NOAA Science Advisory Board
Strategy Synthesis Subcommittee

Strategy Synthesis Session April 16-17, 2015

The purpose of this Strategy Synthesis Session is to help NOAA think through some of the bigger picture issues that it may encounter in the not-too-distant future (a 5-7 year “look ahead”). The SAB, with help from several invited guests, will think through what the world might look like in the near future and how this might affect NOAA’s ability to carry out its mission. In particular, this session is meant to facilitate creative thinking about NOAA and its R&D, future technologies on the horizon, and major potential environmental changes as these relate to NOAA’s mission. The goal of the session is to enable the SAB to provide strategic advice to NOAA about promising future directions for NOAA R&D and to provide strategic advice to NOAA on what types of things it should be thinking about in order to best prepare to meet future challenges.

The Strategy Synthesis Subcommittee initially outlined five substantive areas around which to structure the discussion:

1. **Improving integrated observing systems**: What are NOAA’s observing capabilities now, how can they be better integrated, and what are promising new technologies on the horizon that might increase NOAA’s ability to carry out its mission?

2. **Ecosystem science and management**: What advantages are there for NOAA taking a more integrated and holistic ecosystems approach that goes beyond the traditional fisheries approach, and how might the agency develop such a systems approach?

3. **Impact of ecosystem services on human well-being**: How should NOAA develop the scientific capability to translate ecosystem science and management into impacts on human well-being through the valuation of ecosystem services?

4. **Improving integrated decision-making and system resilience**: What kinds of information are most needed to better prepare for and adapt to changes in environmental conditions and potential disturbances and how should NOAA use information in decision-making?

5. **Communicating success**: How can NOAA best utilize the information developed in its programs to demonstrate the value of NOAA science for society?

The subcommittee felt that “Communicating success” was a large topic, and somewhat different than the other four topics, and that it should be given more time in its own session at a later SAB meeting. We provide more detail on topics (1) – (4) below.

We have invited three eminent scholars who have a big picture view of science and policy to help the SAB to think through these issues. The three are: Professor Simon Levin (Princeton), Professor Granger Morgan (Carnegie-Mellon), and Professor Veerabhadran Ramanathan

(University of California, San Diego). Biosketches for each are provided at the end of this document.

1. Improving integrated observing systems

The heart of NOAA's Environmental Intelligence is its observing system. NOAA's prediction and forecasting capabilities rely on an integrated observing system, but NOAA's current observing systems are fragmented. NOAA's strength is its capability to create an operational framework for forecasts, yet inadequate observing systems challenge this capability. Furthermore, NOAA's observing systems are challenged by a changing world and a changing environment.

Improving NOAA's integrated observing systems requires thoughtful consideration of the following:

1. What are NOAA's observing system capabilities now?

2. What does an integrated observing system look like in the future? What is the vision for system integration so that interactions and feedbacks are adequately addressed? How can NOAA gain efficiency, cost effectiveness, and improve its models and products? An integrated observing system should capture a full suite of ocean, atmosphere, and ecosystem observations, and include the fluxes between these components. The Agency must continue to study the linkages and complexities across systems (human and natural) to improve its forecasting capabilities.

3. How can NOAA take advantage of new technologies (both new observing technologies, and technologies that better integrate NOAA's observations) that would allow NOAA to better carry out its mission? How can NOAA best integrate external technology advances?

One suggestion for integrating new technologies into NOAA's capabilities is for NOAA to form a small standing group that annually reviews the state of the art observing systems to inform NOAA with an adaptive management format. The group may have representatives both internal and external to NOAA, and would be a service to the greater community as well as NOAA.

2. Ecosystem Science and Management in NOAA

Understanding the structure and function of ocean and coastal ecosystems is fundamental to understanding how and why ecological communities behave in the ways they do and the nature and limits to the services they provide. Healthy and resilient ecosystems are essential for human health, food safety, recreation, shoreline protection, and sustainable fisheries. Sustained provision of ecosystem services is threatened by increasing demand for seafood, pollution, rising temperatures, sea level rise, and ocean acidification among other factors.

Ecosystem science is a major discipline comparable in complexity and scope to meteorology and climate science. Yet, whereas these latter disciplines function within NOAA as coherent entities with the necessary scientific critical mass and independent administration to tackle major questions, ecosystem science within NOAA is scattered as a side activity within the Marine Fisheries Service and NOS.

Overriding Scientific Issue: What are the appropriate tools for prediction of changes in ecosystem structure and function in the oceans? Is it reasonable to apply the kinds of non-linear dynamical analysis used for weather and climate prediction? Or do new approaches need to be developed?

The lack of an independent home for ecosystem science within NOAA is additionally problematic on many levels. Some of the most important include:

1) Ecosystem science at NOAA needs independent guidance to evaluate the big picture of ecosystem change and to prioritize resources accordingly. The qualitative trends of emerging threats are increasingly certain, while the uncertainty lies mainly in rates of changes and nonlinear responses. Resolving these issues is fundamental to NOAA's goals for building resilient ecosystems and the services they provide.

Scientific Issue: What are the rates of change and quantifiable (i.e. predictable) responses associated with these emerging threats?

2) There is an inherent, unresolvable conflict of interest in having ecosystem assessments in the same part of NOAA that regulates fishing. Much of the ingrained resistance to setting catch limits with regard to ecosystem health as prescribed by the revised Magnusson-Stevens Act stems from that conflict. To name just one example, the section on ecosystem management in prior assessments for Alaskan Pollock briefly discuss the near threatened Steller Sea Lion *as a threat to the fishery* rather than addressing the potential impact of the fishery on the well being of this declining species. As of 2011, there was no discussion of the impact of the fishery on ecosystem health and the fishery is still managed as a single species.

Scientific Issue: What are the impacts of fishing activity on overall ecosystem health?

3) The Deepwater Horizon spill exposed a lack of a coordinated focus within NOAA regarding shoreline protection in relation to mounting threats of wetland destruction, nutrient and toxic pollution, and sea level rise. Moreover, it was apparent that the lessons of the Exxon Valdez spill and detailed scientific analysis of its consequences had not been incorporated into NOAA thinking on these issues. This is a very large and rapidly accelerating problem that would benefit greatly from a more coordinated focus within an ecosystem context.

Scientific Issue: What are the interactive dynamics of coastal threats and how do they compound or mitigate impacts on ecosystems?

4) There are basic and mounting health issues related to declining water quality of special relevance to food safety from coastal fisheries and aquaculture and health risks to recreational boaters, fishers, swimmers, surfers, and divers.

Scientific Issue: How do ongoing changes in marine ecosystems impinge on human health?

3. Ecosystem Services and human well-being

The past decade has seen a vast increase in scientific capabilities in understanding ecosystem services, which are the benefits that ecosystems provide for society. There has been a similar increase in interest in moving the scientific knowledge into practice to guide policy and management both within public agencies and in the private sector. NOAA is well-positioned to be a primary source for information about coastal and marine ecosystem services. But doing so will require careful thought and investment by NOAA.

Topics/challenges that require intellectual and/or institutional advances to accomplish:

1. *Identification of ecosystem services* from coastal and marine ecosystems and their interactions. What do people care about and what tools are available to measure them? To what extent are the ecosystem services that society want competing (i.e., entail trade-offs, e.g., between recreational and commercial fisheries) and to what extent are they positively synergistic (e.g, improved water quality for recreation *and* shellfish harvest)?

2. *Integrated analysis across intellectual domains.* Ecosystem service science and implementation requires input and integration of information from both natural and social sciences. The logical chain for ecosystem services is often: policy → decisions by public and private actors → changes in ecosystems → changes in ecosystem function → changes in ecosystem services. Each step of logic requires environmental intelligence combined with understanding of institutions, economics and human behavior. How can NOAA best integrate knowledge across disciplines and organizations to provide information about ecosystem services? Does NOAA currently have the necessary skills in-house to accomplish this type of integrated assessment? Are there useful partners in other agencies, academia, or the private sector to best accomplish this type of integrated assessment?

3. *Prediction across NOAA programs.* Predicting and communicating how a set of ecosystem services will respond to a set of environmental changes requires greater integration across NOAA programs (e.g., climate, riverine hydrology, fisheries), perhaps in regionally focused case studies (e.g., Arctic, Gulf of Mexico). What are the key science advancements that need to be made to be able to predict ecosystem services over long time and large spatial scales? How can NOAA best build on its world-class prediction capabilities in some realms (e.g., weather, climate), to provide predictive capability around ecosystem services? What additional capacity needs to be developed to be able to accomplish this? What types of external partnerships would be advantageous to speed the development of predictive capability?

4. *Distribution of ecosystem services across people groups, demographic groups, geography.* Considerations of environmental and social justice, the distribution of benefits and costs across different groups and political jurisdictions require greater social science integration into predictions of changes in ecosystem services. How can NOAA best develop the capacity to

predict changes in provision of ecosystem services to different groups within society either internally or in conjunction with external partners?

4. Improving integrated decision-making and system resilience

NOAA has developed considerable predictive capability in some areas of environmental intelligence. However, even with the best science, some events cannot be predicted ahead of time with certainty. For example, we cannot know for sure whether a hurricane will strike a given coastal location next year or its intensity if it does. But improved predictive capabilities allows for improved assessments of probabilities and the ability to better plan for various possible future events. Improving the integration of NOAA's predictive capabilities into decision-making, planning, and management could yield major societal benefits.

Among the important topics for better integration of predictive capabilities are:

1. *What are the big unknowns?* What are the major potential future events that, if they occur, would be a "surprise," and because they are big, if they occur, they will really matter. Knowing what these events might be allow society to be better prepared and could have significant value for society. How can NOAA tackle the issue of uncovering what are currently the big unknowns?

2. *Scenario development*. Should NOAA invest in scenario development techniques that are currently used by the military and the private sector to expand vision about potential future events and uncover big unknowns? If NOAA invests in scenario development, how should it develop and utilize information from such an exercise?

3. *Value of information*. The "value of information" from better predictive capability allows for improved planning for mitigating risks and adapting to post-disturbance conditions. How can NOAA best determine the events or long-term trends that will affect ecosystems and human communities in ways that pose major threats to the continued provisions of ecosystems services and/or that potentially cause major changes in the value of these services to society? What are the most important types of information that if known would lead to the greatest improvement in net benefits, either in terms of better planning and adaptation to potential future risks (e.g., sea level rise and coastal storms) or improving the flow of ecosystem services in the future? How can NOAA better target its science to provide the type of information that can most improve decision-making?

4. *Integrating predictive capability into planning and management*. How can NOAA best work with managers/policy makers to utilize the environmental intelligence generated by its science? Which methods and approaches from decision science and other fields that can help guide decision-making under uncertainty are most important for NOAA to build competency? How should NOAA build such capacity?

5. *Improving literacy about risk/uncertainty*. Should NOAA invest in better understanding what risk and uncertainty really mean, either internally or externally for decision-makers and the

general public? How best can NOAA communicate information about potential future risks and the uncertainty of predictions about future events?

Additional questions

1. Across these four topical areas, what should be the top research priorities for NOAA?
2. What is missing? Are there additional topics that should be at the top of the research priorities for NOAA that are not covered in the four topical areas?

Biosketches

Simon Levin
George M. Moffett Professor of Biology, Princeton University

Dr. Levin was a professor at Cornell University from 1965-1992, where he was Chair of the Section of Ecology and Systematics, and then Director of the Ecosystems Research Center, the Center for Environmental Research and the Program on Theoretical and Computational Biology, as well as Charles A. Alexander Professor of Biological Sciences (1985-1992). Since 1992, he has been at Princeton University, where he is currently George M. Moffett Professor of Biology and Director of the Center for BioComplexity. He retains an Adjunct Professorship at Cornell. His research interests are in understanding how macroscopic patterns and processes are maintained at the level of ecosystems and the biosphere, in terms of ecological and evolutionary mechanisms that operate primarily at the level of organisms; in infectious diseases; and in the interface between basic and applied ecology. Levin is a Fellow of the American Academy of Arts and Sciences and the American Association for the Advancement of Science as well as a Member of the National Academy of Sciences and the American Philosophical Society. He Chairs the Governing Council for IIASA, and co-chairs the Science Board of the Santa Fe Institute. Levin is a former President of the Ecological Society of America and the Society for Mathematical Biology, and a past Chair of the Board of the Beijer Institute of Ecological Economics. Among other awards, he won the MacArthur Award (1988) and the Distinguished Service Citation (1998) of the Ecological Society of America, and the Okubo Award of the Society for Mathematical Biology and the Japanese Society for Theoretical Biology. More recently, he was honored with the Dr. A.H. Heineken Prize for Environmental Sciences by the Royal Netherlands Academy of Arts and Sciences (2004), the Kyoto Prize in Basic Sciences (2005) by the Inamori Foundation, and the Distinguished Scientist Award of the American Institute of Biological Sciences. Levin has mentored more than 100 graduate students and postdoctoral fellows. Dr. Levin received his B.A. from Johns Hopkins University and his Ph.D. in mathematics from the University of Maryland.

Granger Morgan
University and Lord Chair Professor of Engineering, Department of Engineering and Public Policy; Professor Department of Electrical and Computer Engineering and in the H. John Heinz

III College, Co-Director of the Center for Climate and Energy Decision Making, Co-Director of the Electricity Industry Center, Carnegie-Mellon University

Dr. Morgan is the founding Department Head of the Department of Engineering and Public Policy where he served for 38 years, stepping down in August 2014. His research addresses problems in science, technology and public policy with a particular focus on energy, environmental systems, climate change, and risk analysis. His research interests are focused on policy problems in which technical and scientific issues play a central role. Methodological interests include problems in the integrated analysis of large complex systems; problems in the characterization and treatment of uncertainty; problems in the improvement of regulation; and selected issues in risk analysis and risk communication. Much of his work has involved the development and demonstration of methods to characterize and treat uncertainty in quantitative policy analysis. Application areas of current interest include global climate change; the future of the energy system, especially electric power and air operations; risk analysis including risk ranking; health and environmental impacts of energy systems; security aspects of engineered civil systems; national R&D policy; and a number of general policy, management, and manpower problems involving science and technology. Dr. Morgan serves as Chair of the Scientific and Technical Council for the International Risk Governance Council. In the recent past, he served as Chair of the Science Advisory Board of the U.S. Environmental Protection Agency and as Chair of the Advisory Council of the Electric Power Research Institute, of which he is now again a member. He is a Member of the National Academy of Sciences, and a Fellow of the AAAS, IEEE, and the Society of Risk Analysis. Among other awards he won the Outstanding Educator Award from the Society for Risk Analysis, the Joseph A. Burton Forum Award from the American Physical Society, and the Chester F. Carlson Award from the American Society for Engineering Education. He holds a BA from Harvard College (1963) where he concentrated in Physics, an MS in Astronomy and Space Science from Cornell (1965) and a Ph.D. from the Department of Applied Physics and Information Sciences at the University of California at San Diego (1969).

Veerabhadran Ramanathan
Distinguished Professor, Scripps Institution of Oceanography, University of California at San Diego; UNESCO Professor of Climate and Policy, TERI University, Delhi, India.

Dr. Ramanathan discovered the greenhouse effect of halocarbons, particularly, CFCs in 1975. Along with R. Madden, predicted in 1980 that global warming would be detected by 2000. In 1985, he led the first international NASA/WMO/UNEP assessment on the climate effects of non-CO_2 greenhouse gases and concluded that they are as important as CO_2 to global climate change. He was among a team of four which developed the first version of the US community climate model in the 1980s. In 1989, he led a NASA study that used satellite radiation budget instruments to conclude that clouds had a large global cooling effect. He led an international field experiment in the 1990s, with Paul Crutzen,that discovered the widespread Atmospheric Brown Clouds (ABCs) over S. Asia, which have negative health and climate impacts. He developed light weight unmanned aerial vehicles to track pollution plumes from S. Asia, E. Asia and N. America. His recent finding is that mitigation of short lived climate pollutants (black carbon, methane, ozone and HFCs) will slow down global warming significantly during this century. This proposal has now been adopted by the United Nations and 30 countries including USA and a new coalition, called as the, Climate and Clean Air Coalition is implementing mitigation actions for short lived climate pollutants. He now leads Project Surya which is mitigating black carbon and other climate warming emissions from solid biomass cooking in S. Asia and Kenya and is documenting their effects on public health and environment. Teaming up with California Air Resources Board and R. K Pachauri, he has initiated a World Bank sponsored project to reduce soot emissions from the transportation sector in India. He has won numerous prestigious awards including the Tyler prize, the top environment prize given in the US; the Volvo Prize; the Rossby Prize and the Zayed prize. In 2013, he was awarded the top environment prize from the United Nations, the Champions of Earth for Science and Innovation. He has been elected to the US National Academy of Sciences, American Philosophical Society, the Pontifical Academy by Pope John Paul II and the Royal Swedish Academy of Sciences.