to believe a diverse science conference is a good thing and very useful.
- Theme 1: How does NOAA develop a seamless information capability across time and spatial scales?
- Grand Challenge: Understanding and communicating climate change
  - Quantify or understand uncertainty, not reduce uncertainty.
  - Climate skepticism exists within NOAA, so how do we communicate this as an agency? Consensus within on the nature of the problem to facilitate external communication.
- Grand Overarching Challenge: Develop a complete Earth System Model
- Theme 2: Coupling of physical information (Weather and Climate) with ecosystem processes.
- Infrastructure challenges
  - NOAA wide data sharing – diverse set of data

Group 2

- Macro picture
- Earth System Science Integration
- Water Resource Forecasting
- Ecosystems and Social Sciences
- Habitat Restoration
- Other Issues
  - R2O
  - Alternative energy
  - Leixicon
  - Long term data series

Group 3

- Framed grand science challenges as questions
- Water forecasting
  - Flooding and drought and understanding they are different
  - Where water reaches the sea for flooding and hazard mitigation for storm surge models
- Ecosystem approaches the management for resiliency
  - Use of tools

- Maintain sustainable coastal community
    - Community = ecol, economic, etc. Not any one factor.
    - Indicators across sectors—biogeochemical, biodiversity, etc.)
- Biodiversity in maintaining ecosystem function?
    - Don't know the diversity we have which makes determining this a challenge
    - Thresholds
- OBS to improve forecast skill
    - Optimize and integrate OBS across disciplines rather than independently.
    - OSSEs = Observation System Simulation Experiments
- Themes transcending challenges:
    - Climate literacy
    - OBS for all NOAA foci that are long-term
    - Process studies and test beds
    - People—need the best
    - Communication is central to promote enhanced literacy
- Comments from WG3 members
    - Optimizing OBS—optimizing use of data that is collected

<u>Group 4</u>:

- 4 basic grand challenges to NOAA
    - Provide authoritative of evolving climate and ecosystems
    - Evaluate and communicate predictability and uncertainty
    - Ensuring the continuity of OBS and analysis—concern from funding perspective
    - Develop models to support regional decision making
- Some disagreement on the context and level of integration for social science in NOAA
- Natural fluctuations vs long-term shifts—ENSO and AMOC
- Cost effective ways to get at these issues.
- Climate sensitivity—robustness
- Mechanisms for geo-engineering. NOAA should be at the forefront of proposals
- Buoys should be comprehensively established rather than ad hoc and should include multiple sensor suites so that the data can be more broadly applicable rather than only limited to individual projects
- Spatial scales in modeling is a challenge.
- Parking Lot issues:
    - need more consistent terminology
    - Homeland security issues with foreign nationals
        - Cannot be forced to escort to bathrooms! DOC interpretation is problematic
    - HR issues: Hiring, contracting, Grants; science mission cannot get done without improvements by NOAA. Degradation over last decade is obvious.
    - Reorganization issues and role of OAR is uncertain

    - Infrastructure issues—like importance of labs.

<u>Group 5:</u>

- Coupling whole Earth systems
- Understand the predictability and characterize the uncertainty as a function of spatial and temporal scales across processes.
- What is the value of services provided by intact ecosystems?
- Scenario modeling and simulation to allow scenario development for the emerging societal imperatives.
- NOAA's contribution to informing how society will move forward from a fossil fuel based society to a sustainable society

Day 3 - Report Outs by Breakout Group and Final Plenary:

<u>Group 1:</u>

- Scientific Integrity
    - Spending time responding to requests and follow up requests. Transparency requires even more. End up being held hostage to success. Staffing needed to allow for this – cognizant front end science person to handle initial requests.
    - Muzzling of science – speaking and credentials, billable hours, etc. We are held to a higher standard. Make certain people credentialed spokespeople for NOAA science.
    - Internal reviews of papers – inconsistent across line offices. Perceived as oppressive and politically motivated in some cases. Need explicit guidance with scientific input.
- Science Management
    - NOAA wide data management infrastructure
    - IT infrastructure and regulations are stifling as written
    - NOAA wide HPC and fleet management for efficiency of resource use
    - Contractor positive feedback mechanism – scientists do more management and less science when they are successful. Feeds upon itself with success.
    - Deemed Exports – some have purged foreign nationals. NOAA as an organization has pushed this to the lowest levels for handling. It is a distasteful burden for people at the lab and the scientist. Demeaning for all involved.
    - Penalization for innovation projects that doesn't succeed – current performance metrics discourage risk-taking.
    - Peer review of labs – matrix management creates problems for doing this.
    - Steady funding of labs – more time going into proposal writing and the feedback loop mentioned above. Shouldn't need to go to other agencies for resources.
- Workforce Development

    - Scientists are motivated by certain things – they need a career path that rewards them appropriately. Twenty percent of staff end up doing 80 percent of the work.
    - Improve efficiency of paperwork and burdens on staff
    - Workforce is not diverse – do we know the root causes?
    - How to retain corporate knowledge due to retirement – end of career transition back to scientist to mentor
    - Scientists satisfaction survey
    - NASA end of prime mission reviews – capture what worked and what didn't
- External interactions
    - Problems with MOUs – we need to be able to move money quickly and efficiently. Can cause missed opportunities. One year performance period is also problematic.
    - Encourage international collaboration – travel budgets, etc
    - University partners – partners or competition given scarce resources.

<u>Group 2:</u>

- Science Infrastructure
    - Numerical modeling needed to the science and human dimensions.
    - New data sets
    - New obs platforms
    - HPC and data storage – visionary approaches needed
    - Timely evaluations and reviews and future directions
    - Collaborations and partnerships
    - Flexibility
- Leadership
    - Transparency, succession planning, training and mentorship, and commitment
    - Strong communications and science literacy – timely announcements emphasizing NOAA science.
    - Education/Outreach – frequent science meetings
    - Integration of science – loss of depth cannot be sacrificed as a result.
- Research to Applications
    - Strong support for testbeds
    - Cannot be overly prescriptive
    - Support for high risk research that may never transition
    - Support long time series data
    - Assessments as a high level bar of evaluation and flexibility to engage
- Collaborations
    - Need to ensure partnerships are appropriate, efficient and meeting our needs.
    - Internships are important
- Corporate Services
    - Grants, HR, procurement, MOUs all in decline

  - Taskers and data calls taking up valuable time
  - Transparency in science and in management
  - Practice sound environmental principles across our own facilities.
  - High ethical standards in everything

<u>Group 3:</u>

- Better define what is within the NOAA box and what falls outside. Policy statement and guidance for the nature of NOAA science in support of a mission agency.
- Retain and enhance research, not just heavily applied science
- What makes NOAA labs unique with respect to academic labs? Impacts for workforce and hiring
  - Long term, sustained observations and modeling
  - Congressional and statutory/regulatory
- Relevance, quality, and performance – clear ties to research plans, but enough flexibility to respond to emerging needs that are relevant. Clear path to applications. Use CIs to inject innovation into NOAA
- Workforce
  - Trade-off between FTE [corporate knowledge] vs contractors [flexibility]. FTEs need to be aimed at the long term needs or multi-disciplinary to provide flexibility.
- Science Enterprise Model
  - Clear functional roles across line offices – role of OAR
  - Vertical and horizontal integration are essential – designated responsibility and budgetary authority
  - Efficient money transfers
- NOAA Wide Research Project Database
- Responsiveness –
- Delay in budgetary process – enable multi-year rollover distribution of funding to mitigate problems that arise due to these delays.
- Streamline planning process – update budget requests with current updates
- Transitions
  - Early user coordination and pull
  - Operational science maintenance doesn't get enough funding consideration
- Partnering – erratic funding process makes NOAA less attractive as a partner
- Targeted recruiting based on survey of current new employees to determine best sources for NOAA.
- Enthusiasm - Lab level travel funds, sabbaticals, details to other collaborative labs, participation on international groups

<u>Group 4</u>

- Ethics and Integrity

    - Elevate issue from office of chief scientist to create a culture
- Managing science in an agency environment
    - Prioritize and commit to our core capabilities from a leadership level
    - Collaborative teams
    - Eliminate perceived or actual conflicts of interest
- Workforce – excellence and creativity – recognize other achievements beyond just published papers. Use existing recruiting mechanisms (STEP)
- Partnerships – enhance equity between federal and CI staff – financial and otherwise.
- Contractors and deemed exports – reliance on non-citizens is a two-way street – language issues sometimes make communication more difficult. Science may be sometime undermined by this. Balance in these areas.

<u>Group 5</u>

- Understand what motivates scientists (having an important problem to solve from start to finish) and ensure those needs are being met (make sure they feel like premier scientists).
- Provide 21st century tools and tolerate risk and failure in the organization
- Enhance capability and usability of NOAA websites – key word searching
- Inventory of post doc and grad student fellowship opportunities that PIs can access
- Make sure we continue to have top quality equipment and infrastructure to ensure best scientists stay with NOAA.
- Partnerships – up to date inventory of MOUs
- **Scientific integrity – always strive to be unbiased, dispassionate, and scientifically accurate**

Final Plenary: Grand Science Challenges – Paul Sandifer

1. Develop a holistic integrated earth sciences approach to enable new levels of understanding and forecasting of effects of stressors and environmental change
    a. Add land explicitly
2. Acquire and incorporate knowledge of human behavior into our assessments and the effects of the environment on humans and other organisms
3. Understand and characterize the ocean's role in climate change and the effects of climate change on the oceans
4. Assess and understand coastal and marine ecosystems, including biodiversity and interconnections between humans and marine ecosystems, to develop a capacity for integrated ecosystem management
5. Improve understanding of the water cycle at global and local scales
    a. Increasing the lead time by three is a huge challenge and will include short term weather forecasts and convection
6. Develop and evaluate ecosystem restoration and geo-engineering approaches to mitigate effects of environmental degradation.

7. Communicate scientific information and the associated uncertainties and unknowns effectively and with as little bias as possible.
    a. Characterizing the uncertainties too.

Question #1 Summaries
Discussion on Grand Challenges
NOAA Science Workshop April 21, 2010

Summary of Breakout Group #1

Overview

- Some discussion on what is difference between science and research
    - Would be useful to explicitly define these
- Interesting side-note: discussion was not along line offices or even strongly along goal lines – it quickly tended towards the holistic "box in the middle"
    - Leads me to believe that having NOAA science workshops across all line-offices will be rewarding and fruitful
- Tried to organized discussion into broad themes – but ran out of time….

Theme #1: How does NOAA develop a seamless information capacity across time and spatial scales?

- More than simply model resolution: need to understanding relevant processes, how they interact.
- Can/should weather and climate use same (unified) model
    - Unified framework allows pooling of resources and improvements to benefit all
    - But there are differences in techniques and users of product.
    - Should be openly debated and reach a NOAA consensus
- Distinct challenges:
    - Role of aerosols: weather, climate, air quality, nutrient transfer
    - Role of clouds, cloud microphysics, precipitation, cloud feedback
- Predictability, how to deal with a deterministic forecast in a stochastic system
    - Bigger issue – not enough time to discuss – but essence was ensemble mean forecasts work well for weather – are they appropriate for climate?

Challenge: Understanding and communicating climate change

- Challenge: Understanding climate change attribution and uncertainties
    - Agility needed because of potential surprises and Earth system inertia
    - Humility for the whole process
    - Earth system has intrinsic non-linear variability, separability of anthropogenic signal is complicated
    - Quantifying versus reducing uncertainties
        - "reducing uncertainties" is the wrong scientific motivator
        - e.g., adding aerosols to analysis would improve our capability but would increase uncertainty
- Interesting communication issue
    - How does NOAA communicate climate change (specifically anthropogenic global warming) when reasonable skepticism exists within our ranks
        - Again, tends to support the idea of having weather/climate/ecosystem community meeting within NOAA

Grand Overarching Challenge: to Develop a complete Earth System Model

- Challenge: Comprehensive Earth-System model required space environmental component
  - Required to support existing products and services that support economic and national security infrastructure
  - Also necessary to improve understanding of solar variability of the full climate system
  - Geomagnetic field for weather sensors
  - Lack of research component

Theme #2: Coupling of physical information (weather and climate) with ecosystem processes

- Different than the scaling issue in that it is bring two worlds together
  - e.g., unique in that biosphere can act on itself, adds new dimension
- Connection between ocean and human health
  - Have only touched surface of problem
  - Have not focused on long-term stressors and implications for human health
- Already working towards defining parameters – very difficult – but obvious need to work towards linkage with climate models
- Fisheries needs to be predictive (rather than reactive)
  - What climate parameters do fish care about?
  - Objective would be a weather service like forecast
  - Education component to gain public trust of stock assessment
- Need to integrate social sciences (e.g., economic and political analysis) into all levels natural science research and applications
- Clearly a NOAA mandate and NOAA has the ability to integrate.

Infrastructure Challenges

- Challenge: Identifying, Developing, and Implementing the required observing system (in-situ, ship, aircraft, satellite) to support "the challenge"
  - Clearly a NOAA mandate
  - Evolving needs (e.g., greenhouse gas information system at cap-and-trade scales) and shift from science to operational products.
  - "What measurements must be started today so that future generations have the long-term datasets they need to make decisions? We must ensure that our monitoring programs particularly those run by the NOAA and USGS reflect a long-term climate-quality monitoring that anticipates future policy needs" (William B. Gail, Feb. 2010 BAMS p.197-207)
  - Gaps in scientific knowledge – unknown deep ocean
  - Remote sensing to map and monitor marine resources at multiple scales
  - Development of technologies to define the impacts of stressors on organisms at the cellular to community level.
- Build an enterprise data management system across all of NOAA
  - Preserves information content of data
  - Facilitates exchange of data (and collaboration) between broad disciplines
  - A "vehicle" to bridge ecosystem goals with weather and climate

Summary of Breakout Group #2

Earth System Science Integration

- NOAA has a long history of observations, modeling and understanding related to climate.
  - specific issues and expertise
- Understanding causes and consequences, informing, and predictive capabilities – science/research in L/O ➔ integration
- Emerging ➔ linkages across the sciences, extending to the Earth System sciences, ecosystem science, and social science
- Increasing requests from customers for more sophisticated products that need the linkages
- *Example: Global climate - rate of change -sea-level changes – also cryospheric variations/changes - consequences for ecosystems- socio-economic impacts. Abrupt changes and vulnerability thresholds.*

Water Resource Forecasting

- Water – how much, how little, and quality – extremes in precipitation/ dryness
  - In a changing population
  - In a changing climate (including extremes)
  - In a regional context (floods, droughts)
  - How do we effectively communicate/ provide the new information and services, with knowledge on the uncertainties?
  - How can NOAA become more *Predictive* instead of *reactive,* enabling sound water resource and ecosystem management?

Ecosystem and Social Science

- Integrated science will be needed to achieve a full understanding of the ecosystem
- Future observations will be needed to support this work – unified, integrated observing?
- Better understanding of how humans impact ecosystems and ecosystem impacts humans, including 'indirect' connections
- Balance between utilization and sustainability, recognizing multiple stressors. Social science critical mass to address the challenge.
- NOAA needs to ensure that science (including social) is at the table when policy decisions are made.

Habitat Restoration

- Through better understanding of the ecosystem- a better understanding of ecosystem services will emerge
- Science integration
- Increased/improved observations
- Changing climate impacts will increase the demand for these services
- How does NOAA build capacity to meet this demand

A Number of Issues

- Transition Research to Operations/Applications

- Alternative energy – impacts across NOAA capabilities
- Lexicon conundrum
- Attribution
- High-quality, long term time series of data
- Geo-Engineering
- Bureaucracy vs. Science
- Ensuring societal impacts are addressed
- Retention and Recruitment and Promotion

Summary of Breakout Group #3

What are the interactions between the ocean and climate?

- Meridional Overturning Circulation-observations and modeling
- Observing the deep ocean-physical, chemical, biological, transport of properties
- Transformation of ocean ecosystems (e.g., ocean acidification, biodiversity, species migration)
- How would changes in polar climate affect ecosystems in mid and lower latitudes?

How can we increase water resources forecast lead time by a factor of 3?

- Needed for both high (flood) and low water (drought) flow conditions
- Need to integrate hydrologic models with storm surge models
- Relevance to NOAA's mission-forecasting of water quality – e.g. fisheries, transportation, energy, etc.

How do you implement ecosystem approaches to management to maintain resiliency and sustainable ecosystem goods and services?

- Covering coastal-pelagic-deep ocean ecosystems
- How will human activities change the ecosystem?
- How will humans respond to ecosystem changes?
- Integrated ecosystem forecasting
- Example-marine spatial planning currently lacks its scientific foundation

How do we maintain sustainable coastal communities?

- Forecasting to support coastal community adaptation to climate change, urban planning for climate change
- What are the key 'indicators' of tipping points (too much development)?
- What are the socio-economic costs and benefits of climate change?
- How do we enhance development of coastal resources (e.g., aquaculture, energy, biotechnology, capture fisheries)

What is the role of biodiversity in maintaining ecosystem function and resilience to change?

- *Are there low diversity thresholds that result in loss or resilience and phase shifts?*
- *Are there high diversity thresholds where more diversity doesn't provide more resilience?*

How do we optimize observations to improve forecast skill (ocean, weather, climate, atmosphere)?

- Data assimilation
- Observing System Simulation Experiment (OSSEs)-high priority for broad spectrum
- Investment in new technologies
- Constrain ocean estimates

How can we reverse the trend in climate and ecosystem literacy/understanding?

Common Themes

- All Grand Challenges Require:
- Interdisciplinary, Integrated, long-term observations (and evolving technologies)
- Process studies, test beds, experiments
- Predictive and forecast modeling across time and space scales
- Commitment to highest quality scientific staff
- Communication and outreach

Summary of Breakout Group #4

Providing timely and authoritative explanations of evolving climate and ecosystems

- Ocean acidification impacts on ecosystems
- Sea level rise and regional impacts on coasts
- Climate and carbon cycle feedback mechanisms involving marine and terrestrial ecosystems
- Earth system modeling (geophysical/biological/social science*)
- Anthropogenic impacts (ocean noise, marine pollution, air quality)
- Natural fluctuations vs. long term shifts (eg ENSO and AMOC)
- *Lack of agreement on degree of required integration of social sciences

Evaluating and communicating predictability and uncertainty

- Hydrologic cycle
- Short term forecasts: Severe storms, Winds, Hurricanes -- Extending forecast lead time, life cycle of convection
- Ecological forecasting
- Annual catch limits
- Climate sensitivity
- Geo-engineering

Ensuring continuity of observations and analysis

- Satellite observations
- Full exploitation of platforms.
- Better utilization of resources.
- Data assimilation for integrated Earth system analysis

Developing models to support regional decision-making

- Marine spatial planning
- Renewable energy
- Hydrologic
- Biodiversity

Summary of Breakout Group #5

Grand Challenge 1

- OAR was originated because the grand challenge at the time was coupling oceans and atmosphere. Now the Grand Challenge is coupling whole earth systems
    - Ecosystems
    - Society
    - Climate
    - Geophysical
    - Land/ocean /atmosphere interface
    - Planetary boundary layer (convection)

Grand Challenge 2

- NOAA is being asked to predict and forecast. The grand challenge for NOAA is to understand the predictability, or lack thereof, and characterize the uncertainty as a function of spatial and temporal scales across processes. Can we do it with skill?

Grand Challenge 3

- Answering the "so what" question.
    - Keeping NOAA honest by involving stakeholders in the development of NOAA services. Formally incorporating social, behavioral and economic science in NOAA's research priorities.
- What is the value of the services provided by intact ecosystems?

Grand Challenge 4

- Increase modeling and simulation capability to allow scenario development for the emerging societal imperatives. Examples:
    - Catastrophic/high impact events
    - Renewable energy development
    - Ecological forecasting
    - Agility to accelerate research
    - Requires interdisciplinary modeling approaches
    - Abrupt Climate change
    - Addressing impacts of geoengineering

Grand Challenge 5

- NOAA's contribution to informing how society will move forward from a fossil fuel based society to a society based on sustainable energy

Question #2 Summaries
Discussion on Practices
NOAA Science Workshop April 21, 2010

Summary of Breakout Group #1

Organized and editorialized conversation along these topics

- **Scientific integrity: How do we ensure a healthy atmosphere of scientific inquiry and communication?**
    - Spending time responding to requests (for data, supporting material, algorithm details, interpretation, etc.) versus doing the research NOAA hired us to do
        - Transparency and traceability of scientific results comes at a cost.
        - Holds scientists "hostage" to previous successes.
        - Should be factored into planning, staffing, and life-cycle budgets.
            - Transition to non-science personnel to manage this activity?
        - FOIA requests need support mechanism – should have science cognizant "front-end" to the process
            - One concern is that we need to discriminate between legitimate and "harassment" requests.
    - "Muzzling" of scientists is obviously not consistent with NOAA vision of educating the public
        - Perception (by those that ask) is that NOAA policy still limits government employees from speaking to the general public
            - Cannot use credentials or billable hours for certain speaking engagements.
            - In academia, it is understood that the institutions are not accountable for statements made by professors, but in government they are.
                - Could make only certain people (e.g., SESs) able to speak for agency.
            - Academic freedom (e.g. public speaking and expression of ideas) is related to attracting and retaining talent.
        - Internal reviews of papers
            - Perceived as an inconsistent implementation across/within line-offices.
            - One example where a paper accepted by journal but not by NOAA
            - Perceived as oppressive and politically motivated
        - Need explicit guidance on these issue
            - Scientists' input in creation of this guidance is strongly recommended.
- **Science management: What are good management practices that NOAA should apply broadly to its science operations?**
    - NOAA-wide Data Management Infrastructure
        - Without this, the coupled atmosphere/ocean/biosphere modeling/observing challenges being raised are impossible

    - IT environment is stifling, need balance between open and rapid exchange of data and literature and need for protection of IIP, ITAR, etc.
- Ditto for High Perf. Computing, Fleet, other infrastructure.
    - Related Issue: keeping NOAA ships at sea 24 h/d, 260 d/y (now 125 d/y)
- Contractor "positive feedback mechanism"
    - Prolific scientists end up with more work than they can do
    - Hire (more) contractors to do the work
    - Training and management (proposals, SOW's, invoices, deemed export, performance review comments, annual reports, etc, etc).
    - Slow acquisition of critical contractors into the government puts government at risk of losing its "investment."
    - Scientist does more management, less science
    - Recommend that contractor management be part of the GWPAS and that supervisors take corrective action when requested.
- The "deemed export" problem
    - Number of science and high-technology contractor/post-doc applicants with citizenship or green-card has precipitously declined in recent years.
    - Some NOAA organizations have "purged" or avoided hiring non-US.
    - Organizationally, NOAA has delegated responsibility to the lowest levels where organizational need for quarterly (EAR, ITAR inventories, status lists) and annual renewals is a disruption.
        - Is an additional, confusing, and distasteful burden for scientists.
        - Even when delegated to low level administrative staff, they do not have the "authority" or awareness of the activities of the foreign national and ultimately need information from cognizant scientist.
    - Is demeaning for foreign national contractors – possibly even to the extent that they would consider other career paths.
    - Does not foster open collaboration with centers of excellence that are not in the USA and hence is detrimental to our international interactions.
    - Getting rid of foreign nationals or forcing scientists to be escorts would have devastating and long-lasting impacts on NOAA's mission
    - Can this process be re-evaluated or somehow improved?
- How do we promote innovation without penalty for failure within high risk/high reward endeavors
    - A proposal is unlikely to get funded if there is low probability of success.
    - Current performance metrics will tend to discourage scientists from taking risk.
    - Would need to define "who gets to fail"
        - Then, how do we reward success without punishing failure.
        - Concept of investing in people (Ravi's presentation) is one management strategy that should be explored
    - Peer review of laboratories is a great idea, but how many reviews are too many
- Concern is that matrix nature of NOAA (and cooperative institutes) can lead to science staff to be called upon for multiple reviews.
- Need <u>steady</u> funding of laboratories and science in line-offices.

        - Scientists investing too much time writing proposals (even to NOAA program offices)
        - Financial insecurity → can lead to a depression of innovation
        - Should not need to go to other agencies for science needs for mission maintenance and infrastructure. Examples:
            - Long-term in-situ (e.g., biophysical moorings since 1990's)
            - Follow on space missions (e.g. Quikscat, SeaWIFs)
            - R2O of NASA missions – no one pays for research.
            - Validation of satellite sensors and/or in-situ networks
    - Natural tendency to fund high visibility new technologies
        - But typically same people are utilized (the 20/80 issue)
    - Increased size of funding chunks would help (Ravi "decreased granularity" presentation)
        - Significant time is spent, by scientists, acquiring and tracking of small amounts of funding (≈ 100K)
- **Workforce development: How do we improve NOAA's ability to attract, retain, and promote high-quality scientists and technical personnel?**
    - Overarching personal thought: NOAA management should recognize that what motivates scientists is not the same as others.
        - Some of this is subtle
    - Allow scientists to do (and continue to do) science
        - Need a career path for scientists
            - Reward science, not science management within performance reviews.
            - Expansion of Science and Technology (ST) will help motivate a pathway for top end
            - But need other solutions for majority of NOAA science staff.
        - "20/80 problem" – 20% of staff ends up doing 80% of work
            - Tendency for successful/prolific staff to get overwhelmed with mundane work (*e.g.* contractor positive feedback effect, foreign national, $(\text{etc})^{n+1}$, n >> 1)
            - There is a need for a load balancing mechanism within GWPAS so that scientists can maintain their skill, motivation, and enthusiasm.
        - Administrative work load and complexity has increased over the years (this may apply for non-science NOAA staff as well)
            - Evaluate, streamline or improve efficiency of paperwork
            - Evaluate, streamline or improve on-line training.
    - NOAA workforce does not appear to be diverse, do we know why?
        - Would be interesting to see analysis of statistics (e.g., as a function of length of service). Is it a "latency" effect that will self-correct over time or is there an understanding of the root cause?
    - How do we retain corporate knowledge while retirement rate is high?
        - Loss of specific disciplines (charting, acoustics)
        - Enabling "end-of-career" transition paths where senior staff could transition out of management roles, back to a science role to document and/or train future scientists.

- If management really wants to know scientist satisfaction a survey could be done
  - Need to guarantee anonymity
  - Need to ask the right questions. Previous employee surveys ask vague questions and do not target scientific issues or the 20% of the "20/80"
- Another idea is when a project is near completion have the equivalent of a NASA "end of prime mission review"
  - Capture and understand reasons for success and failure

- **External Interactions: How can we strengthen NOAA science through interactions with the external community?**
  - Problems with MOU's and 1-year limitation on using money.
    - NOAA should have funding lines for mission related research.
    - Delay's (and lack of visibility) with implementation of MOU's (experience up to 15 months) leaves a poor external perception of collaboration with NOAA, prohibits meaningful collaborations, and possibly missed opportunities.
    - 1-year restriction on money coupled with delays of getting money allocated creates other problems
      - Sometimes opportunities ($$'s) are lost
      - Also, inability to travel or participate in MOU related activities
  - Strengthen mechanisms to encourage international cooperation
    - In some cases this is mission critical (fisheries, need cooperation of Mexico and Canada to achieve ecosystem scale).
    - Provide travel budget to support the typically unfunded collaborations.
    - International collaborations also add to job satisfaction at NOAA.
  - University partners: collaborators or competitors?
    - External expectation to be awarded fraction of NOAA budget.
    - Recognition that there is tension
    - Issue is related to infrastructure funding in a declining budget.

Summary of Breakout Group #2

Science Infrastructure

- Extensive numerical modeling will be needed to better understand and predict the Earth System: weather-climate-ecosystems-human dimensions
- New data sets are going to be required to support the modeling and advance the understanding
- New observational platforms created and improved
- High Performance Computing upgraded continuously to address the emerging challenges, with support including data storage etc. – visionary approaches needed
- Timely evaluations and reviews of the NOAA science accomplishments and future directions
- Support collaborations and partnerships (more details below)
- Flexibility, within the scope of the Mission, to set and adjust priorities based on science, including cross-LO collaborative planning and execution

Leadership

- It starts at the top and translates downward into all of NOAA – need Transparency, Succession planning, Training and Mentorship, Commitment
- This will enable overall scientist recruitment and retention
- Strong science leadership fostering enthusiasm, with appropriate rewards structures and recognition
- Strengthen communications and science literacy, with timely announcements emphasizing NOAA's science
- Strengthen education and Outreach, including frequent science meetings such as the present one
- Integration of science to address the major issues without risking loss of depth in key science areas

Research to Operations/ Applications

- Continued strong support for testbeds
- Constrained by limited resources (funding and manpower)
- Linkages with NOAA Partnership Programs
- Must include a Operations to Research Component
- Be careful not to create a one size fits all processes or limitations on all projects
- Be more willing to support high risk, yet potentially high pay off research - some things may never transition yet could advance the understanding
- Ensure the funding for long time series of data both in the research and operational mode of data collection
- Flexibility for performing the science applications and assessments, and for providing information

Opportunities for Collaboration

- Yesterdays slides indicated $230 Million worth
- Add in grants and other programs would push this total way over ½ billion dollars!
- Collaborations are great, but come at a cost:
    - Science manpower to support
    - Resources from across the agency
- NOAA needs to ensure these are appropriate, efficient, and meeting our needs
- Remember the importance of internships

Provisions for Corporate Services

- Fix the basics!
    - Grants, Human Resources, Procurement, Transitions ……
- Taskers and Data calls taking up valuable time. Frequency impacts capacity to respond substantively to scientific issues
- Ensure changes in the budget process meets the needs of science – and does not deplete our science capacity
- Make all of our NOAA science activities and science management transparent e.g., rationale and future directions of the corporate science enterprise.

- Follow sound environment management principles within facilities, making appropriate investments.
- High ethical standards. Proper scientific conduct and practices.

Summary of Breakout Group #3

Character of NOAA's Science

- Spectrum: conceptualization through application
    - "Basic" research is in the Pasteur quadrant, rather than Bohr quadrant
- Aimed at addressing specific issues/questions aligned with NOAA's mission
- Must retain and enhance NOAA's research function to support service and stewardship
    - Must avoid reducing NOAA science to only "assembly line" science functionalities

Expectations for NOAA's Science

- What is the expected role of Fed / NOAA labs vs academic labs?
    - Need to clarify and integrate into strategic and research planning
    - Implications for workforce structure and hiring decisions
- Envisioned role:
    - *Long term, large scale research and sustained observations/monitoring (e.g. satellites)*
    - Congressional/statutory requirement (e.g. ESA)
- Returns value to NOAA: relevance, quality, performance
    - Aligned with the NOAA Research Plan
    - Has an identifiable path into application / operations
    - Cooperative/Joint Institutes, etc., develop and deliver innovations and products of use to NOAA

Workforce Structure

- Federal science hires are typically long-term commitments, staying in the federal workforce for extended periods, with little turnover
- Trade-Off
    - FTEs develop and retain corporate knowledge
    - Contractors provide flexibility in responding to evolving priorities

Science Enterprise Model

- Clear functional roles across Line Offices and missions
- Role of OAR versus Line Office labs/science centers?
- Vertical and horizontal integration ***essential***
    - Corporate enterprise efforts and cross-NOAA programs
        - Environmental Modeling, National Climate Service, Coral Reef Conservation Program, calibration/validation …
- Clear Business practices
    - Integrated planning
    - Designated responsibilities and corresponding authority
        - Clear alignment of resources

  - Accountability
    - Monitoring and evaluation
  - Efficient and timely processes for accessing/transferring/receiving resources

Transparency

- NOAA-wide research project database
  - Planning and tracking tool
    - Efforts
      - Internal
      - Grants, including cooperative/joint institutes, etc.
      - Contracts, including CRADAs, etc.
      - External leveraging (competed non-NOAA funding, etc.)
    - Resources
    - Progress
  - Internal communication and coordination
    - Facilitate integration and collaboration
    - Reduce redundancy
  - External communication
    - Accessibility for the public; searchable subject matter
    - Source for external NOAA reports, e.g., to Congress

Responsiveness

- *Short-notice (< 2 years) funding needs*, e.g.:
  - Inter-agency leveraging opportunities
    - E.g., National Ocean Partnership Program
  - Seed money
  - Event/crisis response
    - E.g., Significant natural event or discovery
  - Legal requirements
    - E.g., Endangered Species Act response
  - Field campaign
  - Collaborative effort
    - Internal or external
- Reserved Research Funding Pools
  - NOAA
  - Line Office
  - Lab / Science Center

Effectiveness

- The fiscal year execution process is badly distorted
  - Funding not confirmed/accessible to programs for approximately the first half of the execution year
  - All contracts/grants must be submitted within approximately 3 months of receiving the program's funding.
- *Enable multiyear (rollover) distribution of funding to research projects*
  - Permits the time for a more-reasoned distribution of resources

  - Permits better alignment with leveraging opportunities
  - Permits better alignment with field work constraints

Planning and Budgeting

- Streamline planning process
  - Reduces expending science FTE resources on administrative tasks
- Account for results
  - Update budget requests prior to submission to reflect changes that have occurred during the budget development period

Transitions

- Research to Applications / Operations (R2O)
  - Early user coordination and pull
    - Facilitates commitment to operational funding
- Transition funding and funding transition
  - Developmental products/services create expectations and user bases
  - Frequently, mature developmental products/services must be routinely produced using research funding
    - No transition funding
    - No operational funding
    - If research funding transitioned to operations with product/service, research resources correspondingly reduced in perpetuity.
    - Research funds must be restored for subsequent efforts.
- Operations to Research (O2R)
  - Exploit operational data, products, services in research
    - Provides feedback on operational product
    - Assists in validation
    - Iterative cycle for advancing the science of the operational output
- Operational science maintenance
  - Largely ignored in planning and funding

Partnering

- NOAA science enterprise comprises: federal FTEs, grantees, in-house contractors, external contractors, cooperative/joint institutes and labs, partners, collaborators, …
- Strengthen and expand the science relationship between NOAA and collaborators.
- Fed-to-Fed partnering needs to be notably promoted and expanded at the NOAA level to open doors for and expand working-level partnerships.
  - Enhances leveraging expertise and resources
  - Reduces duplication and inefficiencies
- Enhance collaborations/partnerships with states and local governments
  - Major user and source of expertise at regional and more local scales
- Applies NOAA's investments for societal benefit
- Erratic funding process makes NOAA a less attractive partner
  - Inconsistent funding timing and uncertain funding levels impose significant burdens on existing and potential partners who have made commitments in support of NOAA.

- Funding MOU’s impose significant legal and administrative burden, in addition to significant time delays, on potential partners with whom NOAA desires an exchange of funds.

Recruitment

- Survey existing NOAA employees to highlight principal recent and historical sources
- Competitive salaries can be an issue
- Scientific merit promotion opportunities appear to be inconsistent across NOAA
- Caps on senior scientific billets appear to be inconsistent across NOAA
- Steady Fed salary is a big bonus
- Pay band salary caps, in conjunction with a lack of promotional opportunity are demoralizing
- Pay raises plus COLAs, coupled with flat funding, result in unfilled billets due to the lack of funds for salaries.

Enthusiasm

- Refresh, excite, and engage
    - A lab-level pool of travel funds for “visit” trips to engage scientists at other institutions (domestic and international)
    - Sabbaticals
        - Perhaps just salary, leaving travel and housing costs to the individual
        - Remotely working with home organization
    - Scientific rotational assignments or details to other NOAA labs with collaborative opportunities
    - Engage more on the international level, e.g., GEOSS-related efforts

Summary of Breakout Group #4

Professional Ethics and Scientific Integrity

- Our number one asset is the integrity of the science which informs our mission. We are concerned about
    - Increasing responsibilities, declining resources (mission dispersion) undermining NOAA science
    - Need for increased transparency
    - Diversity of opinion/interpretation is valued, but this cannot be allowed to undermine NOAA’s science enterprise
- Establish a culture of professional ethics and integrity in NOAA. Make opportunities to raise awareness of these issues
- Commit to executing our core scientific capabilities in a transparent and open manner

Managing Science in an Agency Environment

- Identify and commit to strengthening our core capabilities, both in research and operations
    - Given erosion of base funds, improve the corporate prioritization of science and focus on achieving our core competencies very well
    - Establish collaborative teams to create critical mass around important issues

- Establish a culture of continuous and open communication across NOAA's science enterprise, from the level of the Chief Scientist down to the bench
  - Eliminate perceived or actual conflicts of interest in budgeting and science prioritization
  - Need for objective advisory mechanisms
  - Break down barriers to the internal flow of science
  - Cross functional steering teams for major science themes

Workforce

- Enable excellence and enhance creativity in our workforce through a system of incentives, opportunities, and rewards throughout the career
  - Recognition for contributions to agency mission, not just peer reviewed publications
  - Explore variety of recruitment mechanisms (STEP)
  - Cross NOAA encouragement for sabbaticals, telework, details, and similar opportunities
  - Instill a sense of ownership in the organization
- Identify and develop future leaders

Building Strong NOAA/University/ Private Sector Connections

- To promote the most effective science enterprise, address inequities between our federal and cooperative institute workforce
  - Adjust salary discrepancies
  - Implement bridge contracts
  - Increase CI/JI role in science planning
- Additional flexibility to partner with universities (post-docs and CESUs)

Summary of Breakout Group #5

Why be a NOAA Scientist?

- What motivates people
- What retains people
- What are impediments to becoming and succeeding a scientist
- Why is being a scientist at NOAA is different than being a Academic scientist
- How to get beyond the perceived 2nd tier status of being a government scientist
- Recognizing the value of the individual scientist and their contribution to the scientific unit

NOAA needs to 21st century tools to meet 22nd century scientific needs

- High performance computing to implement the biogeochemical whole earth system model.
  - Need to move forward toward interoperability
- 4-D data cube and infrastructure to generate the integrative capability.
  - Ex: Data mining/pattern recognition
- Incorporate Innovations for high-payoff
- Support operational and accelerated transitions (budgets) for long term capabilities

Create the Human Network

- Provide opportunities for developing partnering across line offices and other agencies to decrease inefficiencies.
- Social networks/Natural working group for NOAA scientists to build bridges across the agency.
- Build interdisciplinary technical working groups, such as used at this workshop
    - Practical action: Create the ability to search for key words identifying areas of interest relative to NOAA's mission

Recruit the Next Generation of NOAA Scientists

- Creation: We need to train and retain quality scientists.
    - Create a fellowship program and a post doc program that has students at NOAA facilities, paid off NOAA money, doing the work of NOAA.
    - Practical Action: Inventory of Post doc and grad student fellowship opportunities that PIs can access
- Retention
    - We have facilities, capabilities, capacity that are attractive to new scientists
        - Need to be able to acquire and maintain cutting edge infrastructure to be competitive

Organizational Effectiveness

- Partnerships
    - Need to have an on-going and up to date Inventory of MOUs
        - Figure out what the impediments are to a streamlined MOU process
    - Where is the funding coming from outside of NOAA supporting research within NOAA
- Streamline science management processes
    - Who is the customer and who is the client internally
    - Acquisitions, General Council, CIO-IT etc should support the scientific enterprise
    - Training
- Build capacity in terms of IT infrastructure,
    - Lack broad scale sharing of IT resources/cyber . It isn't just the collection of the data and not just the use of the data.
- Corporate strategy for mutually beneficial investments
    - Ships, people, facilities, computing

Scientific Integrity

- It is a slippery slope from providing scientific information to being advocates.
    - We must be wary of our objectives and always strive to be unbiased.
    - Dispassionate delivery of the science vs. suggesting what it means and how to use the information.
    - Keep the debate on the hard science, not the personal or political.

F. Evaluation Form Results

Evaluation forms were provided to participants at the final plenary on Day 3. We received at total of 44 completed forms (41 written, 1 e-mailed, 2 completed online as of 5/4/10) out of 65 non-staff participants, for a response rate of 67.7%.

1. *Was this workshop a good use of your time, as a scientist? Did you enjoy the experience?*
   All respondents found that the workshop was a good use of their time, and nearly all found it enjoyable. Several respondents noted that follow-through on the communication and response to workshop outputs would determine whether the workshop was worthwhile.
2. *Would you recommend that NOAA do more of this kind of meeting, that is, workshops and conferences specifically targeted to bring active scientists from across NOAA together?*
   All respondents recommended that NOAA hold similar meetings in the future, with six respondents indicating that meetings should be held bi-annually or annually at most, possibly in combination with a larger conference.
3. *What did you like the best and least about the workshop? Do you have suggestions for improving the way such meetings, if held, would be managed in the future?*
   Best: Most respondents appreciated the opportunity to interact with peers from across NOAA and be exposed to a diversity of ideas. Respondents were generally pleased with the workshop format, and felt that the breakout sessions allowed all voices to be heard. Several respondents particularly appreciated the opportunity to share their thoughts with upper management.
   Least: Approximately 20% of respondents felt that the venue could have been improved in terms of rooms, hotel availability, and promotion of greater interaction at on off-site location. One respondent noted that holding the meeting at NOAA headquarters elevated its importance. Respondents would also have appreciated more lead-time in receiving materials in order to better prepare. Several respondents found plenary sessions tedious due to redundant breakout reports, wordsmithing, or overly bureaucratic in nature. A small number of respondents lamented the lack of focus on solving environmental problems, and one recommended that future meetings focus on achievable solutions for improving science management.
   Suggestions: A minority noted the need for clarifying next steps; others suggested that the composition of participants could have included more young scientists, and others found an imbalance in the ratio of atmospheric and weather scientists to oceanographers, with more oceanographers needed. To reduce redundancy in plenary, one respondent suggested having paired breakouts (with two breakout groups per topic). In addition to more lead time, one respondent suggested limiting workshops to two days maximum.
4. *What are the most important things you personally got out of the workshop?*
   Most respondents felt that the opportunity to interact with their colleagues across NOAA and appreciate the scope of the science occurring at NOAA was one of the most important things they got out of the workshop. Respondents also noted a new appreciation for holistic and integrated approaches, including the human element, and the

exchange of new ideas and perspectives as take-aways. Several found sharing of common interests, challenges, and frustrations to be valuable. Other respondents noted the interest of HQ in science, and appreciated the opportunity to provide input. And a small number of respondents felt hopeful following the workshop for the future of science at NOAA.

5. *In the future, how should representatives from our external partners be included in NOAA science meetings?*
   Respondents in general felt that external partners should be involved in workshops with specific science topics, but that meetings touching on "in house" topics should be kept NOAA only. Several respondents felt strongly that Cooperative and Joint Institute representatives and Primary Investigators funded by NOAA should be included in workshops. Others suggested involving other agencies, or looking to other organizations for examples of management practices NOAA could learn from. One respondent noted the difficulty of where to draw the line given the range of external partners NOAA works with.
6. *Do you have suggestions for topics that would be appropriate for future meetings?*
   Respondents suggested a number of topics, most of which dealt with the linkages required to achieve an integrated Earth System approach or with sub-topics raised in the workshop, including scientific integrity, communication, research to operations, socio-economic science integration, and ecosystem based management and coastal and marine spatial planning. Additional topics raised included implementation of grand science challenges, ensemble forecasting for climate, climate skepticism within NOAA, improving service delivery, cross-line office partnerships, interagency interactions, and what science should be phased out.
7. *Would you be willing to assist in the planning and execution of future NOAA science meetings?*
   About half of the respondents indicated they were willing to assist with planning (11 names recorded).
8. *Should NOAA leadership commit to a much larger NOAA Science Conference sometime in the next 6-12 months?*
   Respondents were generally in support of a larger NOAA science conference, with a number recommending a longer timescale (12-18 months out), and noting the need for clearly articulated purpose and goals (one suggested a focus on solutions). A couple noted that "bigger isn't necessarily better" in support of keeping meetings small. Another suggested dedicating efforts to preparing 2-pagers on topics raised in the workshop rather than hold a conference. Another suggested involving other agencies in a conference.
9. *Are there any other comments you would like to make?*
   Other comments were generally positive in appreciation of the organizers and having been invited to participate. One thought there were too many managers involved, while another suggested inviting Assistant Administrators and Deputy Assistant Administrators. Several noted guarded optimism depending on how leadership reacts to the workshop outputs.

G. List of Acronyms

AGU – American Geophysical Union
AKFSC – Alaska Fisheries Science Center (division of NMFS)
AMOC – Atlantic Meridional Overturning Circulation
AMS – American Meteorological Society
AOML – Atlantic Oceanographic and Marine Laboratory (division of OAR)
ARL – Air Resources Laboratory (division of OAR)
BAMS – Bulletin of the American Meteorological Society
CDR – Commander
CESU – Cooperative Ecosystems Studies Units
CI – NOAA Cooperative Institute
CICEET – Cooperative Institute for Coastal and Estuarine Environmental Technology
CIO – Chief Information Officer
CPC – Climate Prediction Center (division of NWS)
CRADA – Cooperative Research and Development Agreement
CSC - Coastal Services Center (division of NOS)
CSD – Chemical Sciences Division (division of OAR/ESRL)
EBM – Ecosystems-Based Management
EAR – Export Administration Regulations
ELDP – Department of Commerce Executive Leadership Development Program
EMC - Environmental Modeling Center (division of NWS/NCEP)
ENSO – El Nino Southern Oscillation
ESA – Endangered Species Act
ESRL – Earth System Research Laboratory (division of OAR)
FTE – Full time Equivalent (employee)
FY – Fiscal Year (October-September)
GEOSS – Global Earth Observation System of Systems
GLERL – Great Lakes Environmental Research Laboratory (division of OAR)
GSD – Global Systems Division (division of OAR/ESRL)
GWPAS – General Workforce Performance Appraisal System
HPC – High Performance Computing
HR – Human Resources
IEA – Integrated Ecosystem Assessment
IPCC – International Panel on Climate Change
IT – Information Technology
ITAR – International Traffic in Arms Regulations
JCSDA – Joint Center for Satellite Data Assimilation (division of NESDIS/STAR)
LCDP – NOAA Leadership Competencies Development Program
LO – NOAA Line Office

MDL – Meteorological Development Lab (division of NWS)
MOU – Memorandum of Understanding
NASA – National Aeronautics and Space Administration
NCCOS – National Centers for Coastal Ocean Science (division of NOS)
NCDC – National Climate Data Center (division of NESDIS)
NCS – NOAA Climate Service
NEP/NEC – NOAA Executive Panel/NOAA Executive Committee
NESDIS – National Environmental, Satellite, Data, and Information Service
NGDC – National Geophysical Data Center (a division of NESDIS)
NGS – National Geodetic Survey (division of NOS)
NCDDC – National Coastal Data Development Center (division of NESDIS)
NCEP – National Center for Environmental Prediction (division of NWS)
NEFSC – North East Fisheries Science Center (division of NMFS)
NGSP – NOAA's Next Generation Strategic Plan
NMFS – National Marine Fisheries Service
NOS – National Ocean Service
NRC – NOAA Research Council
NSSL – National Severe Storms Laboratory (division of OAR)
NWFSC – North West Fisheries Science Center (division of NMFS)
NWS – National Weather Service
OAR –Office of Oceanic and Atmospheric Research
OBS - Observations
OCWWS – Office of Climate, Water and Weather Services (division of NWS)
OER – Ocean Exploration and Research (division of OAR)
OHD – Office of Hydrologic Development (division of NWS)
OMAO –Office of Marine and Aviation Operations
ONMS – Office of National Marine Sanctuaries (division of NOS)
OSSE – Observation System Simulation Experiment
OST – Office of Science and Technology (division of NWS or NMFS)
PIFSC – Pacific Islands Fisheries Science Center (division of NMFS)
PMEL – Pacific Marine Environmental Laboratory (division of OAR)
PPI – Program, Planning, and Integration
PSD – Physical Sciences Division (division of OAR/ESRL)
Quickscat – Quick Scatterometer
R2O – Research to Operations
RISA – Regional Integrated Sciences and Assessments
SeaWIFs – Sea-viewing Wide Field-of-View Sensor
SEFSC – South East Fisheries Science Center (division of NMFS)
SES – Senior Executive Service
SL – Senior Level (employee)

SOW – Statement of Work
ST – Senior Scientist
STAR – Center for Satellite Applications and Research (division of NESDIS)
STEP – Student Temporary Employment Program
SWFSC – South West Fisheries Science Center (division of NMFS)
USEC – Office off the Under Secretary
USGS – US Geological Survey