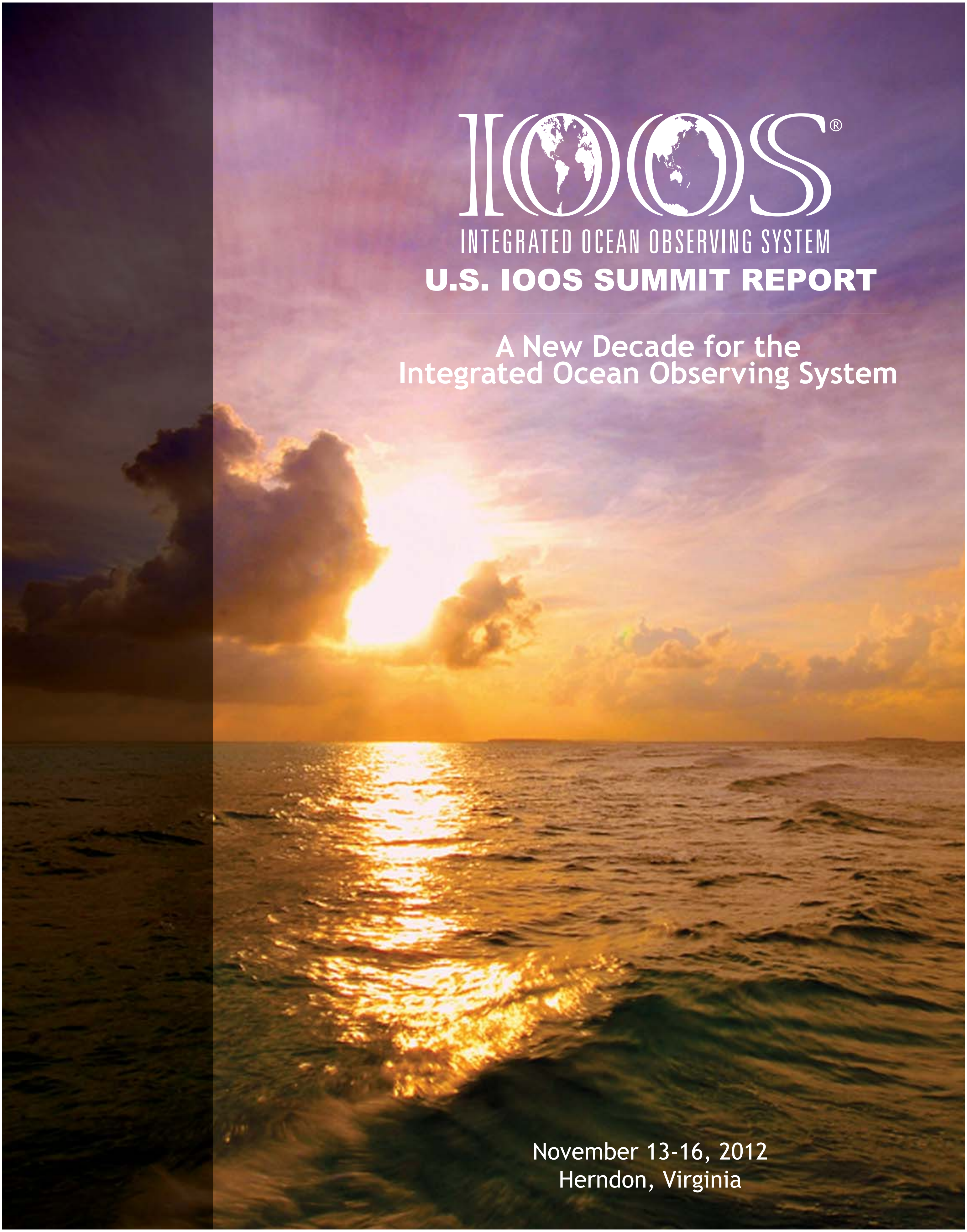

IOOS
INTEGRATED OCEAN OBSERVING SYSTEM

U.S. IOOS SUMMIT REPORT

A New Decade for the Integrated Ocean Observing System

November 13-16, 2012
Herndon, Virginia

IOOC

The Interagency Ocean Observation Committee (IOOC) was created by The Integrated Coastal and Ocean Observation System Act of 2009 and oversees efforts to develop the U.S. Integrated Ocean Observing System. Led by three federal Co-Chairs and supported by agency representatives and support staff, the Committee carries out various provisions of the Act for implementing procedural, technical, and scientific requirements to ensure full execution of the system. Interagency collaboration is essential to achieve ocean science and technology priorities and, in particular, for planning and coordination of the System.

U.S. IOOS®

The U.S. Integrated Ocean Observing System (IOOS) is a national-regional partnership working to provide new tools and forecasts to improve safety, enhance the economy, and protect our environment. Integrated ocean information is now available in near real time, as well as retrospectively. Easier and better access to this information is improving our ability to understand and predict coastal events - such as storms, wave heights, and sea level change. Such knowledge is needed for everything from retail to development planning.

August 2013
U.S. IOOS Summit Report: A New Decade for the Integrated Ocean Observing System

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EXECUTIVE SUMMARY

The ocean is of fundamental importance to the national security and economy of the United States. Decades of focused investment in ocean observing and prediction have produced many examples of substantive societal and economic benefit resulting from improved knowledge of ocean and coastal waters and their behavior. Many complex and difficult questions about the ocean remain, including many that have implications for the lives and livelihoods of millions of Americans. Because the ocean provides much of the oxygen in the Earth's atmosphere, provides all of the fresh water on land through a cycle of evaporation-to-clouds-to-rain, and regulates the Earth's climate, the overall state of the global ocean and its changes profoundly affect all Americans, in fact all of humankind. Recognizing this, the United States has embarked on a series of efforts to develop an ocean observing system capable of addressing broad societal needs. This system is known as the U.S. Integrated Ocean Observing System (U.S. IOOS®).

The activities and members of the U.S. IOOS community are broad and complex. There are 18 Federal agencies involved in the U.S. IOOS program, as well as 11 U.S. IOOS Regional Associations that encompass efforts focused in U.S. coastal waters, the Great Lakes, and U.S. territories and their waters in the Pacific and the Caribbean. In addition, there are many Federal and academic scientists representing the U.S. Government in various United Nations-sponsored groups that plan and oversee global ocean observation programs. This diverse community is managed largely through cooperation rather than clear directive or budgetary authority, which has contributed to both the strong growth, and the integration weaknesses, of the U.S. IOOS program.

A major focus for the next decade of U.S. IOOS is to develop comprehensive processes that more fully integrate the requirements, technologies, data/product development and dissemination, testing and modeling efforts across the regional, national, and global sectors of the U.S. IOOS program.

The Integrated Ocean Observing System (IOOS) Summit was held November 13-16, 2012 in Herndon, Virginia, to assess progress over the past decade, and to develop plans for the next decade of observations of the ocean, coast and Great Lakes.

In order to improve the response of the U.S. IOOS program to the broad scientific and societal needs for ocean observations/information over the next decade, the Summit was designed to address:

- Adequacy of the U.S. IOOS requirements lists, priorities, and processes
- Coordination and Information Delivery across regional/national/global boundaries
- New technologies, challenges and opportunities

The Summit addressed these issues and more.

The 2012 IOOS Summit Report presents:

- In Chapter 1, a vision for what the U.S. IOOS capabilities should look like in 2022
- In Chapter 2, a summary of progress over the past decade, including a number of impressive "Success Stories"
- In Chapter 3, steps required, and needed improvements, in user engagement across a diverse community
- In Chapter 4, an assessment of gaps in the system design and current processes
- In Chapter 5, needed improvements in integration across all aspects of the overall program
- And in Chapter 6, the U.S. IOOS community's major themes for future focus and recommendations for action

A significant level of consensus emerged at the 2012 U.S. IOOS Summit around a set of themes for U.S. IOOS planning and implementation over the next ten years.

The major themes and challenges we must focus on in the next decade include:

- Improve governance to address high-level coordination and support needs
- Pursue new funding mechanisms and potential public-private partnerships to complement traditional funding
- Develop a complete census of existing observing efforts
- Increase the breadth and scope of ocean observations to address increased demand
- Develop a web-based central "market-place" for bringing users, requirements, data providers, new technologies, and available data and products together
- Improve branding, attribution, and user awareness of U.S. IOOS and its many contributors and participants
- Develop common design processes and common data/product standards
- Increase the level of integration across the U.S. IOOS enterprise, moving from cooperative to more coordinated approaches
- Maintain forward momentum and continue to grow U.S. IOOS, while addressing needed improvements.

Twenty-five major recommendations arose from the presentations and discussions of participants at the Summit. These cover the gamut of U.S. IOOS concerns, including governance, funding, user engagement and outreach, as well as design processes and integration. Detailed recommendations address: system design processes, alignment of system design and modeling, assessments, integration projects, expanded observation needs, new observing technologies, data management and communications, and modeling and analysis.

Most of the recommendations are directed at various segments of the U.S. IOOS community, with a major focus on improving the integration of activities across those involved at the local, regional, national, and global levels. But several significant recommendations are also directed outside the immediate U.S. IOOS community to governing bodies who have oversight of the programs, like the National Ocean Council, the Office of Management and Budget, and the Ocean Caucuses of the U.S. House of Representatives and the U.S. Senate. All recommendations are presented in Chapter Six of the Report.

The Interagency Ocean Observing Committee (IOOC) and Integrated Ocean Observing System (IOOS)

IOOS SUMMIT 2012 DECLARATION

There was sufficient agreement among those attending the IOOS Summit 2012 that a Summit Declaration was prepared. The Declaration has been signed by 144 Summit participants and others in the ocean observing community.

In the United States, critical decisions affecting our lives, livelihoods and quality of life depend on successful communication and understanding of accurate and reliable scientific information about our oceans, coasts and Great Lakes. The U.S. Integrated Ocean Observing System (IOOS®) is a coordinated national, international, regional and local network of observations, modeling, data management and communications that provides the knowledge needed by society to protect life and property, to sustain a growing economic vitality, to safeguard ecosystems, and to advance quality of life for all people. Building upon progress over the past several decades, we must continue to expand, improve, and sustain the system to address the growing societal needs for ocean observations and information.

BACKGROUND

The Interagency Ocean Observing Committee convened an IOOS Summit, on November 13-16, 2012, ten years after an initial workshop defining IOOS requirements. The participants at the Summit reviewed progress in the design and implementation of IOOS. They identified the notable successes in developing a functioning system, as well as the technical and practical challenges and opportunities that IOOS will face in the coming decade. This Declaration captures and emphasizes the findings and commitments of the participants in the Summit.

IOOS is a national endeavor that is endorsed by federal and state agencies, tribes, academia, industry and NGOs; and is a partnership at the national and regional levels through the federal agencies and the IOOS Regional Associations. The past ten years have seen substantial progress in designing and implementing U.S. IOOS. We are delivering real value to the American public and foresee even greater contributions in the coming decades.

UNDERSTANDING OF THE NEED FOR IOOS

Recent events underscore the importance of IOOS to the economic, security and environmental interests of the United States.

- Ocean, coastal and Great Lakes observations have proven to be essential for responding to weather, ocean, and human-mediated disasters on global, regional and local scales; as well as in reducing and mitigating the economic, social, and cultural risks of extreme events.
- The increasingly clear understanding of the scope and impacts of environmental changes, including sea level rise, the increase in ocean acidity, and the need to respond, adapt to and manage those changes, calls for a more extensive and sustained monitoring of the oceans and coasts as critical to understanding and predicting the earth's climate systems.
- Challenges of maintaining the quality and quantity of food and water for the US population and a rapidly growing global population will require improvements in our ability to predict ocean state conditions, weather, climate and extreme events including drought, harmful algal blooms and other conditions.
- Economic development and job growth in areas experiencing dynamic change, such as the energy sector and maritime transportation, accentuate the need for the public and private sectors in the United States to understand ocean and coastal conditions as they relate to a transforming global economy, and to ensure safe and efficient operations.
- A new dynamic of national and homeland security emphasizes that we must enhance our ability to monitor the oceans.
- The increasing need for sustained marine ecosystem goods and services requires a robust infrastructure for biological, biogeochemical and ecological observations.
- Ocean, coastal and Great Lakes observing leads to the creation of new high quality jobs to provide information supporting improved decision making in industries that depend on the oceans.

Now, more than ever, the United States requires a sustained and integrated ocean observing system.

ACCOMPLISHMENTS

1. IOOS has become well-established, supporting real-time decision making, providing critical products and information for weather, climate and ocean applications. Regional implementation is established covering all coastlines and constituencies. Global implementation now covers all areas of the ice-free oceans, providing leveraged international support to coastal IOOS.
2. Federal law strongly supports IOOS and provides a governance framework for a federal/regional partnership with a unified policy and operational success.
3. Investments in observations and data assimilating models have developed essential data and more reliable techniques and methodologies for monitoring and predicting conditions above and below the water's surface.
4. Data have been made interoperable between diverse systems, and standards have been established so that data can now flow between federal and non-federal partners.
5. A broad set of different ocean observing and stakeholder communities, public and private, have been engaged in developing IOOS and the need for an ocean observing system.

MOVING FORWARD – THE NEXT TEN YEARS

A system for ocean observing has been established over the past several decades. IOOS will continue to evolve by revising, enhancing and integrating current and planned observations systems in order to meet user requirements, emerging challenges, and to achieve societal goals. The opportunity is set for moving forward for the next ten years.

OBSERVING CAPABILITY

All IOOS components currently under-observe their target phenomena. IOOS will seek to encompass deep-ocean observations, nearshore and estuarine observations, biological and chemical variables, ecosystem variables; to better integrate remote sensing; and to meet spatial (including sub-surface) and temporal requirements for ocean data, addressing user needs. This will build on the successes of the coordinated global ocean, terrestrial, atmospheric observing systems.

TECHNOLOGY AND WORKFORCE

IOOS will promote leading edge technology development capabilities. IOOS will incorporate emerging technologies as a standard operating procedure, in particular leveraging the development of the Ocean Observatories Initiative. IOOS will foster the development of a workforce for the future, adept at developing, using and furthering these technologies.

MODELING AND PREDICTIVE CAPABILITY

Models and observations will work together to provide the information needed by user communities. Improved and more sophisticated models will better exploit IOOS observations, leading to more precise and accurate predictions to aid in making economic, environmental and societal decisions.

INFORMATION PRODUCTS

IOOS plays a foundational role by providing reliable access to quality-controlled data and information products that support critical decision making for multiple uses. The system preserves the value of the information now and for future generations. This information plays a critical role in ocean literacy and education at all levels.

PARTNERSHIPS

IOOS will continue to succeed as a collaborative effort among federal and state government agencies, tribes, regional partnerships, the academic community, and the private commercial and environmental communities. The U.S. collaborative will help to sustain global efforts, as well as derive understanding and context from parallel efforts around the globe.

USER COMMUNITIES

As the demand for economic growth and stability in sectors influenced by marine resources grows, it becomes more imperative to support an increasingly diverse user community.

RESOURCES

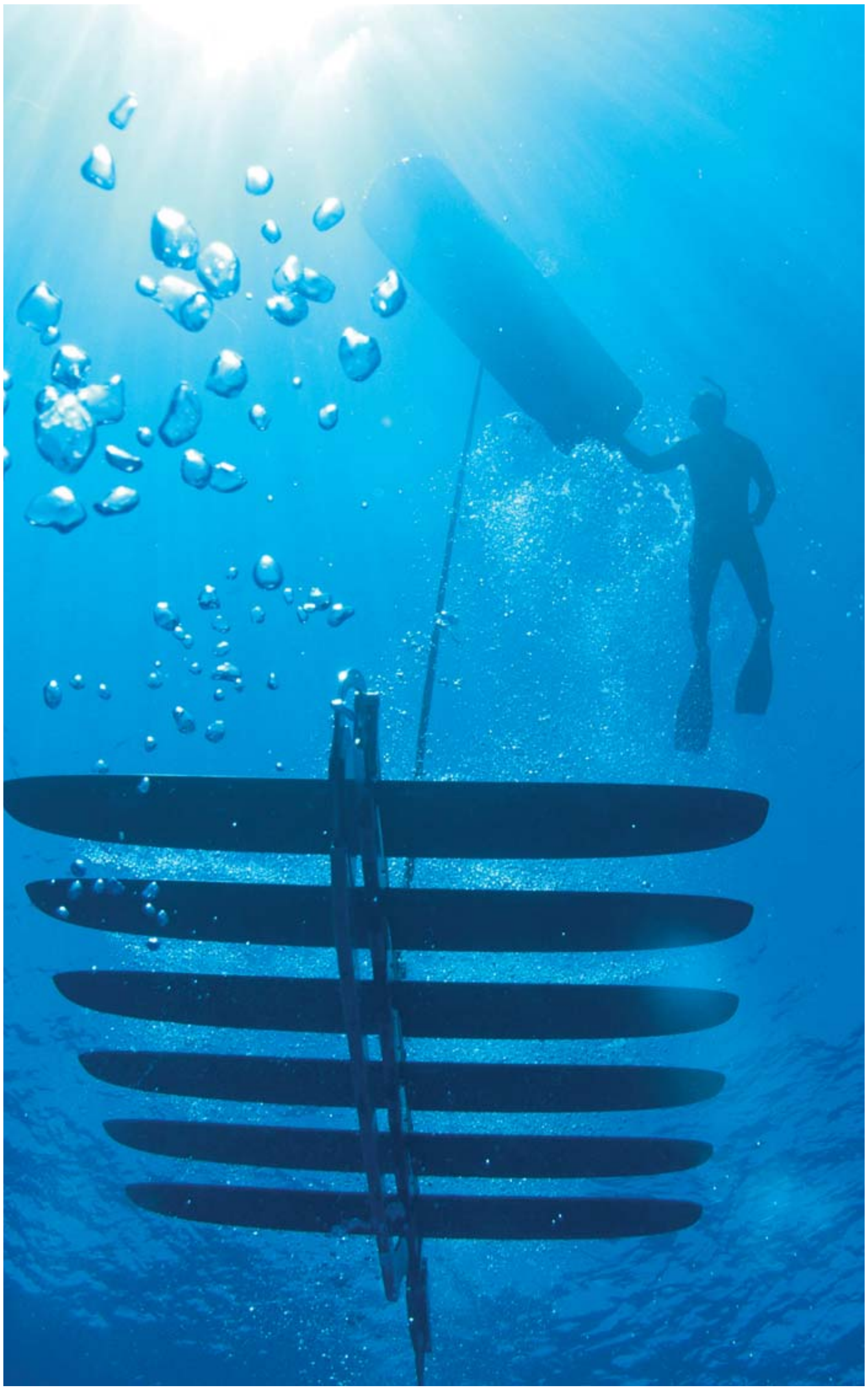
Federal support has been and will continue to be critical to the success of IOOS. New approaches to product development and distribution need to consider a broadening of funding support, additional funding sources, and innovative public-private partnerships.

November 16, 2012

TABLE OF CONTENTS

U.S. IOOS SUMMIT REPORT

A New Decade for the Integrated Ocean Observing System



INTRODUCTION

The ocean is of fundamental importance to the national security and economy of the United States. Decades of focused investment in ocean observing and prediction have produced many examples of substantive societal and economic benefit resulting from improved knowledge of ocean and coastal waters and their behavior. Many complex and difficult questions about the ocean remain, however, including many that have implications for the lives and livelihoods of millions of Americans.

Because the ocean provides much of the oxygen in the Earth's atmosphere, provides all of the fresh water on land through a cycle of evaporation-to-clouds-to-rain, and regulates the Earth's climate, the overall state of the global ocean and its changes profoundly affect all Americans, in fact all of humankind. Recognizing this, the United States has embarked on a series of efforts to develop an ocean observing system capable of addressing broad societal needs. This system is known as the U.S. Integrated Ocean Observing System (U.S. IOOS®).

"We must create consistent, accessible IOOS products for all users from the family's dining room to the corporate Boardroom to the White House Situation Room."

— Dr. Kathryn Sullivan
Acting NOAA Administrator
At the 2012 IOOS Summit

A major, government-funded workshop, held at the Airlie House in Virginia in May 2002, identified goals and approaches for a U.S. Integrated Ocean Observing System. Ten years later, the Integrated Ocean Observing System Summit was held 13-16 November 2012 in Chantilly, VA to assess progress and develop plans for the next decade.

"We must create an IOOS system-of-systems that is operationally reliable, financially sustainable, politically defensible, and technologically extensible and evolvable."

Dr. Richard Spinrad
Chairman, IOOS Advisory Committee
At the 2012 IOOS Summit

Goals of the 2012 Summit were to:

- Review U.S. IOOS Requirements.

  System requirements -- the essential ocean variables that must be observed to address pressing societal issues -- were discussed to determine major gaps, new requirements, and high-priority variables to focus on in the coming decade.

- Assess Coordination of Data Collection and Information Delivery across regional/national/global boundaries.

  The many challenges of integrating the requirements, planning, and implementation of information collection, processing, and delivery across geographic and administrative boundaries were discussed, and recommendations for improvement were made.

- Confront new Frontiers and Opportunities.

  Improved processes for assessing and integrating new technologies were addressed.

The Summit met these goals, with robust discussions and resulting recommendations in all of these areas, but it also addressed many broader issues such as overall governance and funding of the U.S. IOOS efforts, and branding of U.S. IOOS products.

"IOOS must be an enterprise that is user-driven, science-based, and policy neutral."

A Summit Participant
At the 2012 U.S. IOOS Summit

The Summit Report presents:

- **Chapter 1. A vision for 2022.**

  Vignettes are presented that illustrate potential U.S. IOOS capabilities for the next decade, and the challenges of attaining this vision are discussed.

- **Chapter 2. History, programs, and progress over the past decade.**

  U.S. IOOS projects and progress over the past decade are presented, with assessments of the present capabilities, a host of detailed "success stories" and a summary table comparing U.S. IOOS in 2002 and 2012.

- **Chapter 3. Needed improvements in user engagement.**

  Steps in the user engagement process are discussed, along with challenges and proposed approaches to overcome them.

- **Chapter 4. A discussion of gap assessment and comprehensive design**

  A review of advances across the range of U.S. IOOS activities is presented – new observing technologies, data management breakthroughs, modeling advances, and steps for creating more robust processes across the global/national/regional/local scales of U.S. IOOS.

- **Chapter 5. Needed improvements in integration of the overall program.**

  Progress and next steps to implement a more integrated U.S. IOOS are discussed.

"U.S. IOOS is critical infrastructure for a maritime nation."

Dr. Eric Lindstrom
Co-Chair, IOOC
At the 2012 U.S. IOOS Summit

- **Chapter 6. Major themes and recommendations.**

  Major themes/challenges for the next decade, and detailed recommendations for action that arose from the Summit presentations and discussions are presented.

Throughout the report, use of the word "we" refers to the broader U.S. IOOS community, including those who prepared white papers before the Summit, and participants in the 2012 IOOS Summit.

The Summit Agenda, Attendees, and the Chapter Authorship Teams are presented in Appendices A, B, and C, respectively. All References cited throughout the Report are listed in Appendix G.

CHAPTER ONE: A VISION FOR THE FUTURE

1. Vignettes from 2022

- A major storm is headed for the Eastern seaboard, and a well-known U.S. IOOS® site is providing coordinated 24x7 wind and water-level forecasts on high-resolution local scales, block-by-block, to support the media and decisions of community planners, emergency response personnel and individual homeowners.
- A public health warning has been issued based on U.S. IOOS products to hotels, chambers of commerce, hospitals and clinics, in three coastal counties. A harmful algal bloom, with potential health impacts, will occur next week. Emergency medical supplies are shipped to the area, and alternative vacation options are sent to prospective travelers.
- Immediately upon the grounding of a New Panamax class container ship approaching a U.S. port, a fleet of unmanned surface vehicles, gliders and autonomous underwater vehicles is deployed to monitor the release and dispersion of fuel oil. The vehicles and their data are managed by a commercial marine response service, and disseminated to all interested parties through U.S. IOOS links.
- A major canoe and kayak race drawing 30,000 visitors is scheduled from Maine to Rhode Island during late summer. Race organizers consult weather and sea state forecasts for flexibility in the race course and schedule, associated guided tours, and support for on-the-water spectators. Smart phone apps link all tournament participants into hourly U.S. IOOS updates on sea conditions.
- Data from U.S. IOOS and the National Weather Service indicate a doubled winter snowmelt for the upper Mississippi River Basin. A coordinated set of U.S. IOOS outlook products support emergency managers in early flood preparations; support a doubling of breakbulk barge scheduling from the Great Lakes through New Orleans due to higher water levels; and allow water reservoir managers to decide the timing and rate of water releases to reduce the extent and duration of "dead zone" hypoxic events in the Gulf of Mexico caused by increased river runoff.
- The location and movements of endangered species are provided by U.S. IOOS nowcast and forecast products, so they can be avoided by ship operators and fishing vessels.
- A nationally-coordinated U.S. IOOS site supports interested users in developing and rating their personal ecosystem "footprint" – the impacts of their many land- and water-based activities on the nearby ecosystems.
- Federal, State and local personnel, the media, and the general public are all well-aware of the range of U.S. IOOS data and products and how to access, understand and use them.

2. Drivers for a New Decade of Ocean Observing

During the past decade of U.S. IOOS design and implementation, the world and our nation have experienced significant changes in technology, economy, security, and the environment. Data processing capacity has moved from kilobytes to terabytes to zettabytes, and pocket-sized smart phones are ubiquitous among potential users of ocean data. Despite major economic cycles across most of the world economies, most goods continue to be delivered by sea, in ever larger merchant ships. The increase of global terrorism has brought attention to the relatively open access of ports and potential gaps in security for most of the world's most intensely populated and commerce-filled areas. The awesome power of nature has been seen in devastating tsunamis and widespread damage from super-storms, which have affected trillions of dollars of wealth and commerce.

The societal needs that inspired the development of U.S. IOOS ten years ago have largely progressed as anticipated -- except that need has grown far greater and faster than projected. As we envision the needs of U.S. IOOS users in 2022, we must examine, and attempt some predictions about, the drivers of ocean product needs over the next decade.

The world population today is 7 billion, projected to increase by another billion over the coming decade, and people continue to move towards coastal areas in the United States and around the globe.

The role maritime commerce plays in our national economy is largely underappreciated. The bulk of U.S. foreign trade -- 99% by volume, 62% by value – travels by ship. Beyond shipborne commerce, investments in a wide range of ocean-related services – for petroleum exploitation, fisheries, recreation and tourism, as well as growing areas like wind, wave and tidal power, aquaculture, and reinsurance – will provide new jobs and will increasingly depend on expanded, reliable, more timely, more user-friendly ocean and coastal observation and prediction products.

Ocean information will become an increasingly valuable commodity worldwide, because of the role of maritime commerce and new ocean-related investments, vulnerability to ocean-related natural disasters, the need to provide security for coastal populations, and the challenges of providing food and water for more people.

Continued advances in information technology and social networking will require significant changes in how we interact with users. We must not only provide U.S. IOOS products on these platforms, and keep up with the technology advances, but we must also develop ways to respond to the fact that these users will increasingly become more active in both providing local data and real-time critiques of U.S. IOOS products.

Over the next decade, a number of drivers will affect the budget climate in the U.S. for ocean observation. Public policy will demand greater accountability, with Congress and local jurisdictions asking for measures of effectiveness in safety, security, economic development and general public welfare.

U.S. Government budgets will face increasing downward pressures; technology innovations will reduce costs for ocean observations and data dissemination; and private sector investment in U.S. IOOS-related efforts will increase. The U.S. IOOS community will need to resolve numerous policy issues concerning public-private partnership, governance, and shared liability for ocean observations and products.

Parallel ongoing revolutions in communications, knowledge processing and transportation are realigning the standing of countries all over the world, including the relative position of the United States among the leading societies and economies of the 21st century. Indeed, some have characterized the challenge of the future in terms of defining the role of a “Blue Economy” in addressing the key applications of water, food, coastal real estate, and energy (Michael B. Jones, 2012).

3. The Challenge

There has been an unprecedented boom in information content providers with increasing numbers of people consuming all types of information, and this data explosion will continue. The accuracy and reliability of the information is critical, however, especially if it is used for business decisions or public safety purposes, and U.S. IOOS must address this issue more fully.

People need technology and access to the right information so they can make the best decisions possible, wherever they are and whenever they need it. Most people do not know when they will need critical information, or what kind of information they will need until they get into a situation where critical, even life-saving, decisions need to be made. We must address this problem by delivering clear, user-friendly access to coordinated national, regional and local products—before, during and after disasters.

The amount of ocean observations collected today is impressive, and storm and natural disaster forecasting and warnings are improving, but we have yet to understand some fundamental questions about storm intensification. The future U.S. IOOS must offer proactive alerts and messages when certain warning criteria are met, along with local implications of these changes, and the delivery pathways of this information to serve citizens must be improved.

In many emergency response situations, where multiple jurisdictions and disciplines interact, rapid information exchange is severely hampered by differences in hardware, software, data formats, and mapping/visualization products. As a result, potentially critical information often does not make it into the hands of the people who need it the most. U.S. IOOS must address this issue by championing data and product standards.

Our challenge is to build a system that is operationally reliable, economically sustainable, politically and scientifically defensible, and technologically evolvable.

4. The Vision

Certain 'boundary conditions' must be met to define a successful enterprise of ocean observing for 2022. That vision will be defined by the following characteristics:

The ocean observation services provided must be "full spectrum".

A greatly expanding user base will require a wider array of relevant observations and products via operationalized and sustained networks. Services will need to expand to provide -- more data, more variables, and more products, in varied types, from new areas, and at rates that are user-friendly and accessible to all.

The U.S. Integrated Ocean Observing System will be a public-private enterprise.

Public sector support will be insufficient to support all applications, while private investment will not tolerate footing the bill for what should arguably be a tax-payer funded public service. Substantial national public investment will continue to be needed to ensure support for a core set of measurements of essential ocean variables. But partnerships of new sorts must emerge, allowing a legal co-mingling of resources and risk. Individual ('angel') and collective (venture capital, or crowd sourcing) investors will recognize a meaningful return on investment for the added-value products based on publicly-funded observations and services. Industry cooperatives will form to support the development of sector-specific capabilities that can enhance their bottom line. These private investment activities will launch a broad array of creative business plans, a handful of which will become standard models for the ocean observation industry.

The economic investment and value of ocean observation programs will expand.

Ultimately a commercial enterprise of equity valuation in excess of $10B will emerge. This will require, as happened in the global telecommunications and information technology industries, the development of global standards for data acquisition, assimilation, analysis, application, and dissemination.

The ocean observing enterprise will require new governance approaches.

A new set of governance concepts must be developed to address research investments, operational configuration control, requirements prioritization, sustained operations and upgrades, and product development and outreach for combined public-private efforts. Governance concepts such as Indefinite Delivery/Indefinite Quantity (IDIQ) acquisition, establishment of public corporations, Government Owned/Contractor Operated (GOCO) principles, and others, must be addressed to provide accountability to both taxpayers and stockholders.

The ocean observing system will require the establishment of new models for workforce development.

The breadth of skill sets combined with the logistical challenges -- operating to full ocean depth, at all times, throughout the globe, with rapid data assimilation, analysis, product creation and dissemination -- will demand some focused new initiatives in education and training for the ocean observation community.

CHAPTER TWO: PROGRESS OVER THE PAST DECADE

1. History of U.S. IOOS®

During World War II and the Cold War that followed, the U.S. Navy invested a great deal in oceanographic data collection and research to support marine weather forecasting and anti-submarine warfare. The U.S. civil science community focused on collection of ocean data from space, ships and buoys to support oceanographic research. During the late 1990's, several international scientific organizations, with strong leadership from the U.S. ocean research community, worked together on a plan to increase understanding of the oceans – for both research and broader societal needs. From these efforts, the Global Ocean Observing System (GOOS) was born.

Recognizing the importance of expanded ocean observations for both research and societal needs, both in open-ocean and coastal waters, the U.S. has taken a number of legislative and executive steps over the past several decades to develop the U.S. IOOS as summarized in Table 1. An organizational chart of the resulting collaborative national/regional/global program is in Appendix D.

Table 1. History of U.S. Ocean Observation Governance

Sep 1996	Defense Authorization Act (PL 104-201) established the National Ocean Partnership Program (NOPP), under the National Ocean Research Leadership Council (NORLC)
Apr 1998	US Global Ocean Observing System (GOOS) steering team formed
Oct 1999	International Global Ocean Observing System meeting Ocean Obs '99 defines requirements, coordination and recommendations
May 2000	Ocean.US, an interagency planning body, established under the NORLC
Mar 2002	Airlie House Workshop hosted by Ocean.US
Sep 2004	US Ocean Commission recommended a US Integrated Ocean Observing System (U.S. IOOS)
Dec 2006	NOAA Established an U.S. IOOS Program Office
Feb 2008	National Federation of Regional Associations (NFRA) established
Sep 2008	Ocean.US disestablished
Mar 2009	Integrated Coastal Ocean Observation System (ICOOS) Act: Established the Interagency Ocean Observation Committee (IOOC) Designated NOAA as lead Federal agency Included "all relevant non-classified civilian coast and ocean observations"
Nov 2009	International Global Ocean Observing System revised requirements and recommendations at Ocean Obs '09 in Venice
Jul 2010	Executive Order #13547 established National Ocean Council (NOC) IOOC reports to Deputy-Level of the NOC
Jan 2011	NOAA U.S. IOOS Program Office recognized as U.S. IOOS Program Office
Jun 2012	Framework for Ocean Observations published
Nov 2012	National Federation of Regional Associations (NFRA) changed its name to the IOOS Association (IA)
Nov 2012	IOOS Summit held in Herndon, VA near Washington, DC

In the late 1990s, the National Ocean Research Leadership Council (NORLC) convened a Task Team of Federal Government and academic ocean experts to address the needs of the nation in ocean observing. Among other things, the team's report (NORLC, 1999) identified seven areas of societal benefit that should be drivers for the design and implementation of a U.S. IOOS program (Table 2). These seven drivers are still used as guidance today.

Table 2. The Seven Societal Benefit Areas as Drivers for IOOS.

- Detecting and forecasting oceanic components of climate variability
- Facilitating safe and efficient marine operations
- Ensuring national security
- Managing resources for sustainable use
- Preserving and restoring healthy marine ecosystems
- Mitigating natural hazards
- Ensuring public health

The Ocean.US interagency program hosted a major workshop at Airlie House in Warrenton, Virginia in March 2002 to develop a strategic design for a U.S. IOOS. Broad consensus was reached in a number of important areas:

- U.S. IOOS efforts would include both global/open-ocean and coastal components
- Regional institutions would have to be developed for coordination in coastal areas; and these would have to be overseen by a national association
- U.S. IOOS would be a distributed system of linked elements, including:
  - An ***Observing Subsystem*** consisting of platforms, sensors, instrumentation and techniques to measure required parameters at the temporal and spatial scales relevant for user requirements
  - A ***Data Management and Communications Subsystem*** consisting of the hardware and software necessary to provide telemetry, exchange protocols, standards for quality assurance and control standards, data dissemination, and an archive of the parameters measured in the Observing Subsystem,
  - An ***Analysis, Modeling and Applications Subsystem*** consisting of data assimilation and blending techniques, data and knowledge synthesis and analysis; and the procedures for translating data and knowledge into user-specified products.
- The seven areas of societal benefits were endorsed as drivers for U.S. IOOS
- The group identified twenty high priority core ocean observation variables necessary to meet the seven societal goals. This list of variables was codified in the U.S. IOOS Development Plan, the International Global Ocean Observing System Coastal Theme Report and the GOOS – Coastal Module Implementation. An additional six variables have since been added in the 2010 U.S. IOOS Blueprint for a total of 26. (Table 3)

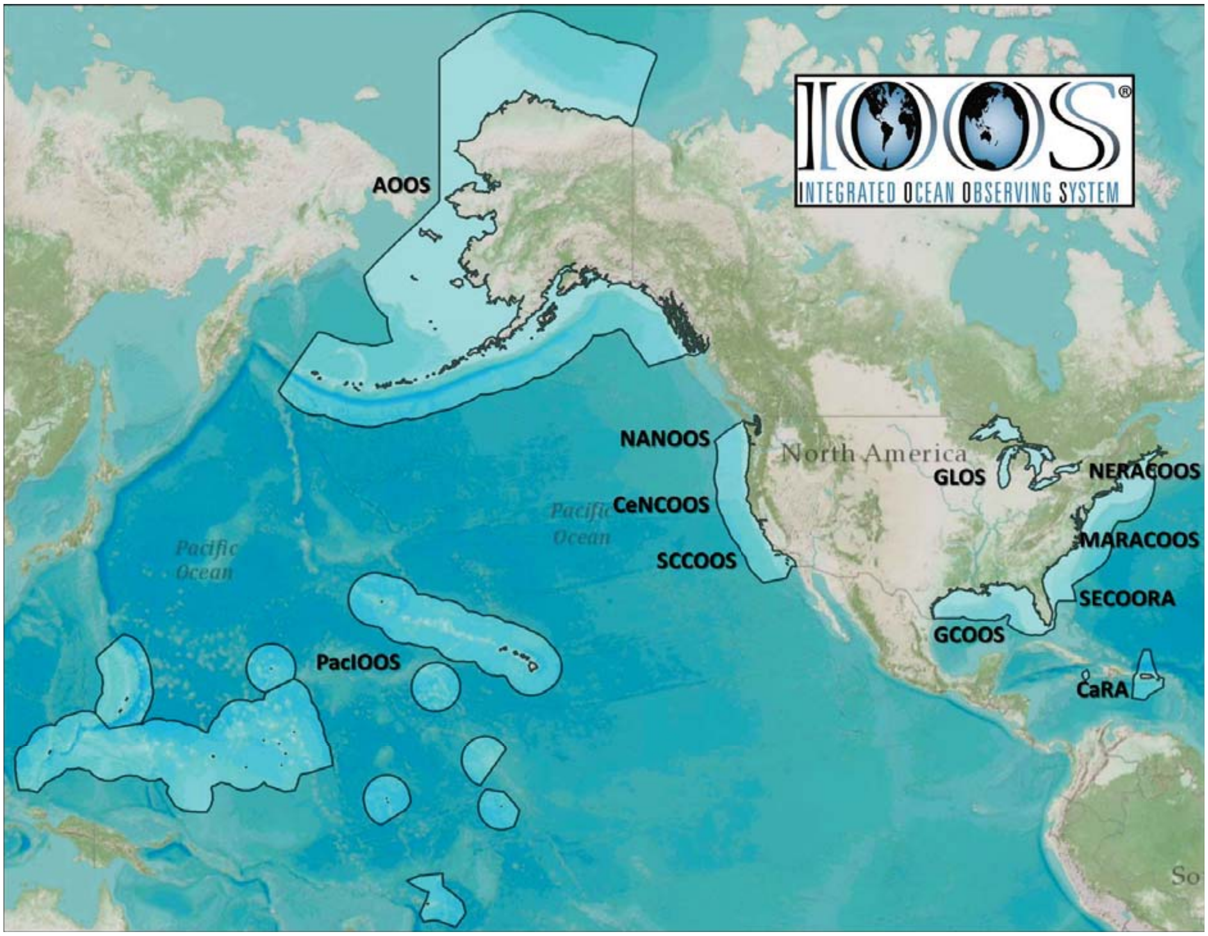
Table 3. The 26 High-Priority Variables to Meet the Seven Societal Goals.

	CORE VARIABLE	WEATHER AND CLIMATE	MARINE OPERATIONS	NATURAL HAZARDS	NATIONAL SECURITY	PUBLIC HEALTH	HEALTHY ECOSYSTEMS	SUSTAINED RESOURCES
CORE VARIABLES IDENTIFIED AT AIRLIE HOUSE	SALINITY	X	X	X	X	X	X	X
	TEMPERATURE	X	X	X		X	X	X
	BATHYMETRY	X	X	X	X	X	X	X
	SEA LEVEL	X	X	X	X		X	X
	SURFACE WAVES	X	X	X	X	X	X	X
	SURFACE CURRENTS	X	X	X	X	X	X	X
	ICE DISTRIBUTION	X	X	X	X			
	CONTAMINANTS				X	X	X	X
	DISSOLVED NUTRIENTS					X	X	X
	FISH SPECIES						X	X
	FISH ABUNDANCE						X	X
	ZOOPLANKTON SPECIES					X	X	X
	OPTICAL PROPERTIES				X	X	X	X
	HEAT FLUX	X					X	X
	OCEAN COLOR	X	X				X	X
	BOTTOM CHARACTER	X	X				X	X
	PATHOGENS				X	X	X	X
	DISSOLVED OXYGEN						X	X
	PHYTOPLANKTON SPECIES	X	X		X	X	X	X
	ZOOPLANKTON ABUNDANCE						X	X
ADDITIONAL CORE VARIABLES ADDED POST-AIRLIE HOUSE	WIND SPEED AND DRIECTION	X	X	X			X	X
	STREAM FLOW	X		X			X	X
	TOTAL SUSPENDED MATTER					X	X	X
	COLORED DISSOLVED ORGANIC MATTER			X			X	X
	PARTIAL PRESSURE OF CARBON DIOXIDE (pCO2)	X				X	X	X
	ACIDITY (pH)	X				X	X	X

Ocean.US also recognized the need for regional leadership to sustain coastal ocean observations and in 2003 sponsored a summit to address the structure and functions of regional coordination. As a result, the Regional Associations (RAs) were recognized as a part of overall U.S. IOOS governance, and a National Federation of Regional Associations (NFRA) was formed to coordinate activities among the RAs and facilitate collaboration with the federal agencies. ***The NFRA has recently changed its name, in November 2012, to the IOOS Association***.

Funding for U.S. IOOS was included in the Administration's FY08 budget for the first time. Regional funding was awarded by NOAA through a competitive, peer-reviewed process for the first time in FY07. NOAA also provides the leadership, management, and oversight to ensure U.S. IOOS Regional activities are consistent with national U.S. IOOS data management standards and infrastructure. There are currently 11 Regional Associations within the U.S. IOOS Program (Figure 1).

Figure 1. Geographic Boundaries of the 11 IOOS Regional Associations.



PacIOOS - Pacific Islands Ocean Observing System
AOOS - Alaska Ocean Observing System
NANOOS - Northwest Association of Networked Ocean Observing Systems
CeNCOOS - Central and Northern California Ocean Observing System
SCCOOS - Southern California Coastal Ocean Observing System
GLOS - Great Lakes Observing System
GCOOS - Gulf of Mexico Coastal Ocean Observing System
NERACOOS - Northeastern Regional Association of Coastal Ocean Observing Systems
MARACOOS - Mid-Atlantic Regional Association for Coastal Ocean Observing Systems
SECOORA - Southeast Coastal Ocean Observing Regional Association
CaRA - U.S. Caribbean Regional Association

In response to Federal funding for U.S. IOOS, NOAA established an IOOS Program Office within NOAA's National Ocean Service (NOS) in late 2006. To avoid duplication, the Ocean.US Office was closed in September 2008.

There are currently 18 Federal organizations named as partners in U.S. IOOS (Table 4).

Table 4. The 18 Federal Agency Partners in the U.S. IOOS Program

National Oceanic and Atmospheric Administration (NOAA)
National Science Foundation (NSF)
National Aeronautics and Space Administration (NASA)
Environmental Protection Agency (EPA)
Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEM and BSEE)
Marine Mammal Commission (MMC)
Office of Naval Research (ONR)
Oceanographer of the Navy, representing Joint Chiefs of Staff (JCS)
U.S. Army Corps of Engineers (USACE)
U.S. Coast Guard (USCG)
U.S. Geological Survey (USGS)
Department of Agriculture, Cooperative State Research, Education, and Extension Service (CSREES)
Department of Energy (DOE)
Department of State (DOS)
Department of Transportation (DOT)
Food and Drug Administration (FDA)
U.S. Arctic Research Commission (USARC)
National Park Service (NPS)

The Integrated Coastal and Ocean Observation System (ICOOS) Act of 2009 authorized the establishment of U.S. IOOS and designated NOAA as the Federal agency lead. The ICOOS Act also established the IOOC to manage budgeting, standards, protocols, and coordination. NASA, NOAA and NSF currently serve as co-chair agencies. Numerous individuals within these agencies also serve as U.S. Government representatives to United Nations groups that plan and oversee global ocean observing programs.

2. Accomplishments and Assessments

U.S. IOOS has evolved over the past decade into a national program including:

- An active IOOC providing oversight
- Federal agencies creating observations, data management, products and services to meet their own missions, but in formats that contribute to the greater U.S. IOOS
- A robust U.S. contribution to GOOS efforts
- A network of 11 U.S. IOOS regional associations that connects U.S. IOOS to the local level
- A national U.S. IOOS Program Office that provides overall integration
- A new IOOS Advisory Committee to address major issues for the future

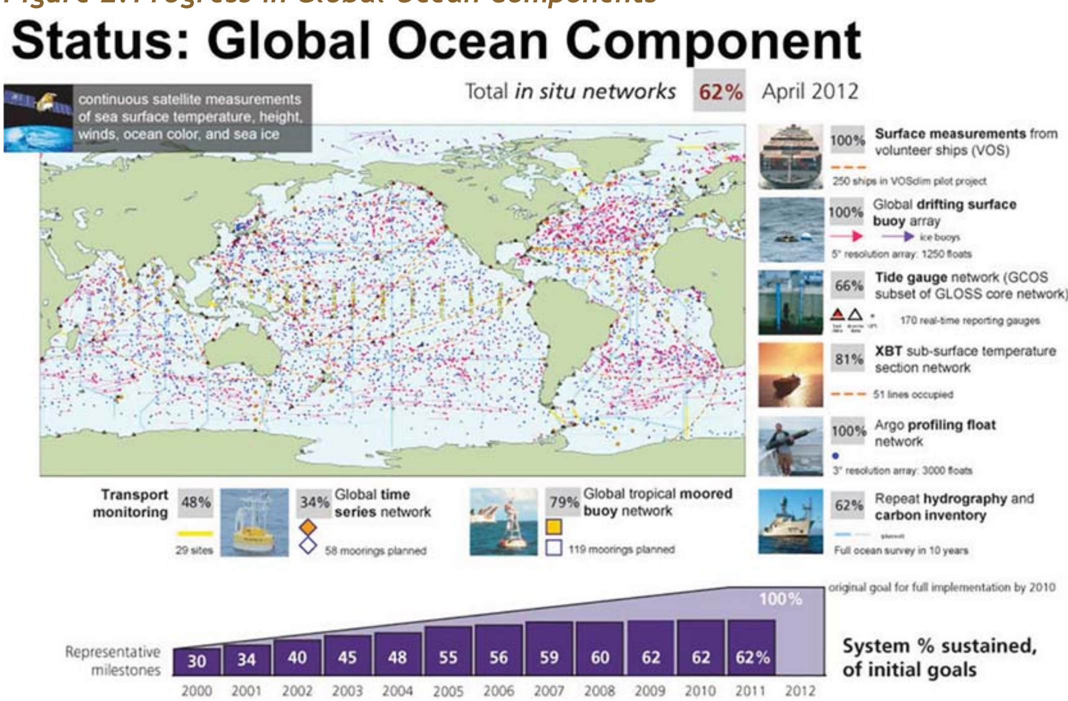
Since 2009, the IOOC, the U.S. IOOS Program Office, the Regional Associations, their IOOS Association, along with other partners and collaborators, have achieved several significant objectives in developing the system. We now have a formal policy on the public/private use of data, descriptions of functions and activities need to complete U.S. IOOS, build-out scenarios for the RAs to meet the requirements of the coming decade, and an independent cost estimate has been completed and disseminated.

The IOOS Program Office and the community over the past decade have engaged in a number of self-assessments.

Global Programs

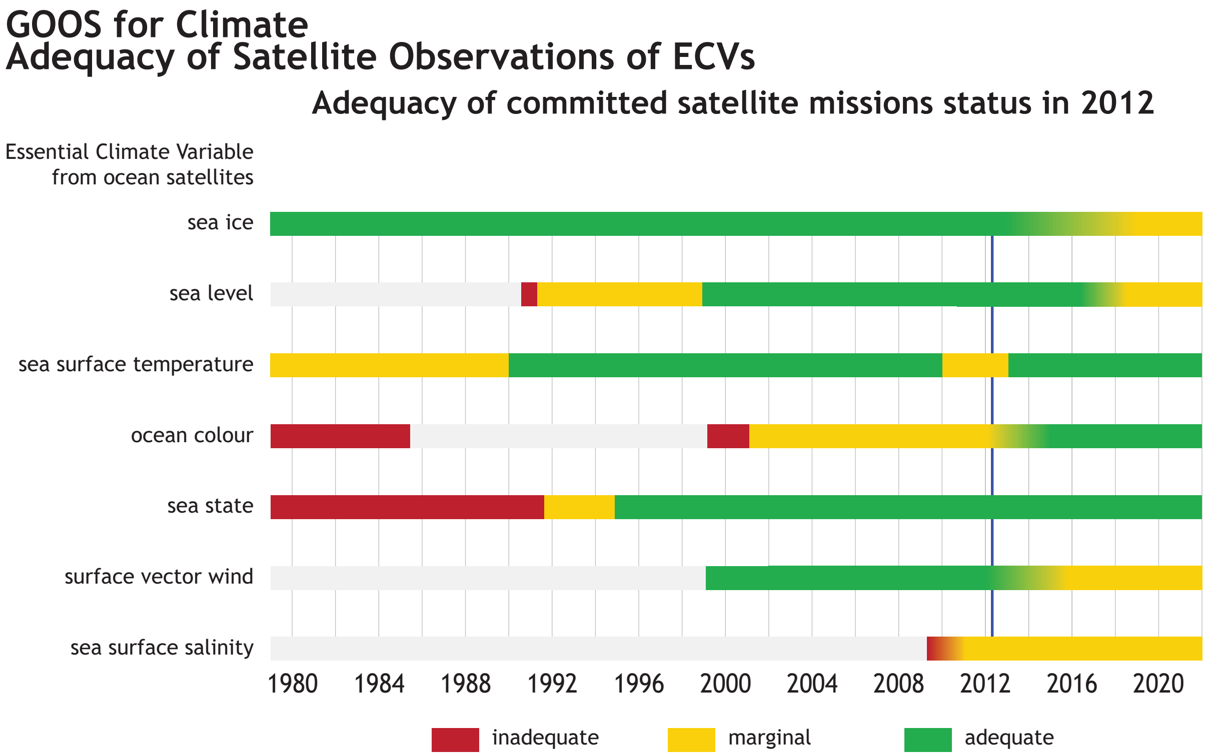
The GOOS, to which U.S. IOOS provides 50% of the funding, has determined an initial end state and progress toward it over the past decade.

Figure 2. Progress in Global Ocean Components



A related priority of U.S. IOOS is the sustainment and improvement of satellite observations. Figure 3 shows that through strong international collaboration we have raised the awareness of gaps in the adequacy of satellite observations, but the overall health of our ocean-related remote sensing capability is marginal. Efforts in this area have focused on extending and improving observing capabilities that were already in place during the 1990s, and maintaining those that have been launched subsequently.

Figure 3. Satellite Observation Status



In June 2011 the Aquarius satellite (a collaboration of NASA and the Space Agency of Argentina/ Comisión Nacional de Actividades Espaciales) was launched to measure Sea Surface Salinity, and will provide the global view of salinity variability needed for climate studies. The Suomi National Polar-orbiting Partnership, a partnership between NASA and NOAA, was launched in October 2011. It collects and distributes remotely-sensed land, ocean, and atmospheric data to the meteorological and global climate change communities. It will provide atmospheric and sea surface temperatures, humidity sounding, land and ocean biological productivity, and cloud and aerosol properties.

National Programs

The U.S. IOOS Program Office produced the U.S. Integrated Ocean Observing System: A Blueprint for Full Capability, Version 1.0, in 2010. The IOOS Blueprint can be found at *http://www.ioos.noaa.gov/about/governance/welcome.html*. The Blueprint provides an architectural framework for describing a full capability (FC) for U.S. IOOS, including partnership roles and responsibilities and implementation requirements. The architectural guidance and documentation in the Blueprint are used to:

- Establish initial requirements
- Describe what needs to be accomplished, by whom, and in what order
- Provide functional descriptions and relationships among U.S. IOOS components

In 2011, he U.S. IOOS Program Office conducted an assessment of the Federal Agencies and RAs that are part of IOOS to determine which functions and activities are currently being performed by which IOOS Federal and non-Federal partners, and which activities remain to be developed. The Blueprint identifies core functional areas (CFA) -- minimum capabilities required for an effective U.S. IOOS -- derived from stated or implied requirements in the ICOOSA and the U.S. IOOS Development Plan. The survey did not determine the effectiveness or efficiency with which any activity is conducted, but focused on the readiness to perform an activity. The survey of Federal efforts highlighted a number of opportunities, across all IOOS subsystems, to pursue growth in U.S. IOOS capability through interagency partnership agreements. The survey of RAs indicated they are active in all of the subsystems, and collectively display a solid foundation of IOOS capability, but no region has "full capability" in any subsystem.

The U.S. IOOS Program Office evaluated U.S. IOOS capability as it existed in 2010 for the coastal component. Federal and regional contributions to the observing subsystem are shown in Figure 4.

Figure 4. Federal and Regional Contributions to the U.S. IOOS Observing Subsystem

Some Federal agencies do not have sustained programs or systems, but provide valuable observations. One area of progress is the Bureau of Ocean Energy Management (BOEM) requiring oil & gas platforms to collect and transmit current data in near real time, and the sharing of pre-drilling survey data in the Arctic.

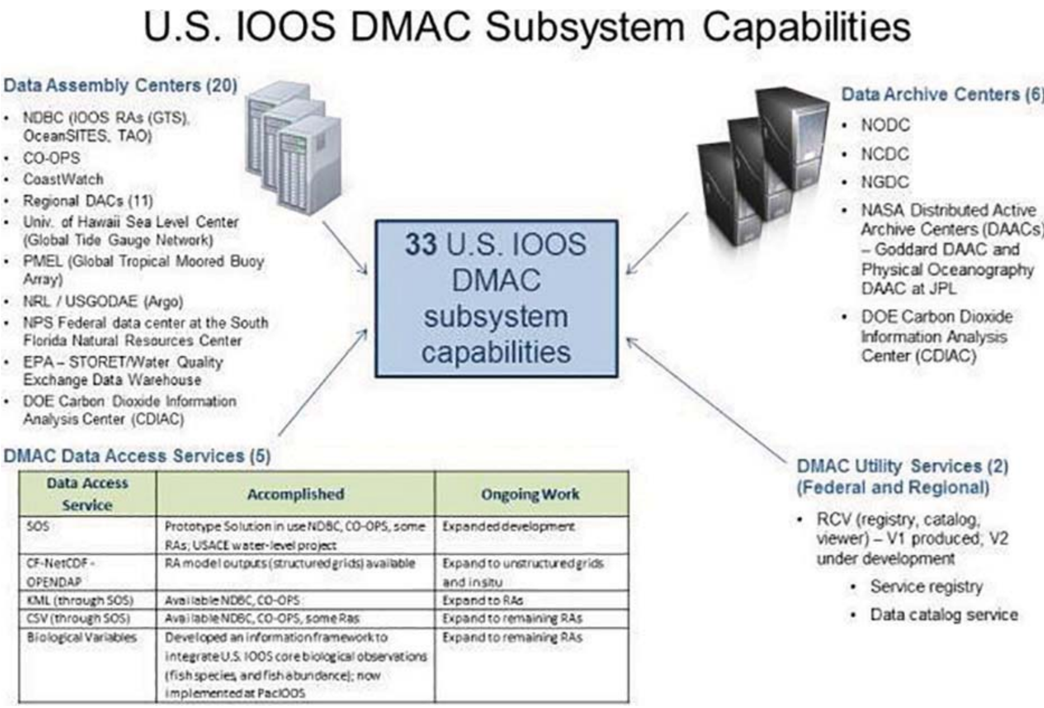
The RAs provided an initial inventory of assets, established Regional Data Assembly Centers (RDACs), completed Regional Build-Out Plans, and identified priority user needs in four primary categories: marine operations; coastal, beach and near shore hazards; ecosystems, including fisheries, and water quality; and long-term trends in ocean and Great Lakes conditions.

In the Build-Out Plans, each RA identified its own user needs, products and assets, and the information was synthesized to identify common elements across the nation. A national synthesis document, Synthesis of Regional Build Out Plans *http://www.ioosassociation.org/documents*, defines 27 common products and services that should be provided in all the regions over the next 10 years. These requirements are addressed in Chapter 4.

The Alliance for Coastal Technologies (ACT) has provided an understanding of sensor performance and data quality, while facilitating the maturation of novel technologies. Since 2004, ACT has evaluated 49 sensors from 25 international companies, which has helped manufacturers improve their technologies and users make informed choices.

The DMAC Subsystem, represented in Figure 5, is the central mechanism for integrating all IOOS data sources into compatible formats.

Figure 5. Federal Contribution to Data Management & Communication Subsystem



Data Access Service	Accomplished	Ongoing Work
SOS	Prototype Solution in use NDBC, CO-OPS, some RAs; USACE water-level project	Expanded development
CF-NetCDF - OPENDAP	RA model outputs (structured grids) available	Expand to unstructured grids and in situ
KML (through SOS)	Available NDBC, CO-OPS	Expand to RAs
CSV (through SOS)	Available NDBC, CO-OPS, some Ras	Expand to remaining RAs
Biological Variables	Developed an information framework to integrate U.S. IOOS core biological observations (fish species, and fish abundence); now implemented at PacIOOS	Expand to remaining RAs

At the Global level, individual programs such as Argo and OceanSITES have their own global data assembly centers. National and international meteorological services rely on the Global Telecommunications System (GTS) for ocean data dissemination to support atmospheric modeling, and the IOOS Data Assembly Center at the National Weather Services's (NWS) National Data Buoy Center (NDBC) provides this service. The number of ocean data records sent via the GTS has risen from less than 500,000 in 2003 to over 11 million in 2011. At the Regional level, each of the RAs has established DACs which have significantly increased user access to ocean data.

In the IOOS Modeling and Analysis Subsystem, NOAA's NOS provides Operational Forecast Systems (OFS) for thirteen U.S. water bodies (~30% of the coastal continental U.S) to support safe and efficient marine navigation and emergency response, as well as marine geospatial and ecological applications. Transitioning from individual local models to a regional modeling approach is being implemented to enhance efficiency. The first NOS regional model was recently implemented for the northern Gulf of Mexico and includes a high resolution model of the continental shelf as well as higher resolution grids (nested models) for six ports in Texas, Louisiana, Mississippi and Alabama. A similar approach is planned for the U.S. West and East Coasts.

In 2010, U.S. IOOS established the Coastal and Ocean Modeling Testbed (COMT) to accelerate the transition of advances from the modeling research community to improve operational ocean products and services. Results of this project include:

- Development of skill metrics for specific issues of societal importance
- Development of standards, web services, and tools that work across a variety of different model types, enabling interoperability, and software reuse
- Improvements to all models through comparisons

A major advance in research and development is the funding of the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI), a long-term program to provide 25-30 years of sustained ocean measurements to study climate variability, ocean circulation and ecosystem dynamics, air-sea exchange, seafloor processes, and tectonic plate-scale geodynamics. The OOI will support new ocean observation technologies and will enable powerful new scientific approaches for exploring the complexities of Earth/ocean/atmosphere interactions, thereby accelerating progress toward the goal of understanding, predicting, and managing the ocean environment.

Assessing a complex system such as U.S. IOOS is difficult, but we have summarized our progress using plans and recommendations from the Airlie House workshop of 2002, the first U.S. IOOS Development Plan of 2006, and the US IOOS Blueprint of 2010. This resulted in both a quantitative and qualitative evaluation. A detailed comparison of the ocean observing enterprise we set out to create in 2002 with its state in 2012 is contained in Appendix E. A summary of the comparison appears in Table 5.

Table 5. U.S. IOOS Progress in the Past Decade

	Past – 2002	Present – 2012
IOOS Global Contribution to GOOS	45% completed in 2004	62% completed
Observing Subsystem	• 12 PORTS® operational nationwide • 175 National Water Level Observation Network (NWLON) (none with real-time data delivery or meteorological sensors) • 60 NDBC buoys • 89 stations measuring directional waves	• 21 PORTS® operational nationwide • 210 NWLON (all real-time; 181 with meteorological sensors) • 103 NDBC buoys • National Waves Plan completed. 200 stations
Data Management and Communications Subsystem	• Disparate and uncoordinated standards, protocols, and formats • No coherent data management strategy • Call for National Standards • Ocean Biogeographic Information System (OBIS) in the pilot stage with the first set of OBIS nodes funded by the National Oceanographic Partnership Program (NOPP) in the mid-2000	• Quality Assurance of Real Time Oceanographic Data (QARTOD) was established in 2003 with increased development of quality control • DMAC Steering Team was established by Ocean.US in the Spring 2002 and continues to function today • Data Management and Communications System Architect in the U.S. IOOS Program Office • Creation of Data Integration Framework (DIF) Master Project Plan • Eleven Regional Associations Data Assembly Centers in the Regional Coastal Ocean Observing System (RCOOS) • OBIS with over 22 regional and thematic nodes has become a Project Office within the United Nations Educational, Scientific and Cultural Organization, Intergovernmental Oceanographic Data and Information Exchange, the USGS through OBIS-USA node has been an IOOS partner in development of biogeographic data standards.
Modeling and Analysis Subsystem	No coordinated effort on: • improving, developing, testing and validating operational models; • producing accurate estimates of current states of marine systems, or • developing assimilation techniques	• US IOOS Coastal and Ocean Modeling Testbed endorsed by Federal agencies • Regional models and products are now serving stakeholder needs • While capabilities exists in the community, funding has not yet been applied towards optimizing the observing subsystem

Research and Development	• Less than 15 High Frequency radar nodes for coastal current mapping nationwide • Limited Glider projects for water column profiling • Call for in situ sensors for real-time measurements and data transmission of key biological and chemical variables • Call for coupled physical-ecosystem National Oceanographic Partnership Program (NOPP) and NASA awards	• 130 High Frequency Radars and a national data management; assimilated operationally by Coast Guard and NOAA • Navy using gliders operationally; 52 gliders in Regions; employed by OOI; National Glider Asset map and national Glider plan being developed. • Partially operational Harmful Algal Blooms forecasting system
Education and Outreach	Call to: • Establish an IOOS Allied Education Community • Develop an ocean literate society based on US IOOS information • Develop Professional certificate programs	• NSF COSEE program in place • A number of regions have developed lesson plans using IOOS data for classrooms (*http://www.ioos.noaa. gov/education/welcome.html*) • MARACOOS has developed HF Radar and Glider technician certificate programs

3. Success Stories/Delivering the Benefits

U.S. IOOS has proved to be a vital set of tools for tracking, predicting, managing, and adapting to changes in our coastal and ocean environment. U.S. IOOS has addressed safety, economic, and environmental issues of the U.S., and there are many success stories over the past decade in all of these areas.

Observations to Weather Forecasting. Observations that support global atmospheric modeling have increased by 1000%, with much of the data increases coming from U.S. coastal areas from RA sources.

Oil Spill Response. The U.S. IOOS response to the April 2010 Deepwater Horizon oil spill in the Gulf of Mexico was threefold: observing technologies (satellites and gliders) were used in new ways to aid response; immediate access to non-federal data in the region impacted by the spill, and a project that tracked surface and subsurface oil. The IOOS partnership brought assets from across the United States, and the data and models were immediately usable in the Federal emergency response, This coordinated data management effort also revealed that sufficient baseline information was not available.

Tsunami Warning. U.S. IOOS played a part in the warning of the March 2011 Japanese tsunami's reach to the United States. Nationally the Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys and tide gauges provided vital data for adequate warning along U.S. coastlines. RAs saw five to ten-fold increases in web-traffic for their products. Coastal Ocean Dynamics Applications Radar (CODAR) SeaSonde® radars in Japan and California detected and measured tsunami current flows 10 to 45 minutes prior to the wave's arrival at neighboring tide gauges (Lipa, Bellina, et al., 2011), representing the first such tsunami observations made with radar technology.

Hurricane Monitoring and Forecasting. As Hurricane Irene moved through the Caribbean and up the U.S. East Coast in August 2011, NOAA used buoy data from the Caribbean, Southeast, and Northeastern Regional Associations to track the storm, initialize and verify forecasts. These forecasts relied heavily on satellite data from the global observing system. The Coast Guard, NOAA's National Hurricane Center, and NOAA's Weather Forecast offices in New England all used RA models to support local forecasts. The Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) collected and distributed high frequency radar data, operated glider routes, and phytoplankton bloom monitoring, and delivered new forecasts to the New Jersey Board of Public Utilities. Underwater glider RU-16, deployed by the Environmental Protection Agency, N.J Department of Environmental Protection, and Rutgers University, rode out the storm in deeper waters offshore and collected an unprecedented dataset that will be analyzed to improve future forecast models.

Storm Surge Display Program. The National Hurricane Center (NHC) runs a computerized model, called the Sea, Lake, and Overland Surges from Hurricanes (SLOSH), to predict storm surges. Real-time water level and wind data have been incorporated since 2010, so forecasters have access to water level observations, predictions, and winds, as well as roads, populated areas and city boundaries, to display with surge information from the SLOSH model.

Search and Rescue. The Coast Guard has added U.S. IOOS surface current data and forecasting to their Search and Rescue Optimal Planning System (SAROPS) and estimates this can reduce search areas by as much as two thirds over a 96 hour period, saving more lives and significantly lowering search costs. A "Bar Forecast" that relies on U.S. IOOS wave data has reduced the number of USCG rescue incidents in the San Francisco area by 50%.

Emergency Responder Support. When USAIR 1549 landed in New York Harbor in January 2009, water temperature was a deadly 32ºF, river currents were swift, and rescue support data were critical. Within 30 minutes, MARACOOS was providing real-time oceanographic information to New York's Office of Emergency Management. Following the crash, MARACOOS provided around the clock assistance to various agencies, including National Transportation Safety Board (NTSB), to support aircraft salvage.

Harmful Algal Blooms. There is now an operational Harmful Algal Bloom (HAB) bulletin for the Gulf of Mexico and pre-operational bulletins in the Northeast, Great Lakes and Northwest regions. The California Harmful Algal Bloom Monitoring and Alert Program, Central and Northern California Ocean Observing System (CeNCOOS) and Southern California Coastal Ocean Observing System (SCCOOS), jointly developed pier-based monitoring networks to enhance HAB data. Similar observations exist for Oregon and Washington but are not yet linked to HABMAP. In 2005, Woods Hole Oceanographic Institution (WHOI), working through NOAA's Gulf of Maine HAB program, developed a coupled biological/physical ocean model to predict whether a HAB will occur and where it will move. This model and observations from Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS) predicted a bad HAB season in 2007, which triggered additional sampling and better tracking, allowing decreases in beach and fishing closures and saved revenues. New technologies (optical sensors on Autonomous Underwater Vehicles (AUVs), the Environmental Sample Processor) are approaching transition to IOOS operations.

Safe Drinking Water. The Great Lakes provide drinking water to 22 million people, but face conflicting uses such as waste disposal, shoreline development, shipping, recreation and fishing. The Great Lakes Observing System (GLOS), with researchers at NOAA, and Cooperative Institute for Limnology and Ecosystem Research (CILER), worked with township and county officials to implement the Huron to Erie Connecting Waterways Forecasting System and developed a tool for managers to use when planning for spills.

Storm Water Plume Tracking. SCCOOS provides local views of near real-time surface currents, modeled surf zone waves and currents, and meteorological observations to simulate Tijuana River plume tracking. This supports San Diego city managers' decisions on where to conduct intense sampling for contamination and when to close a beach.

Shellfish Industry Savings. Real-time data from offshore NANOOS buoys provide early warning one or two days before cold, acidified seawater arrives in sensitive coastal waters where shellfish larvae are cultivated, allowing hatchery managers to schedule production to avoid these conditions. Based on improvements at oyster hatcheries, the U.S. IOOS support is expected to contribute significantly to this estimated $45 million annual business in coastal communities of Oregon and Washington.

Barge Operation Savings. Data from a Pacific Island Ocean Observing System (PacIOOS) buoy has saved fuel barge companies in Hawaii approximately $66,000 per year since 1977 in aborted trips by indicating ahead of time when ocean conditions are too rough to safely make oil deliveries. There are additional benefits in improved crew safety and reduced threats of oil spill.

Safe, Efficient Shipping. The Physical Oceanographic Real-Time System (PORTS®) integrates and delivers real-time environmental observations, nowcasts and near-term forecasts to maritime industry users in many of the nation's major ports. Studies in three ports have shown a 50% decrease in ship groundings following the installation of PORTS systems. Quantifiable benefit from Columbia River PORTS data is about $7.4M/year. (Kite-Powell and Kite-Powell, 2010)

Return on Investment. An economic evaluation of the estimated value of NERACOOS data is about $6M/year based on a $2M investment, a 3-fold return on investment (Kite-Powell et al., 2012).

Tagging and Telemetry Data. The U.S. IOOS office worked with the Tagging of Pacific Predators (TOPP) Program at Stanford University's Hopkins Marine Station in a 6-month project for NOAA and Navy scientists to assess the value of data collected from animals wearing data collection/tracking devices known as "tags". Tagged animals provide data from remote areas that are sampled poorly or not at all, and the data were deemed valuable. The aquatic animal telemetry community is developing a strategic plan to establish a national network under U.S. IOOS. Recent projects include: the Great Lakes Observing System effort to track 1700 tagged fish for population restoration actions.

Integrating New Technologies. The United States is transitioning its HF-Radar network to an operational system, a comprehensive national network tied together through data architecture, common practices, and a national plan.

Marine Industry Advances.

- As providers of observing system infrastructure, a number of U.S. companies are worldwide leaders, especially in the areas of HF Radar, gliders and marine instruments. Today the U.S.-produced SeaSonde® makes up 80% of all HF radars built worldwide. US companies provide 95% of the global market for ocean gliders, including the first surface glider powered by waves. And the U.S. is the largest manufacturer globally of marine instruments for the measurement of salinity, temperature, pressure, dissolved oxygen, and related oceanographic variables.
- U.S. IOOS has begun to spawn ocean related value-added companies providing:
  - Surf, wind and swell reports and seven-day forecasts to a wide array of private, commercial and government users worldwide based on U.S. IOOS observing system and model outputs
  - Local fishing forecasts, and act as both a user and provider of U.S. IOOS ocean information

Global Advances. U.S. IOOS has contributed greatly to the observing and sharing of ocean information through the international GOOS umbrella:

- With the development of profiling float technology under the World Ocean Circulation Experiment (WOCE), the Argo Program reached its target of 3000 floats in 2005.
- The Tropical Ocean-Atmosphere (TAO) array has expanded to the TAO-TRITON (Triangle Trans-Ocean Buoy Network) array, with a series of standard moorings, flux reference sites, CO2, and biochemistry sites in the Pacific, an expanded tropical ocean Prediction and Research Moored Array in the Atlantic (PIRATA), and the beginnings of a Research Moored Array for the African-Asian-Australian Monsoon Analysis and Prediction (RAMA) array in the tropical Indian Ocean.
- A new observing program, the OCEAN Sustained Interdisciplinary Time series Environmental observation System (OceanSITES) includes approximately 100 moorings, considered sentinel sites, providing high quality air-sea flux data in key, unique, or strategic portions of the global ocean (Busalacchi, 2009).
- The Global Ocean Data Assimilation Experiment (GODAE), Argo, and the Global High Resolution Sea Surface Temperature (GHRSST) programs have shown that it is possible to reach global consensus on common standards.
- With the emergence of web portals that can serve data to users in real-time, a number of Global Data Assembly Centers such as GHRSST, Argo, Global Ocean Surface Underway Data (GOSUD) Shipboard Automated Meteorological and Oceanographic Systems (SAMOS), and the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) Observing Platform Support Center have been established.
- Global solutions to facilitate the sharing of biodiversity data have emerged, including the Global Biodiversity Information Facility (GBIF) and the International Ocean Biogeographic Information System (OBIS). The associated regional nodes, (e.g. OBIS-USA) and focused taxonomic nodes (e.g. OBIS-Seamap) have developed worldwide infrastructure to publish and share their data (Pouliquen et al., 2009).
- GOOS participation in the international Group on Earth Observations (GEO) has increased their focus on ocean observations. The GEO System of Systems (GEOSS), workplan for 2012-2016, recognizes the societal benefits of ocean observations in a section titled Blue Planet that emphasizes the need for sustainment, improved coverage, and data accuracy in a global operational ocean forecasting network.

4. Introspection

Significant progress has been made in delivering the promise of U.S. IOOS by:

- Setting up the national framework for ocean observing and providing the mechanism for integration of regional observations from non-Federal sources
- Integrating data from various sources for combined products
- Moving the U.S. IOOS enterprise from planning to implementation
- Greatly adding to observing capability
- Initiating an ocean modeling capacity
- Fostering industries which lead the world in ocean observing technology
- Integrating with NSF's Ocean Observatories Initiative (OOI), which is delivering a significant boost to ocean observing research and development

But even the assessments of U.S. IOOS efforts over the past decade are still too much focused on categories such as international, national, and regional efforts, or on specific sensor technologies like satellite observations. The planning, implementation, and assessment of U.S. IOOS programs must all be more fully integrated.

Both external and internal factors continue to inhibit progress. The fiscal environment during the past decade did not lend itself to large infusions of resources for U.S. IOOS, and the present budget trend is a continuing challenge. There have also been internal factors which present ongoing challenges:

- The ICOOS Act provides a comprehensive definition of U.S. IOOS that includes contributions by all civilian Federal Agencies, but this is not fully embraced in a budgetary or staffing sense by those agencies
- The U.S. IOOS Program Office is a good start, but is not truly an interagency program office funded, staffed, or supported by the partner agencies
- IOOS proponents have yet to develop a consensus view on priorities for the national program; or a process for getting there
- There are many people committed to IOOS inside and outside the federal government, but the leadership and governance processes are not well developed
- Quantifying the economic case (costs vs. benefits) for IOOS is difficult, partly because many benefits are for the public good and not established in the marketplace
- The ocean research community has yet to adequately recognize the value of IOOS to their research while, ironically, IOOS is often perceived as having a narrow academic focus
- There are many examples of RA successes, which have demonstrated that the U.S. IOOS enterprise has the ability to maintain a national network (e.g. HF Radar) and respond to crises, but U.S. IOOS is generally perceived as pursuing too many activities without clearly defined priorities and processes
- Financial and implementation interdependencies among Federal, Tribal, State, local, academic, and NGO stakeholders are expressly encouraged. However, this presents a very complex business model, and new approaches to funding and partnerships must be pursued

CHAPTER THREE: REQUIREMENTS & USER ENGAGEMENT

1. Introduction

What did we know about user requirements 10 years ago and how does that compare to today? The Airlie House Workshop in 2002 formulated a scientific, technical and, governance structure for a U.S. IOOS® program, but the needs of end-users were not well understood at that time. Over the past ten years, the Regional Associations (RAs) have engaged with users of all types, resulting in a much improved understanding of the wide range of users, their interests, and the types of data, products, and information they need to improve decision-making for themselves, their businesses, and their communities.

Many stakeholders are involved in the planning, construction, operation, and use of U.S. IOOS:

- Providers of observing system infrastructure, including those who manufacture sensors and platforms; operators who deploy, run, and maintain them; those building, launching and operating satellite systems; those providing the cyberinfrastructure that exchanges data and products across U.S. IOOS components; and those who develop and maintain data management systems, software tools and models used to turn U.S. IOOS data into useful information
- Intermediate users who add value by taking U.S. IOOS data or information and tailoring them for specific end-uses
- End-users who use value-added products generated in whole or in part from U.S. IOOS data and information as an input to their activities or businesses to derive specific scientific, societal or business benefits

End-users of U.S. IOOS data and information fall into five main types:

- Operational end-users who use ocean data and products to support decision-making related to safety, emergency response, and economic efficiency
- Science end-users whose research relies on sustained observations of the ocean
- Policy end-users who require sustained ocean information to support policy formulation, monitoring of compliance, and assessment of policy effectiveness
- Public end-users interested in products relevant to their safety or leisure activities
- Education end-users who teach ocean science formally (K-16) and informally

Many users are beginning to see that a mature U.S. IOOS can deliver broad and multiple benefits to them, but the program is not yet mature. Over the next decade, the engagement process must ensure that new data providers continue to be entrained; the program addresses changing requirements as the state of the oceans and Great Lakes change; and the information on providers, users, and requirements continues to be consolidated and used to inform decisions on the development of the U.S. IOOS. In all these engagement activities, the RAs will remain at the forefront of the effort to evolve the coastal module of U.S. IOOS.

2. User Requirements

As opposed to ten years ago, sources of information on user requirements today are extensive, as shown in Table 6.

Table 6. Documentation of IOOS User Requirements

U.S. IOOS Summit community white papers (For requirements associated with SAR, HABs, waves, offshore renewable energy, and ocean acidification, see Allen, Anderson, Bailey, Birkemeier, Hall, and Gledhill papers, respectively)

Price, H. and L. Rosenfeld. 2012. Synthesis of Regional IOOS Build-Out Plans for the Next Decade. Washington, DC., which includes 27 common products needed by users in 11 RAs

National Operational Wave Observation Plan (2009), which includes plans for a surface-wave monitoring network to meet the maritime user community's needs

Plan to Meet the Nation's Needs for Surface Current Mapping (2009), which delineates plans for a national network of high-frequency radar stations to support search-and-rescue efforts and oil-spill response, among other societal needs

U.S. Integrated Ocean Observing System: A Blueprint for Full Capability Version 1.0 (November 2010), which "identifies, describes, and organizes the specific functional activities to be developed and executed by U.S. IOOS partners". Additionally, the U.S. IOOS Office is developing a series of perspective papers, including one on user requirements and gap analysis

Requirements for Global Implementation of the Strategic Plan for Coastal GOOS, Panel for Integrated Coastal Observation (PICO-I) (2012)

Attaining an Operational Marine Biodiversity Observation Network (BON) Workshop (2011)

Toward a National Animal Telemetry Observing Network (ATN) Workshop Synthesis Report (2011)

NOAA Ocean and Great Lakes Acidification Research Plan (2010)

The RAs are systematically organizing user requirements from these and other sources, including engagement of the regional offices of many of the U.S.IOOS Federal partner agencies. The requirements, for both data and products, are summarized from the 10-year Build-Out Plans of the 11 RAs in five major user categories: Marine Operations, Coastal Hazards, Ecosystems and Fisheries, Water Quality, and Long-term Variability (Price and Rosenfeld, 2012). This report summarizes the requirements in a table that presents the 27 common products required by users across all 11 RAs. A table showing the common products required is shown in Appendix F.

3. User Engagement and Its Challenges

To understand user requirements with the specificity needed to transition ocean observations from the research stage to operations, users, and providers must be fully engaged. Successful user engagement is an iterative process, with eight steps presented in Figure 6. Although a purely circular process is depicted, many of the steps will be revisited during the process. If all the steps are carried out sufficiently, a natural by-product will be advocacy (Step 8). The users will better understand what the enterprise is trying to accomplish, both as a whole and for them as a user group. This understanding, coupled with successful provision of data and products, will lead to user-initiated advocacy for the enterprise, effectively turning end users into U.S. IOOS advocates.

Figure 6. The Steps Required for Successful User Engagement

Each of the steps presents challenges, many of them related to communication and coordination. How can the requirements of users be better communicated to observers and data providers? How can potential users be made more aware of data and products available through U.S. IOOS? How can different federal agencies, countries and RAs better coordinate to meet the diverse array of user requirements? How can we prioritize activities to address user requirements?

There are also technological, financial and ideological challenges in meeting user requirements. Many users want biochemical measurements, but the system's initial focus has been primarily on physical measurements. Due to lack of resources, users are often asked to supply funds in order to see their requirements fulfilled. There are cultural challenges that arise from different communities working together: the research and operational communities; the public, private industry and university sectors; different federal agencies; and different countries. These communities have defensibly different views on user requirements and priorities. Hearing and merging all of their views into a coherent program requires rigorous involvement in all steps of the user engagement process, and in overcoming their challenges.

Step 1. Identify the users.

This seemingly straightforward step has been a major undertaking, but considerable progress has been made over the past decade to identify users and build relationships.

Challenge. This challenge has been met, but the range of users that are and could be served by U.S. IOOS is so extensive it is difficult to know how to serve all of them.

Step 2. Prioritize the users and/or the products.

Existing and potential users of U.S. IOOS are extensive, which follows from U.S. IOOS having a purposefully broad scope. However, limited resources require that we prioritize who we are going to serve and/or what products and services the system will provide.

Challenge. There are cultural differences among U.S. IOOS user communities, and they have different views on user requirements.

Setting priorities for an enterprise with the scope of U.S. IOOS is a daunting task. The current economy requires that choices be made, but the existing U.S. Federal budget process is not conducive to developing U.S. IOOS-wide funding priorities.

At the global scale, there is increasing recognition that the U.S. will have to rely on foreign sources of satellite data to meet our requirements. The Committee on Earth Observation Satellites (CEOS *http://www.ceos.org*), which is a part of GEO *http://www.earthobservations.org*) is coordinating environmental satellite observations of the Earth. With limited resources, how do we ensure the widest range of U.S. local, regional, national, and global requirements is met?

The United States' ocean observing community has never been more organized, disciplined and collaborative towards common national goals and objectives than it is now, but challenges remain at the interfaces of the various communities. Many Federal agencies have operational needs that could be addressed by other U.S. IOOS partners. An improved mechanism is needed to facilitate broader sharing and partnering across the U.S. IOOS enterprise. Since the non-Federal observing system is being implemented mostly through academic institutions, the academic value structure -- based on publication and grant proposals -- needs to be more widely understood and integrated into IOOS planning.

Step 3. Define user requirements.

Defining user requirements is an iterative step that can only be executed if adequate human resources are committed. Each user's decision processes and operational needs must be fully understood.

Challenge. It is a legislative mandate for U.S. IOOS to be based on the needs of users (Ocean.US, 2002), but documenting user needs is not straightforward. Which users should be included? How should their requirements be prioritized?

The timing of engagement with end-users to understand their needs must be considered. Requirements have a shelf life. If the resources are not available to act on requirements, then documenting them may have the negative impacts of raising expectations of users when nothing can be done; and wasting effort because the requirements may change and need to be revisited. Catastrophic events cause sudden and dramatic changes in user requirements, often without an increase in necessary resources. User requirements will change with time, changing technology, and unforeseen events. The requirements documentation process must be able to accommodate this.

Different types of users have very different requirements. An operational model may require a continuous, near real-time data stream, whereas the public's needs are more episodic and usually require interpretation -- a product -- rather than a data stream. User requirements extend to the data dissemination process; active communication between users and data providers is crucial to establish efficient, user-friendly data and product distribution. Improved mechanisms are needed for collaboration among users, researchers, and private industry to ensure the development of meaningful products. We need to engage more intermediate users who bridge the gap between providers and users. We need increased private enterprise activity to fill the gaps in U.S. IOOS.

The present system has been built largely around collecting and modeling physical oceanographic parameters, but a large and growing segment of potential users requires biological and biogeochemical observations. There have even been efforts to incorporate biological measurements, but these have been driven largely by leveraging available technology rather than as direct responses to the highest priority user needs for biological data. The investment in sensor development and modeling necessary to optimize the observing system for biological and chemical questions is still lacking. Such investment towards products beyond the purely physical models will be required.

There is also a spatial mismatch between the observing system and many desired applications. U.S. IOOS was initially built primarily to support large scale global oceanographic models, with kilometer-scale resolution and the coastal shelf as a boundary condition. Many of the U.S. IOOS user needs are located much closer to shore and on much smaller spatial scales. While the spatial resolution of the models continues to improve, and there are some nascent efforts to move the model's boundary conditions closer to shore, there is still much fundamental technical work to be done before many user community needs can be addressed.

Step 4. Develop Solutions.

This stage focuses on partnering of the RAs and IOOC agencies with private enterprise, non-governmental organizations, and/or local, tribal, state partners. A key to success is keeping the user engaged and understanding that several iterations will likely be necessary before users are satisfied. Since this step can take months or years, user requirements will evolve during the process, requiring adjustments to the solutions.

Challenge. The Research-to-Operations (R2O) transition process has always been difficult, earning it the nickname of "Crossing the Valley of Death," but it is a fundamental part of U.S. IOOS. There are many examples of a strong "push" from research communities to operationalize their products, but a lesser "pull" from the users. No organized process exists to foster a strong and consistent "pull" from the operational communities, but this is needed to improve transition of the products that are most needed by users. We need a formal process for user-driven product development.

The RAs have significant experience in user-driven, product development approaches. (See *http://www.usnfra.org/products.html* for 71 RA created products.) The RAs often serve as the linchpin between data generators, data product developers and users in their region. Improvements are needed to shift these processes from a cooperative approach (working together toward independent goals) to a more coordinated approach (working together toward common goals).

The governance structure for an expanded product development process could include a number of supporting structures, including user councils, thematic product working groups, a stakeholder engagement council, and leveraged use of existing stakeholder networks. A partnership between the U.S. IOOS Program Office and the IOOS Association could engage all U.S. IOOS Federal agencies and RAs to populate and support a User Engagement Council charged with defining and fostering a U.S. IOOS R2O strategy.

Step 5. Conduct Outreach.

In the private sector, this step is called marketing. Products will not be used if users are not aware of them. This step is most often cut from public sector development programs. It is highly important, but requires infusion of human resources and funding.

Challenge. There must be more investment in building a community of informal education specialists who can promote the use of U.S. IOOS information to achieve ocean literacy. U.S. IOOS must facilitate the development of new strategies for virtual social structures that encourage communication and sharing of ideas across disciplines (Thoroughgood et al, 2013). For outreach to the general public, data dissemination must move beyond web pages and take advantage of expanding media technologies, such as smart phone applications and twitter feeds, to make data and products more easily available to public users.

NOAA's Sea Grant extension services provide agents with ocean expertise who interact directly with specific stakeholder groups; the Sea Grant system should be used to improve stakeholder engagement within U.S. IOOS.

Additional resources for the existing IOOS Association Education and Outreach Council would support an increase in engagement with formal and informal educators, undergraduate and graduate level students, and the general public. These outreach efforts to put understandable information into the hands of the public are just as important as the DMAC subsystem that puts quality data into the hands of users.

Step 6. Assess and Maintain Products.

Follow-up assessments are required to ensure any U.S. IOOS data, product, or service continues to meet the user's need. Maintenance is critical to keep user groups, their requirements, and the associated resources to meet them up-to-date with the changing states of the ocean and Great Lakes. When accounting for resource needs, long-term costs of maintaining user engagement must be included.

Challenge. Many 'levels' of products are available for U.S. IOOS stakeholders, ranging from minimally processed data to decision-support tools. The challenge is to build more robust assessment, maintenance, and product updates into the U.S. IOOS structure.

Step 7. Provide Training.

Training of the technicians, programmers, scientists, educators, and others who will be needed for a mature U.S. IOOS is required. This step in engagement is often overlooked and hence under-planned and under-resourced.

Challenge. Dedicated human resources are required to conduct meaningful outreach and training. NOAA's Sea Grant extension services can serve as models for, and support, stakeholder engagement within U.S. IOOS to ensure that data and product dissemination meets user requirements and is user-friendly.

Step 8. Increase Advocacy.

There is a need to develop and maintain advocacy for U.S. IOOS.

Challenge. U.S. IOOS is a line item in the NOAA budget, but it remains a largely unfunded federal mandate. The existing approach of individual agency ocean observing programs addressing agency-unique missions with uncoordinated agency budgets is inadequate. This fragmented Federal approach lies at the heart of the U.S. IOOS challenge to thrive.

Advocacy will develop naturally if stakeholders and users are actively engaged and their requirements are being met. But a proactive advocacy strategy is also needed. There are many users that have come to rely on U.S. IOOS products without providing any support for the system. The ocean observing community is not adept at turning that supportive relationship into advocacy for continued or expanded funding.

Significant, well-qualified human resources are necessary to maintain effective user engagement. U.S. IOOS must recognize the importance of this process and support implementation of a user engagement infrastructure in order to meet the vision of U.S. IOOS for the next decade.

Table 7. The Steps of User Engagement, Challenges & Potential Approaches

#	ENGAGEMENT STEPS	CHALLENGES	PROPOSED APPROACHES
1	Identify Users	1: How can we identify the users of U.S. IOOS?	1: Organize information about users, their requirements and available products into a “marketplace”
2	Prioritize Users and/or New Products Lines	2A: How can different Federal agencies, different countries and different RAs agree on priorities since resources are not available to meet all user requirements? 2B: How are cultural challenges involved with different communities working together, and what are their different attitudes/ perceptions of user requirements?	2A(i): Develop an “Action Agenda” for U.S. IOOS that prioritizes near-term investments and steps along the path to a fully operational system 2A(ii): Devote a portion of each IOOC meeting agenda to resolving coordination issues 2B: The IOOC agencies should provide recognition, incentives and/or rewards for partnerships across cultural interfaces
3	Define Requirements	3A: How can the requirements of users be better documented and communicated to U.S. IOOS stakeholders? 3B: How to address the mismatch between many of the user needs and the technical capabilities of the observing system?	3A: Institutionalize a process to identify, vet, and prioritize user requirements -- make it clear to users what is available, and clear to data providers where the gaps and opportunities are 3B: U.S. IOOS needs to invest in development of the necessary biological and chemical sensors to meet established user requirements
4	Develop Solutions	4: How can we ensure that users are properly engaged in the transition from research to operations for observational data streams and models?	4A: Organize existing U.S. IOOS user engagement efforts into an ad hoc User Engagement Council 4B: Open up the Federal agency ‘pull’ opportunities 4C: Incentives for private industry
5	Effective Outreach	5: How can the public and other potential users be made more aware of the data available through IOOS?	5: Increase support to the IOOS Association’s Education and Outreach Council
6	Assess and Maintain Products	6: How can we ensure that U.S. IOOS products continue to meet user needs?	6: Establish product metrics
7	Provide Training	7: How can we ensure that U.S. IOOS products are used?	7: Provide marketing and training
8	Increase Advocacy	8A: How can we develop and maintain advocacy for U.S. IOOS? 8B: How can we address funding issues which can result in user alienation and loss of existing observational resources?	8A: IOOC Federal agencies increase their branding for U.S. IOOS 8B: The IOOS Association coordinates with the business community on advocacy training for IOOS personnel; the IOOC should open Federal agency cooperation avenues at the regional level

4. An Assessment of User Engagements

Successfully defining user requirements is an iterative process characterized by mutual understanding, commitment, and trust between the user and provider. The "corporate culture" of U.S. IOOS must be one where user engagement is a top priority, and these efforts must be funded at a significant enough level to make a difference.

At the level of the Global Module of U.S. IOOS, engagement is usually conducted within the spheres of Federal agencies and their consultants and contractors. At the level of the Coastal component, the U.S. IOOS Program Office and the agencies of the IOOC are, in effect, serving two masters. The contributions by Federal agencies are assets supporting their own missions and these need to be better integrated into U.S. IOOS, both to more fully represent all the user groups and to improve entrainment of the data, products, and information from these agencies into the U.S. IOOS enterprise.

The RAs have devoted significant resources over the past decade to user engagement on the local, regional and national scales, establishing strong relationships with many users. The level of user engagement has ranged from excellent to mediocre, as illustrated in the examples below.

Example 1. Turning Users into Data Providers

There is always a shortage of in-situ data for the assimilation and validation of coastal ocean circulation models. In the Northeast Region, the Environmental Monitors on Lobster Traps (see *http://emolt.org*) project addressed that problem by working with lobstermen to place sensors on their traps. Start-up funds were provided by NOAA's Northeast Consortium. Maintaining the program requires only low-cost replacement probes approximately every five years, and a few months of personnel time each year to process the data. There is now more than a decade of hourly bottom temperatures at dozens of fixed locations from this program. Salinity sensors, bottom-current meters, acoustic listening devices, tide-gauges, and underwater cameras that provide a time series of biological activity have also been deployed on the traps. The fishermen also assist with deployment and recovery of student-built satellite-tracked drifters in order to help document surface current flow (see *http://www.nefsc.noaa.gov/drifter*). In addition to providing data for coastal ocean circulation models, the project has engaged many fishermen in the process of monitoring their environment. These fishermen have the biggest stake in preserving our coastal marine resources, and are most knowledgeable of the local waters. This is an excellent example of developing a solution to a data deficiency, which resulted in engaging users by turning them into data providers.

Example 2. Research to Operations (R2O) Success Is Not Enough

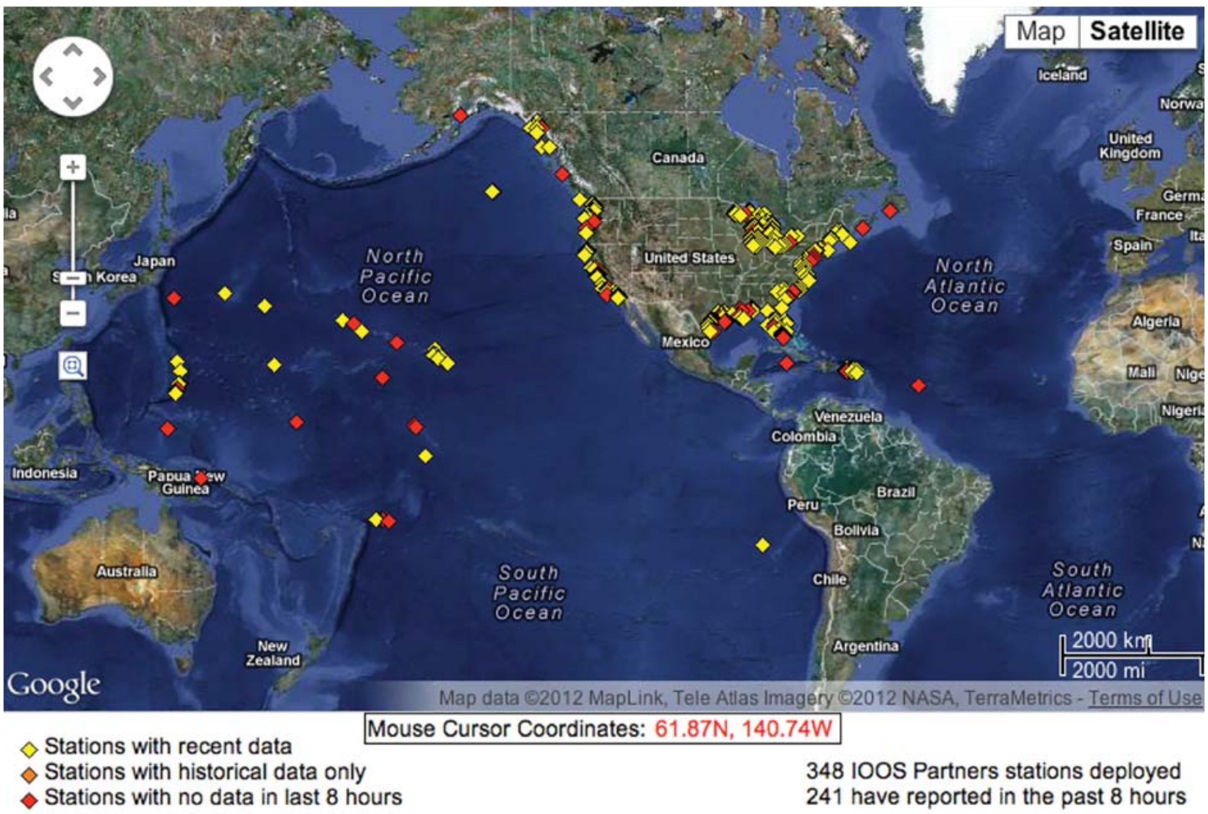
Small networks of HF radars operated by academic institutions appeared around the nation in the 1990's. Based on early successes, in 2001 a best-practices workshop was convened and by 2007 individual academic systems were combined into an aggregate network. Today the U.S. IOOS has established a National HF Radar Network based on the U.S. Surface Current Mapping Plan. The Network supports the operation of approximately 120 HF Radars along the U.S. coast. The Network supports the aggregation of the radial surface currents, produces total vector maps, and the dissemination of surface current fields to a broad range of users including the U.S. Coast Guard. Results of a four-day test in July 2009 showed that when HF radar data were ingested into the U.S. Coast Guard's Search and Rescue system, the search area was greatly decreased. The use of HF radar data is currently integrated in to Coast Guard Search and Rescue on a national level, but even this research-to-operations (R2O) success has not led to needed resources for expansion in the HF radar assets distributed around the nation's shorelines (Glenn, Barrick, 2012)

Example 3. Changing "corporate culture"

Early in the formulation of the U.S. IOOS vision, the National Data Buoy Center (NDBC) took on the task of becoming a central Data Assembly Center (DAC) collecting data from regional ocean observing systems, providing quality control, and distributing the data in realtime via the Global Telecommunications System (GTS), their website, via netCDF files, and via Sensor Observation Service. There are about 400 non-Federal observing stations in the coastal ocean and Great Lakes that contribute to the data stream disseminated via GTS (Figure 7). The NDBC efforts in collecting, managing and disseminating data from both Federal IOOS efforts and from Regional Associations illustrates how a Federal agency can change its "corporate culture" to entrain itself into the greater vision of the national U.S. IOOS enterprise.

Figure 7. Stations in the IOOS DAC Operated by NDBC.

This shows stations at 2200 CT on 26 August 2012
(available at <http://www.ndbc.noaa.gov/obs.shtml> by selecting "IOOS Partners").



Example 4. Data is not enough; it must be integrated

The Gulf of Maine buoy array of NERACOOS has provided continuous oceanographic measurements for over a decade. There are now seven buoys in the array sited at coastal shelf depths ranging from 50 to 250 meters and providing temperature measurements at 3 to 7 depths throughout the water column. Analysis of this time series shows statistically significant warming trends at all depths for all locations, providing the first depth-resolved rates of temperature variability for the U.S. East Coast from continuous data. Ecosystem data are lacking, however, so there is no telling what impact this warming condition is having on the ecosystem. User engagement is successful when the data are integrated in new ways to provide new understandings or new information for decision-making. The impact of data is limited without human resources funded for analysis and for making the results available to broader user groups.

Example 5. Catastrophes radically change users requirements

Sudden catastrophic events, such as Hurricane Katrina and the 2010 Deepwater Horizon oil spill, can have sudden and profound impacts on user requirements. Twice in just five years, the GCOOS efforts were altered from a steady pace of engagement, entrainment and building solid commitments with users and providers, to an on-demand, urgency-driven engagement process with myriad new stakeholders. Ongoing projects, such as the development of a Harmful Algal Bloom (HAB) Integrated Observing System, were postponed in order to deal with emergency situations. Engagement personnel, many of whom were volunteers facing their own major losses associated with these events, were stretched thin, and the dramatic shifts in stakeholder needs still reverberate through the engagement process today. Both of these events imposed a prioritization scheme on a response and monitoring system that had no mechanism for establishing priorities, and illustrated how vital an effective prioritization process can be. Other changes in the environment and climate, such as increases in hurricane intensity, habitat losses from sea level rise, new invasive species, and increases in HABs will also impact user needs for data, products and information. It is imperative that the system be designed to recognize and respond quickly to changing user needs.

In summary, these examples illustrate both the successes and limitations of the existing U.S. IOOS user engagement efforts, and argue for improved processes and an infusion of additional resources if we are to meet the U.S. IOOS vision for the next decade.

CHAPTER FOUR: GAP ASSESSMENT & COMPREHENSIVE DESIGN

1. Introduction

The existing U.S. ocean observing system was built with the support of a wide range of sponsors and users with applications as varied as safe navigation and beach water quality monitoring. Much of the system arose as a "mission-dependent, uncoordinated collection of sensors rather than a carefully designed, multi-sensor, multi-user observing system. We must examine the existing system to identify improvements -- from co-locating more sensors on existing platforms to re-locating existing platforms based on scientific and operational need.

In the coming decade it will be important for the U.S. IOOS® program to develop more mature and comprehensive processes for defining and prioritizing requirements and observing system design that integrate across global to local scales. Accurate products and predictions within the U.S. IOOS geographic area require accurate information at its offshore boundary, thus increased interoperability with international GOOS efforts is required. Inputs from terrestrial watersheds into the coasts and Great Lakes must also be integrated, to combine river flooding and coastal storm surge into coastal flooding predictions. Identification of essential capabilities in each of the U.S. IOOS subsystem components can provide common threads for the design. This chapter assesses the progress toward developing a comprehensive design, and highlights steps that need to be taken.

2. Design Issues in the IOOS Subsystems

Observing Subsystem

There are many ocean observing components, collecting data both in-situ and remotely, and from both fixed and mobile platforms. The sensing a given component can support varies widely by platform characteristics and sensor load. In practice, observing activity is often considered by platform, but ideally a comprehensive design analysis should be done across all observing sensors and platforms based on essential ocean variables (EOVs).

Observing Platforms

In-situ observing depends heavily on access to ships, including both research and commercial vessels, to provide ground truth for overhead sensors, to make observations especially in deep water, and to deploy/retrieve/maintain fixed and mobile autonomous platforms (moorings, drifters, profiling floats or gliders). Access to ships, is a critical infrastructure need. Commercial vessels have played a significant role in the historical collection of meteorology and oceanography observations. Some of these vessels also deploy drifters and profiling floats, tow plankton collection systems, and support underway sampling systems for sea surface salinity and partial pressure of carbon dioxide (pCO2). A variety of other variables could potentially be observed. Private industry has indicated a willingness to support ocean observing, and it is important to follow up on this opportunity (Rossby et al 2013). Ferry-based sampling increases spatial coverage in coastal and estuarine waterways over long durations and a high temporal frequency with application to a range of multidisciplinary observations and the potential for inclusion of new sensors. (Pearl et al, 2009).

Autonomous platforms, both fixed and mobile, offer the ability to collect observations routinely throughout much of the global ocean, with reduced cost and continuous all-weather operation. They have revolutionized our knowledge of the ice-free global open ocean over the past decade and much development is now underway to make these systems capable of sustained operation under ice. The ability to collect observations in conditions too harsh for vessel operations, and at high frequency for extended periods of time, has significantly improved both the statistics of ocean observations and the confidence of predictions.

Fixed moorings offer the unique ability to sample a full time-spectrum of variability in one location with high accuracy. In coastal settings, moored buoys have been the principal automated observing platforms, and they are also an essential component of the global system, providing reference quality observations at selected global sites. These fixed platforms have enabled collection of long time-series of largely near-surface physical variables, sufficient in some instances to define seasonal climates and anomalies from them. Collection of subsurface observations using deeper moorings has increased in recent years, but subsurface observations in coastal areas and the use of these platforms to host a wider variety of sensors, are significant gaps (Virmani 2012).

Mobile autonomous platforms, including drifters, profiling floats and gliders, have proven effective in many coastal areas. Underwater gliders are promising in some parts of the coastal ocean because of their ability to capture smaller spatial scales of variability, and because of the operators' ability to direct the sampling patterns. Rudnick et al. (2012) present a plan for implementing a routine glider observing program covering coastal waters and providing a link to global observations. Other navigable platforms (wave gliders, autonomous underwater vehicles, autonomous ships) are being used in U.S. coastal waters, including those areas not accessible by gliders (estuaries and the nearshore, where unmanned surface vehicles have particular advantages). It is essential to increase the observing capabilities of surface drifters, gliders and profiling floats beyond their present physical variables. Work is ongoing to improve the capabilities of biogeochemical sensors on these platforms, as well as to develop profiling floats capable of sampling the full ocean depth.

Remote sensing technology includes satellites, sub-orbital (airborne Lidar) and land-based platforms (high-frequency radar). Many key U.S. IOOS variables can be derived from remotely sensed observations, providing synoptic, regular and consistent physical and biological observations from regional to global scales that can be used for event-scale responses (oil spills) as well as long-term time-series analyses (sea level rise). Their weaknesses – a lack of sub-surface and other desired measurements, and limitations in spatial, temporal and/or spectral coverage -- can be addressed through new remote sensor development, and through complementary in-situ measurements.

Among ground-based remote sensing technologies, the most widely used is surface current mapping by the National HF Radar Network. The plan for national broad-scale coverage is an example of a design employing a dedicated technology. A review of the plan to consider nested, more high-resolution systems, and additional observational capabilities, would be appropriate. There should also be consideration of other ground-based remote sensing technologies that may provide efficient or novel methods to observe the oceans. An additional issue to address in the coming years is better defining the role that sub-orbital platforms (e.g., aircraft, unmanned aerial vehicles) can play in regional and global data collection for U.S. IOOS.

Satellites make a significant contribution to global observing of ocean essential climate variables (ECVs), including sea-surface temperature, ocean vector winds, sea-surface salinity, sea level, sea state, sea ice and ocean color (GCOS, 2011). From the broader ocean and coastal observing perspective, the list is much longer and includes other ocean color, synthetic aperture radar, scatterometer and derived observations (PICO Coastal GOOS Report, 2012). But numerous recent articles and reports have addressed the need for expanded ocean remote sensing, in support of GOOS (Drinkwater et al, 2010), U.S. IOOS (Muller-Karger et al., 2012; IOOS Summit CWP), and GCOS (GCOS Report #154, 2011), and for broader ocean research and applications (Lindstrom, E.J., and N. Maximenko, 2010; Lindstrom et al., 2010; Bonekamp et al., 2010; OceanObs '09 Proceedings; NRC, 2011). Other relevant reports address emerging applications such as remote sensing of water quality (GEO, 2007).

Significant progress has been made over the past 10 years in: dual-purpose space-based ocean observing for both research and operations (altimetry, scatterometry, ocean color); new measurements (sea-surface salinity from Aquarius; sea ice thickness from Cryosat-2); and expanding the use of satellite data to meet user needs (regional water quality monitoring using ocean color data; ocean products from Cryosat-2 supporting National Centers for Environmental Prediction and National Hurricane

Center). But remaining challenges include: continuity, resolution/coverage, and knowledge challenges (IGOS, 2006; PICO, 2012); integration of sensor outputs (Ocean.US, 2006); free, timely and sustained access to satellite data; robust calibration/validation and quality monitoring of (Chapron et al., 2010; NRC, 2011); future reliance on data from foreign missions/sensors (synthetic aperture radar, scatterometry).

Observing Requirements and Emerging Technologies

There is keen interest in developing new observing technologies as evidenced by a number of community white papers submitted on this topic:

- Ocean acidification and its impacts in coastal regions must be measured, together with ecosystem responses (Gledhill et al., 2012)
- Augmentations to the Integrated Ocean Carbon Observing System will enable improved estimates of carbon inventories and impacts (Wanninkhof et al., 2012)
- Acoustic monitoring of fish populations and marine animals can be expanded through active acoustic survey platforms (Griffith et al., 2012; Horne et al, 2012)
- Passive acoustic monitoring of biological and human activity in support of ecosystem assessment is possible from a wide variety of platforms (Southall et al., 2012)
- Leveraging the Animal Telemetry Network (acoustic and satellite tracking) to add a broad range of variables is considered (Block et al., 2012, Welch et al, 2012; O'Dor et al., 2012)
- Ferry-based sampling increases spatial coverage in coastal and estuarine waterways over long durations and at high temporal frequency with application to a range of multidisciplinary observations and the potential for inclusion of diverse, new sensors (Paerl et al., 2009; Codiga et al., 2012)
- Harmful Algal Bloom (HAB) monitoring/forecasting requires integrating several variables, and observing select toxins (Anderson et al., 2012; Kudela et al., 2012)
- Next generation satellite missions are needed to observe ocean surface current vectors over open and coastal oceans via along-track interferometry (Freeman et al., 2010)
- Federal involvement and investment in GOOS regional observation programs is required, with priority given to regions that impact U.S. waters (the Arctic, Gulf of Mexico, Caribbean, Pacific), especially the Arctic which is experiencing unprecedented change (Auad et al., Calder et al., Stabeno et al., Hicks et al.)
- A number of community white papers explore possible industry roles and relationships with U.S. IOOS (Rossby et al., Codiga et al., Woll et al., Holthus, Manly et al.); given the funding challenges, industry collaboration may be a vital mode of capitalization

Routine collection of biogeochemical variables is probably the greatest recognized gap in the observing subsystem. Typical methods require laboratory analyses and have been ship-based. There is, however, an explosion in automated sensing development, as well as development of "indicators" of ecosystem state, that hold some promise of addressing this large gap in observing capability. There is also a need for new and improved space-based ocean biology and biogeochemistry measurement capabilities.

All these observing approaches, both existing and emerging, should be considered for inclusion in the comprehensive U.S. IOOS observing system design, because no single platform offers a cost-effective strategy for all observing needs. The collection of platforms besuited to a given region will vary due to observing requirements and environmental conditions (water depths, current strength, stratification, intensity of human activity, accessibility), and will change over time as new capabilities become available. An important aspect of a comprehensive U.S. IOOS design will be flexibility in platform use regionally and temporally to address multiple requirements and adapt to changing needs.

Data Management and Communications Subsystem (DMAC)

The data storage and access component of DMAC is well-defined for some data sources such as buoys, high frequency radar, gridded data from satellites, and gridded output from models. Increased involvement is needed from the operational modeling centers, research scientists, data assimilation systems, weather forecasting offices, or product developers is needed to help prioritize DMAC requirements. Decisions on the application of standards will require input from the Observing, DMAC, and Modeling & Analysis Subsystems of U.S. IOOS. And more work on common, standard tools for clients is needed.

The vision for this subsystem is to collect and deliver data and metadata; provide analysis and visualization tools; provide for the long term preservation and reuse of all this information seamlessly across regional, national and global boundaries and across disciplinary boundaries. Some gaps between the existing system and the envisioned system require organizational changes more than technical solutions.

DMAC Structure

The IOOS Blueprint identifies a number of functions that must be fulfilled by DMAC and describes nodes that satisfy these roles. Data assembly centers (DAC) are viewed as a central part of the DMAC architecture, yet the form these take and their roles, responsibilities and funding are not clear. Some DACs are regional, others are thematic and still others focus on specific observing systems. At each exchange across this diverse system, there are possibilities for information incompatibility and loss.

It is useful to compare/contrast the U.S. IOOS DMAC with Australia's Integrated Marine Observing System (IMOS). Australia's IMOS National Centers are integrated by a single data management framework, Data Fabric, as mandated by a central governance facility. U.S. IOOS does not have that level of control, but such an approach should be considered by leadership – the Interagency Ocean Observation Committee (IOOC) and/or the Deputy-Level of the National Ocean Council.

Archiving is an essential element of good U.S. IOOS data stewardship, and the same standards and user interfaces should be used for DMAC metadata, data dissemination, data archiving. The scope of the information system encompasses much more than just the ocean observations themselves, but includes the entire data cycle.

Quality Control and Quality Assurance

Quality control is a key requirement, but remains a challenge due to the lack of common processes and limited funding. Closer coordination is needed between the RAs and data centers at multiple Federal agencies, to ensure that consistent Quality Assurance/Quality Control (QA/QC) and archiving procedures are employed across the nation. This issue will only increase in importance and complexity as the volume of data and products expands dramatically in the years ahead. U.S. IOOS must address the critical importance of QA/QC since it ensures our data and products are reliable for users.

An essential role of the U.S. IOOS cyberinfrastructure is to provide tools to discover and access ocean data and products. Observing system operators have an obligation to keep their instrumentation and reporting methods in line with U.S. IOOS data standards. DMAC operators have a role in ensuring this information is captured and codified using relevant IT standards. The DMAC cyberinfrastructure has the responsibility to deliver U.S. IOOS information using technologies that enable machine-to-machine interaction and unambiguous interpretation. Data users in the Analysis, Modeling & Applications Subsystem have a responsibility to view the data in light of their inherent uncertainties, and communicate back to the observing system operators when anomalies are found.

Quality Assurance of Real-Time Observational Data (QARTOD) has been an effective grass-roots effort to establish best practices in QA over the past decade, and it has recently been endorsed and supported by the U.S. IOOS Program Office. It is an appropriate model for development of variable-specific QA procedures that should be adopted by all U.S. IOOS providers.

Interoperability

Also important to users is the content and structure of U.S. IOOS information -- structure of the data files; conventions used to identify the data elements; linkages between information in a file to information resident elsewhere on the network. Interoperability must be defined with respect to multiple systems, and is therefore a consideration beyond the existing confines of DMAC. U.S. IOOS data will serve various users only if they can (1) locate the particular data of interest, (2) request and receive it, and (3) understand the data such that it is used for public safety in an operationally appropriate way, and for modeling efforts in a scientifically appropriate way. The U.S. IOOS cyberinfrastructure must evolve according to requirements of both the Observing Subsystem and the Modeling and Analysis Subsystem.

Metadata is crucial for understanding the applicability of data to an operational product or science problem. Metadata generation starts with the sensor manufacturers, but they often provide information about the sensor in proprietary formats. If manufacturers were required to publish this information using the same data standards used in the U.S. IOOS cyberinfrastructure, it would avoid the costs of transforming or transcribing metadata, reduce information loss, and improve interoperability. One way to address this issue is to write a standardized metadata document into all contracts and purchase agreements for observing equipment. The U.S. IOOS program should capitalize on the work being done by the National Science Foundation's Ocean Observatories Initiative (OOI) to generate open community standards.

Analysis, Modeling & Applications Subsystem

Numerical models are essential to all aspects of the U.S. IOOS program. The relevant time scales for model predictions range from minutes/hours for processes such as storm surge, port operations, and search and rescue, to weeks/months/years for ecosystem or fisheries forecasts, and increasingly to decades/centuries for climate change.

U.S. IOOS RAs are involved in numerical modeling at different levels. Some confine their role to making products using the results of models run by other organizations. Others also configure and run models for their geographic region, generally nested within or deriving boundary conditions from large-scale models run by a member of the regional observing system or those from a U.S. Navy or NOAA national center. And some RAs also undertake research to develop new modeling capabilities. Of those running numerical models, some are doing only hindcasts and process studies, while others are running at least some real-time models that incorporate observations, and produce nowcasts and forecasts on a continuing basis, which requires computers and personnel available 24 hours a day, seven days a week.

There has not been balanced investment among the observing, information management, and modeling subsystems of U.S. IOOS. Unlike DMAC and parts of the Observing Subsystem, there is no explicitly-stated implementation strategy for the U.S. IOOS Modeling Subsystem. There is a wide range of modeling approaches among the various regional observing systems, and only ad hoc communication between the Federal agencies involved in ocean modeling and regional modeling providers. An effort that considers the critical role of modeling in both design and evaluation of the overall observing system, and in the analysis and prediction of ocean and ecosystem state is imperative.

Regional models require:

- Larger-scale ocean models to provide boundary conditions on sea level, temperature, salinity, and velocity
- Atmospheric forcing including all the relevant air-sea fluxes, at appropriately fine spatial resolution
- Accurate freshwater input, from stream/river gauges and hydrology models
- Assimilation of observations from all sources made within their geographic areas

We are entering a new era of coastal observation, where advanced coastal modeling can provide dramatically improved data-driven simulations and optimal observing system design within available resources. Models should be used for Observing System Simulation Experiments (OSSEs) to help optimize observing systems by revealing which types of measurements at which locations are most important in producing a forecast of sufficient accuracy over a given area. More sophisticated models that take advantage of known physical, biological and chemical relationships can use available data to simulate or predict even remote regions that are dynamically connected. By using inverse techniques, these relationships can be further exploited to determine the impact that different observations have on defined metrics. Prediction and analysis models can identify critical ocean parameters and observing locations needed to improve model skill, thus feeding vital information into the design (sensor type and placement) for future upgrades to the Observing Subsystem.

3. Overarching Issues

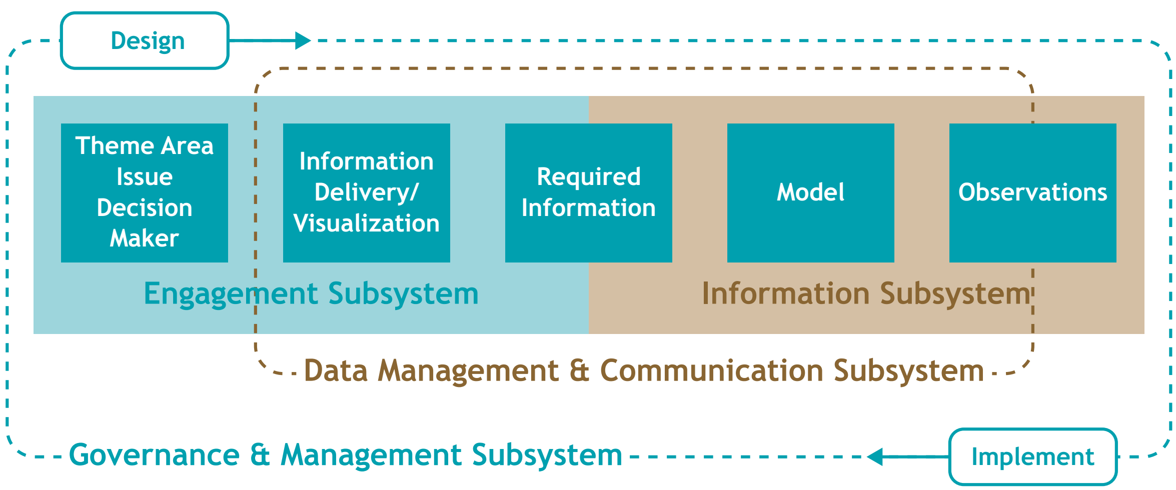
Unifying a design across the breadth of scales of the U.S. IOOS program requires a commonality in vision. The wise use of increasingly scarce resources will guide many of the necessary decisions, but in all cases addressing identified scientific and societal needs -- which must increasingly be recognized as one and the same -- must be paramount.

U.S. IOOS Program Structure

U.S. IOOS is often described as a system with three functional subsystems -- the Observing Subsystem, the DMAC Subsystem, and the Analysis, Modeling & Applications Subsystem -- with an additional three cross-cutting areas of focus in Research & Development, Education & Training, and Governance.

Participants of the 2012 U.S. IOOS Summit considered and approved a new diagram for the structure of the U.S. IOOS Program (Figure 8) that more accurately depicts the improved interactions across the subsystems of U.S. IOOS, particularly between the Observing and Modeling Subsystems. But new gap analysis and design processes are needed for each of the U.S. IOOS functional subsystems, and particularly to integrate more fully across the subsystems.

Figure 8. Interactions Across the U.S. IOOS Program Subsystems.



This updated structure diagram, approved by attendees of the 2012 U.S. IOOS Summit, reflects the growing interactions across all the U.S. IOOS subsystems, especially increased feedback -- in both directions -- between the observing system design and modeling efforts.

At a high level, the current abstract framework (logical/abstract architecture) encompasses the concepts in the U.S. IOOS adequately, but as it is currently implemented (physical/implementation architecture), this system model does not quite fit. In reality, U.S. IOOS more closely resembles a system of systems. Challenges of uniting U.S. IOOS into an integrated system of systems include the patchwork of existing systems of limited interoperability and the limited financial support available for integration activities.

A System-of-Systems is characterized by geographic, operational, and managerial separation of the component systems (Maier, 1998). The components have been prioritized, funded, and built independently (managerial separation) and do not depend on each other for their existence (operational separation). Geographic separation implies that the primary artifact transmitted between systems is information, emphasizing the crucial importance of an adequate cyberinfrastructure, and consistency of approaches to gathering and disseminating information. Given the managerial separation, components of a system-of-systems can evolve separately, but this further emphasizes the importance of ensuring interoperability across all the scales. U.S. IOOS should carefully consider system-of-systems engineering and governance processes as it mounts a comprehensive design effort to encompass its full breadth of scales and users.

The Variables and Approaches

Over the past decade, there has been an evolving consensus on the requirements for ocean observations and the EOVs that must be observed. In 2002, the Airlie House Workshop (Ocean.US, 2002) articulated an initial list of 20 core variables to address national and international needs. An additional six variables were subsequently added to better capture the interdisciplinary observations required (see Table 3). The NOAA IOOS Program Strategic Plan (NOAA, 2007) initiated an effort to integrate 5 of the core variables in U.S. waters. At the global scale, the OceanObs'09 Conference resulted in a framework (UNESCO, 2012) for addressing GOOS requirements through EOVs and assessments of the readiness of new observing technologies for integration into the global system. The recent synthesis of RA Build-Out Plans (Price and Rosenfeld, 2012) endorsed the 26 national/global variables and added an additional 14 of regional/local interest (Table 8).

Table 8. Required Variables from the Regional Associations' Build-Out Plan.

Variable	From manned in situ platforms	From unmanned in situ platforms	Measured remotely
Acidity (pH)	x	x	
Air temperature+	x	x	x
Barometric pressure+	x	x	
Bathymetry	x	x	x
Bottom character	x	x	x
Colored dissolved organic matter			x
Contaminants	x	x	
Dissolved nutrients	x	x	
Dissolved organic matter+	x		
Dissolved oxygen	x	x	
Extent and condition of benthic habitats+	x	x	
Fish abundance	x	?	
Fish species	x	?	
Freshwater flows+		x	
Heat flux	x	x	x
Humidity+	x	x	x

Ice distribution	x		x
Ocean color	x	x	x
Optical properties	x	x	x
Partial pressure of carbon dioxide (pCO2)	x	x	
Pathogens	x	x	
Phytoplankton species, and abundance+	x	x	
Precipitation+	x	x	x
Pressure+		x	
Salinity	x	x	x
Sea surface height+		x	x
Sea turtles and marine mammals+	x		x
Sound+	x	x	
Stream flow		x	
Subsurface currents+	x	x	
Surface currents		x	x
Surface waves	x	x	x
Temperature	x	x	x
Total suspended matter	x	x	
Turbidity+	x	x	x
Visibility+	x	x	
Water level		x	x
Wind speed and direction	x	x	x
Zooplankton abundance	x	x	
Zooplankton species	x		

A "+" next to the variable indicates those not on the national/global list of core variables (in Table 3), but measured by regional observing systems.

The similarity of priorities and approaches suggests that a common set of variables can be identified and broadly endorsed that span the full range of scales of the U.S. IOOS program. A more comprehensive design process is needed, however, to integrate and optimize the observation efforts across the geographic areas and scales of the program. This will support detailed costing and implementation planning over the next decade, and can align interests and methodologies prior to significant expenditures.

U.S. IOOS planning includes some programs that focus on employing a specialized observing technology (e.g. high-frequency radar), or observing a specific variable of interest (e.g. directional wave field) on a national scale. A comprehensive U.S. IOOS design must consider how best to address and integrate these requirements.

The ocean sciences community understands we cannot collect all of the required information at all locations and must employ data assimilation and models to fill the very large gaps in our observations. Although we need to do more to understand the skill of these combined systems, we have seen their impact in providing real-time and near real-time information to users, addressing important societal goals. The scientific community in all sectors – public, private, and academic – must act in an increasingly coordinated fashion to improve and expand on these successes.

The Need for a Complete Census

An inventory, or census, of all existing observing system components is a necessary starting point for gap assessment. This has begun for Federal agency participants in the U.S. IOOS Blueprint for Full Capability. The recently-completed synthesis of Regional Association Build-Out plans (Price and Rosenfeld, 2012) includes a summary of most of the non-Federal U.S. contributions that exist at present. At the global scale, the 2009 summary of GOOS progress lists the initial in-situ global system to be about 60% implemented. The satellite component has been well implemented, but there has been limited progress in the planned in-situ system over the past several years. A frequently updated, complete census that is integrated across these global/national/regional scales of U.S. IOOS is critical to support comprehensive design efforts.

Gap Assessment and Comprehensive Design

Gap assessment compares a system's requirements with its present state to establish what is missing. A comprehensive statement of U.S. IOOS requirements, including resolution and accuracy specifications, is very challenging because of the multiple scales of observations needed to serve the varied user needs. Gap assessment and system design must both evolve to provide an optimization of results for a given investment.

Focusing on a particular type of technology, better incorporation of remote sensing into a comprehensive future design for U.S. IOOS will require: addressing global/national/regional requirements; development of new, improved products; rigorous inter-sensor comparisons and uncertainty characterization; and data merging, integration and synthesis involving both remote-sensing and in-situ data (Chapron et al., 2010; Drinkwater et al., 2010; GCOS, 2011; PICO, 2012). Muller-Karger et al. (2012) recommend greater integration across disciplines, and strong partnerships across private industry, government and education sectors to enhance product development.

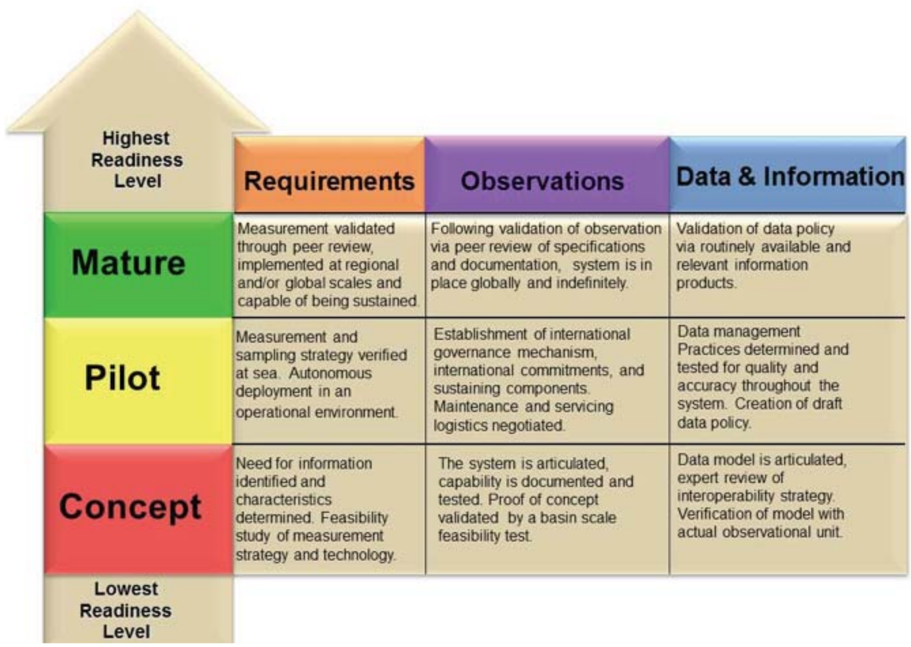
In the global ocean observing programs, identification of a limited set of essential variables to be observed, modeled, and used in information products has streamlined the requirements process. GCOS (154, 2011) includes a list of GCOS Essential Climate Variables (ECVs) for the ocean domain, and GOOS (Report 193, 2012) offers a set of EOVs for the Global Coastal Network. Requirements, which include the spatial resolution, observation frequency/duration, accuracy and speed of distribution needed, may be met solely by observations, or through data synthesis including data assimilative modeling. Derived products impose analysis and processing requirements; information management is required for standards development and exchange protocols that support product development and modeling efforts. Requirements change over time. Space/time/accuracy requirements for the ocean ECVs of GCOS/GOOS are revised routinely and listed in the World Meteorlogical Organization Observing Requirements Data Base (*http://www.wmo-sat.info/db*). The recent GOOS report (193, 2012) presents a good process for translating priorities into observing requirements and using them in design.

Systems engineering processes address a number of approaches to comprehensive design of complex systems. A blend is needed of qualitative expert knowledge on the available tools and how to use them to produce specific designs, and more quantitative assessment tools, such as OSSEs, which provide objective methods for assessing and optimizing the designs. Addressing the multi-scale nature of U.S. IOOS is an outstanding challenge. Priorities at global, national, regional, and local scales differ and, if implemented separately, will lead to designs that are not closely aligned. Careful consideration of the implications for interactions across scales will help identify solutions that cut across scales, increase efficiency, and reduce costs.

Observation and prediction of some variables are already reasonably advanced, such as water temperature and sea level, whereas others, like species-specific harmful algal bloom toxins are much less so. A balance of investment in mature observing system components and in pilot programs to demonstrate new capabilities is needed to ensure that an interdisciplinary system is developed and sustained. Objective techniques are needed to assess tradeoffs among different observing options. Rapid technology advances require rigorous processes for testing the readiness of new technologies for integration into the observing system and assessing their impact if integrated. The GOOS Report 193 (2012) explores how a balance of routine and new measurement techniques at various states of readiness can be employed to acquire the needed observations.

Consistency of approaches to gathering and disseminating information is crucial. A rigorous process (Figure 9) for assessing the readiness of emerging requirements, new observing technologies, and data management practices, for integration into an ocean observing framework is described in the UNESCO Ocean Obs ’09 FOO Report (2012).

Figure 9. An Approach for Assessing Readiness.



The Framework for Ocean Observing (Ocean Obs ’09 Report, 2012) presents this process for assessing readiness levels of requirements, observing technologies, and information products.

As the breadth of priorities for the overall U.S. IOOS increases, so will the complexity of the design effort. An ongoing design and evaluation program must be mounted to enable the growth of the system through infusion of new technologies in an efficient manner. The U.S. IOOS Program should closely review and strongly consider adopting the successful approaches described above from the global ocean observing programs to address the complex design challenges of the multi-scale, multiple-use U.S. program.

4. Summary

Formulating an improved design for U.S. IOOS over the next ten years, to support detailed cost estimates and implementation plans, requires a number of new, comprehensive approaches:

- Systems engineering and governance approaches that treat the U.S. IOOS program as a System-of-Systems should be strongly considered for the next decade.
- There are a number of major gaps in the existing observing system -- in spatial, temporal, and topical coverage (e.g., better subsurface information in continental shelf settings; an expanded set of biogeochemical observations). The bulk of the "Community White Papers", solicited and prepared for Summit discussions, address ways to fill these gaps. A logical next step is adopting the approach of identifying essential ocean variables (EOVs) as a way to condense societal and scientific priorities into a manageable set of objectives to maximize interoperability across scales.
- More use of modeling tools, like the Observing System Simulation Experiments (OSSEs), will provide an objective means to identify optimal design configurations. A closer alignment of the Observations Subsystem and the Modeling, Analysis, and Applications Subsystem was recommended by the U.S. IOOS Summit attendees and should be adopted.
- A process to test the suitability and maturity of new observing technologies, and ways to assess their impact on the aggregate observing system, are needed to deliver a system design that is efficient and economical. The processes introduced in the Framework for Ocean Observations (UNESCO, 2012) should be strongly considered as an approach for U.S. IOOS integration.
- For DMAC, a process for testing architectures of various forms to assess best performance and efficiency is needed.
- For the modeling and analysis subsystem, clarity on statistical certainty (ensembles), spatial resolution (nesting) and connections between domains (coupling) is needed. We must develop a national vision and implementation strategy for U.S. IOOS Modeling that includes optimal observational network design and regional data assimilating and forecasting models. We should also expand the U.S. IOOS modeling test bed nationally, with broad participation by multiple RAs. Additionally, within the analysis portion of this subsystem, the ways in which product development and delivery is assured should be examined to be certain that the design adequately resources this vital component of the observing system.

CHAPTER FIVE: INTEGRATION CHALLENGES AND OPPORTUNITIES

1. Introduction

A truly integrated ocean observing system will not be achieved unless and until the U.S. IOOS® community addresses integration in all of its forms. There is strong consensus that the envisioned integrated system should provide ocean state estimates (past, present and future) to a known degree of accuracy based on the integrated use of ocean observing networks, data management and communication tools and data assimilative model predictions. These estimates should produce “actionable” information regarding physical, chemical and biological characteristics delivered to the various user communities. Such information can range from scientific findings, to operational products that support safe navigation to products in support of public education and public policy, to name a few examples. As envisioned from the outset of U.S. IOOS, these observations and ocean state estimations/predictions should be integrated into programs that quantify the meteorological, terrestrial, and ocean impacts on humans and human influences on the environment across time scales from seconds to centuries.

But this is not enough. An integrated system must engage all providers and all consumers of relevant data and data products at the local, regional, national, and global scales. It must effectively address both the physical and ecological components of the ocean state. And it must bridge the gap between basic and applied research and technology development, and between operations and technology products. We can point to several successes over the past 10 years. The transition of satellite products to operational use in coastal zone management (responses to HABs and oil spills), and the rapid introduction of HF Radar-derived surface current maps and high-resolution data assimilative coastal models are striking examples of successful, integrated action across academia, government and industry.

These achievements were not the result of formal and sustained partnering between the research and operational segments of the community. There have, in fact, been very few opportunities for truly integrated activities, where new knowledge and new technologies enhance operational observing and prediction systems through well-understood transition pathways, and conversely where requirements and lessons-learned from the observing and prediction system operators guide research and development. There is a need to more effectively integrate the activities of the research and development community and the operational community across all sectors (public, private and academic) and across all scales of interest (local, regional, national and global). Only in this fashion can we tap the energy, expertise and creativity of the U.S. IOOS community to address the rapidly increasing societal needs for informed, safe, responsible, secure and sustainable uses of our ocean environment.

2. The “I” in IOOS

The need for strengthened integration among disciplines -- among observations, data product dissemination and modeling/analysis; between the research and operational communities; and among the various Federal and nongovernmental organizations -- is widely acknowledged. Without the capacity to access, verify (QA/QC), and combine data and data products across multiple information types and sources, U.S. IOOS cannot function as an optimal user-driven operational system. Ocean data integration has been a central goal of U.S. IOOS from the start, and DMAC efforts to disseminate data and products were among the first U.S. IOOS projects.

A defining feature of a successful operational system is full integration of its observing and prediction components, because it is not possible, now or in the foreseeable future, to measure the ocean with high enough spatial and temporal resolution to provide the various user communities with the data products they require. Computer models enable us to fill gaps in the four-dimensional information domain, providing estimates of ocean state variables at locations and times where we have no direct measurements, as well as predictions of how these variables will change over time. On the other side of this integrated system, direct ocean measurements provide models with initial and boundary conditions, as well as real-time constraints, to significantly improve model performance and to enable a reasonable understanding of model skill.

It is unclear whether the present U.S. IOOS -- with observing, data management and communications, and modeling and analysis subsystems and implemented via partnerships across the academic, public, and private sectors -- can achieve a sustainable user-driven, operational system. Some leading attributes of an optimal, integrated system would be:

- Certified to meet evolving user requirements, expressed as standard metrics with known error attributes, which vary over time and space
- Demonstrated robust and resilient operations
- Documented sustained sponsorship for real-time product delivery and ongoing research and development with clear transition pathways
- Design that supports both experiments and rapid response to marine crises

Success will require a commitment to ensuring the U.S. IOOS moves away from a cooperative enterprise with numerous partners striving for their individual goals to a coordinated enterprise striving for a comprehensive, integrated system. Such an improved, integrated enterprise would include the following attributes:

- More active participation by the 18 sponsoring U.S. Federal agencies; as well as Tribal, regional, state, and local agencies
- Defined processes and funding to ensure robust transitions both from Research-to-Operations and Operations-to-Research
- Defined processes to validate and prioritize requirements at the global, national, regional and local scales to inform funding and long term planning decisions
- Improved integration of all requisite disciplinary fields to enable widespread and effective dissemination and use of data and data products
- Improved integration of remotely-sensed data with in-situ observations and models
- Improved integration of real-time data management with long-term archives
- Improved integration with ocean science and engineering workforce development, STEM education, public policy and public outreach

3. Overall Integration Challenges and Opportunities

Achieving overall integration of all programs and activities across Federal and non-Federal (local and state government/private/academic) organizations will require cultural changes on all sides. The Federal government cannot own sufficient platforms, sensors, models and analysis systems to cover the entire U.S. coastal ocean and Great Lakes comprehensively and at adequate resolution. Academic and private industry partners must join the government in playing an active role as providers of data and products. This will require trust-building, experiments, failures, and joint action to address weaknesses. It will require that the community address head-on the longstanding issues related to data and data product liability, and the uses of proprietary data.

Once the community has moved from cooperative to coordinated in working together, U.S. IOOS will be in a much stronger position to deal with the very difficult issues that challenge all science and technology programs: understanding the user needs, and developing processes for integrating new technologies. The operational systems must be multi-disciplinary and adaptive and must deliver a clear return-on-investment, across the seven areas of societal benefits targeted for U.S. IOOS support.

Improvement and Integration of the Observing System

There is a need to re-examine the sensor types and placement locations across the entire government and non-government U.S. IOOS enterprise, to optimize the system's usability, reliability, robustness, and resiliency. Prediction and analysis systems can guide this process by identifying critical ocean variables and observing locations that would improve model skill and products for virtually all of our user communities. For the longer (climate) time scales, regional variability (including extremes) are significantly affected by large-scale climate variability occurring in the open ocean. Therefore, it is imperative to improve the linkages of the regional systems with the global observing systems, including the satellite observing systems and in-situ systems such as Argo.

Integration of Biological Data

A significant challenge lies in the integration of data and products derived from physical, ecological and biogeochemical observations, but there has been significant progress in this area recently. U.S. IOOS in collaboration with the Ocean Biogeographic Information System (OBIS), has implemented international standards called "Darwin Core" for sharing of species presence, absence, and abundance observations. The resulting U.S. IOOS Biological Data Service (IOOS BDS) (*http://www.ioos.noaa.gov/dmac/biology/welcome.html*) standard, consistent with Darwin Core and Climate Forecast conventions, allows integration of U.S. IOOS biological core variables (i.e. Fish species, Fish abundance) from different Federal and State agencies (NOAA Fisheries, NOAA National Ocean Service, National Park Service, States Department of Natural Resource and Fish and Wildlife). The standard is extensible to address other richer biological data including life stage, behavior and others Similar efforts are underway for biological data from animal telemetry and passive acoustic, which will soon be integrated with physical oceanographic data.

The IOOS BDS standard enables maximum use of biological data – it can be located, easily accessed (via web services), understood and evaluated by biologists, members of the broader ocean science community, decision makers, and planners. It also offers biological communities assurance that their data will mesh well with other U.S. IOOS data. While considerable challenges remain in the realms of observing technologies for biological data and in ocean ecosystem modeling, integration of the rich variety of biological information with other U.S. IOOS data is well underway.

Ocean Data Integration

This has been a central goal of U.S. IOOS and DMAC efforts from the outset. This focus is understandable, since a user-driven, reliable and robust observing system cannot exist without the capacity to access, verify (QA/QC), and combine data and products across multiple information types and sources. Users must be able to search for and retrieve the data they need; ingest these data into their analysis or visualization software and decision-support tools; and understand the source, quality, applicability and limitations of the data. Future use and reuse of these data make similar demands on data stewardship and archiving. This requires a set of recommended or required standards and protocols, employed and evaluated through a compliance and certification process, to form the framework for DMAC activity.

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS), the National Data Buoy Center (NDBC), and the U.S. IOOS Program Office have been collaborating for several years on a data integration project to increase interoperability between data providers and the user community. The project created the joint NDBC/ CO-OPS' Sensor Observational Service (SOS), as part of a suite of web services offering various new protocols and formats, an expanded set of sensor variables, and increasing machine-to-machine data transfer over the internet. Of the new formats, Keyhole Markup Language (KML) is especially important because it is used by many mapping and visualization applications to display geospatial data of interest to the oceanographic community. These integration efforts have allowed the delivery of ocean data to a wider customer base faster, better and with less effort. Since launching the new capability, CO-OPS has decreased end users' data processing time by 70% and increased their data retrieval speed by 50%. In 2011, fully half of the 30 terabytes of CO-OPS data were discovered, accessed and delivered by this new suite of web services.

Data Handling Challenges

The challenge of the future is the maturation and testing of selected data handling technologies. The data storage and access component of DMAC is well defined for some data sources like in-situ buoys, HF radar, and gridded data from satellites and models, and is evolving for glider data. The availability and use of U.S. IOOS data from the RAs in the USCG Search and Rescue Optimal Planning System (SAROPS) demonstrates the power of defined data sharing protocols, but requires incorporating a special brokering layer software for mission critical applications.

There continues to be significant challenges in the successful population of metadata and registration and subsequent discovery of metadata, data, and associated web services. New catalog systems from the GIS community are being adopted for use in the ocean community, but are not a perfect match, because they were generally designed to manage static information (map features that do not change). The ability of these catalog systems to handle time-varying data from fixed points, unstructured grids, and other complex time-varying datasets is still evolving.

In view of continued and rapid changes in information technology, DMAC should be driven by real-world use cases, emphasizing training and support for existing technology and standards, and then building incrementally as use cases dictate. The U.S. IOOS community should also take advantage of significant partnering opportunities with the NSF's Earthscope and Ocean Observatories Initiative (OOI), to ensure U.S. IOOS standards and protocols are the best practices available and to enable a common trust in our data assets.

The expected explosive growth of data products in the years ahead has the potential to overwhelm both the generators and users of ocean information. The solution will require close coordination among information providers and users, and will likely require a reduction in the information volume, through automated data processing and filtering.

Quality control is recognized by the community as a key requirement but remains elusive due to the lack of definition of processes and limited funding to support the implementation of mature quality control procedures.

Using Open Standards

The use of open standards and technologies has been at the core of the U.S. IOOS DMAC philosophy. This has allowed the academic, Federal, and industry partners to retain the use of their individual tools and approaches, but also collaborate in a unified system of data sharing and access. There has been a strong focus on the development and implementation of standards to enhance interoperability, with significant progress in enabling the sharing of observations and model output between the RAs, Federal agencies and user community.

In a collaborative enterprise such as U.S. IOOS, openness is a well-known enabler of successful system development. Beyond sharing data, shared experience is critical to advancing U.S. IOOS. Open source development is much more than a willingness to share code; it is a commitment to collaborate across the entire software development cycle and is enabled by tools such as online code repositories, wikis, blogs and other information sharing portals. With open source development, coupled with training in using open source tools effectively, many of the software needs of DMAC will be developed faster and with higher quality than could otherwise be accomplished (Howlett CWP). Developers within the RAs have recently begun publishing software on open source code sharing sites and the level of collaboration and code reuse across the RAs has increased significantly.

Testing and Testbeds

The Data Integration Framework (DIF) pilot project carried out by the U.S. IOOS Program Office in fiscal years 2007-2010 had the RAs make observations of seven core variables available via a specific web service protocol. The exercise did not define the use of specific technologies, only the specific web services to be used. The test highlighted the challenges of allowing each RA to select its own path, with independently developed solutions using different software toolsets. This approach should theoretically be successful, but in practice, it faced numerous challenges, including the development of non-interoperable solutions. There has been recent progress, including the establishment of the SOS Reference Implementation Working Group to develop a single SOS standard based on Sensor Web Enablement (SWE).

In the past year, there has been a shift in focus from the development and recommendation of standards to the implementation of technologies that include compliant standards. This is a breakthrough, as a smaller number of technical teams now focus on the solution, which frees up DMAC teams in the RAs to focus on the implementation of these maturing technologies and the other DMAC requirements.

The U.S. IOOS Coastal Ocean Modeling Testbed (COMT) was a unique opportunity to evaluate many of the widely used technologies. A few notes on these technologies:

- The open source tools often have only one developer/maintainer, which may limit their flexibility and usefulness
- Due to the lack of funding and staffing, we do not have reliable pathways for transition, including rigorous testing procedures
- The technologies have not been tested for how they may scale to manage issues such as very large data volumes

An important consensus resulting from the U.S. IOOS Modeling and Analysis Steering Team (MAST) effort (Ocean.US, 2008) was recognition that the academic research and development community and the Federal operational forecast centers should work cooperatively on such matters as observing system design, model skill assessment, and prediction system experiments. The committee recommended establishment of a system of sustained but evolving regional testbeds, where 'regional' may include the domains of two or more RAs. The significant coordination and information sharing required for the design and operation of such testbeds, and the conduct of comprehensive experiments, would move the community toward the integrated public-private-academic collaboration needed to make U.S. IOOS more successful. The assessment of model skill and the communication of model uncertainty would, in addition to improving the state of the science, help to inform the public and various user communities of the accuracy and reliability of integrated sensor, modeling & analysis systems. Transparency and information sharing builds trust among all stakeholders, an essential ingredient to ensure credibility, return-on-investment, and sustainability of the U.S. IOOS enterprise.

Experiments with ensemble modeling of the ocean and atmosphere are important, and should take advantage of the existing global, national, regional, and in some RAs, local scale models. The ensembles may be constructed from a single model run with varied initial conditions or forcing, or from multiple models that have different physics. Ensemble forecasts also provide an estimate of uncertainty, which is vital for decision-makers. This ensemble approach will spur increased collaboration across government and non-government organizations, and provide valuable insight for both model enhancement and forecast skill improvement. The community witnessed first-hand the impact of ensemble modeling during the 2010 Deepwater Horizon oil spill, when several models were employed to support the response, and observations were used to inform first responders which models were performing best at different times and locations.

The Future of Modeling

Models provide us with the ability to deliver real-time nowcasts as well as forecasts. They can also be useful in the reconstruction of past conditions (hindcasts) and in the conduct of hypothetical scenarios (simulations), which are valuable tools in areas such as emergency response and coastal ocean resource management. The need for model simulations and forecasts, on appropriate time and space scales, for processes including waves, ocean circulation, weather, inundation, ecosystems, and water quality, has been identified (U.S. IOOS Program Office, 2010) as a core requirement that should be available in all U.S. IOOS regions ten years from now. Different types of models may be run independently today to simulate these different properties, but more nesting and coupling of U.S. IOOS models is required in the future.

Future model development activities must include an expanded effort to couple existing ocean and atmosphere models. Several RAs have demonstrated the importance of ocean surface boundary conditions to improved atmospheric forecasts, which can, in turn, dramatically improve the skill of coastal ocean models. Regional models require:

- Atmospheric forcing, with relevant air-sea fluxes, at appropriately fine resolution
- Larger-scale ocean models to provide boundary conditions on sea level, temperature, salinity, and velocity
- Accurate freshwater input, from stream/river gauges, and hydrological models

On climate time scales, regional changes are often significantly affected by the lateral boundary conditions between the coastal regions and the open ocean. Therefore, there is an important need to improve the integration between regional modeling and with the global modeling and assimilation efforts. In particular, there exist global ocean data assimilation systems that can provide constraints on regional estimation. Downscaling global ocean analysis/reanalysis to regional scales is an important challenge and opportunity.

Liability, Proprietary Data, and Open Source Issues

Our existing observing systems are an amalgam of Federal, state and local government, academic and private systems. The integration of data and data products from these systems into a single publicly-available report of ocean conditions is impeded by a number of issues, including liability concerns on the part of academic institutions, and the desire on the part of private industry to protect their proprietary data and products. The Meteorological Assimilation Data Ingest System (MADIS), established by the National Weather Service (NWS) to collect, store and disseminate observations from non-Federal weather observing networks, has several categories that designate how contributed data will be handled, including a category for proprietary data authorized for use within NOAA, but not for distribution outside NOAA. Under the National Mesonet Program (NMP), and through the use of restricted licenses, MADIS currently receives observations from nearly 10,000 professional-grade private sector weather stations. Given the success of the NMP and the MADIS data architecture in facilitating access to very large numbers of high quality weather observations via restricted licensing, implementing a similar data policy and architecture for U.S. IOOS must be given serious, high-priority consideration.

Using Social Media

Social media offer tremendous opportunities for communicating in innovative ways and should be used within U.S. IOOS to share techniques and experiences, and to enable broader user data input and access. This will both raise awareness of the enterprise and hasten its development.

Education and Training

The U.S. IOOS community must commit to the education and training of the next generation of ocean observing professionals. Operational systems ultimately are as effective, robust and resilient as the people who design, deploy, maintain and operate them. These are highly specialized skills gained only by education and experience. Some of the skills, such as computer programming and data management skills, are highly valued in other fields. The integration of operational systems into K-12 STEM education will provide opportunities to inspire young people to pursue careers in ocean observing.

4. Summary

Over the past decade, success has occurred most often when efforts were made to ensure interoperability across all aspects of the U.S. IOOS observing, data management & communication, and modeling & analysis subsystems. Our long-term sustained success will require that we make integration and interoperability across systems and organizations the top priority for U.S. IOOS. This must necessarily include interoperability within the U.S. IOOS network -- among the 11 RAs, the 18 sponsoring U.S. Federal agencies, private industry, and a growing number of governmental and nongovernmental organizations -- as well as interoperability of U.S. IOOS assets with the international GOOS and GEOSS. This, in essence, is our challenge.

CHAPTER SIX: MAJOR THEMES AND RECOMMENDATIONS

1. Major Themes

A significant level of consensus emerged at the 2012 U.S. IOOS Summit around a set of major themes for U.S. IOOS planning and implementation over the next ten years.

The themes and challenges we must focus on over the next decade include:

- Improving governance to address high-level coordination and support needs
- Pursuing new funding mechanisms and potential public-private partnerships to complement traditional funding
- Developing a complete census of existing observing efforts
- Increasing the breadth and scope of ocean observations to address increased demand
- Developing a web-based central “market-place” for bringing users, requirements, data providers, new technologies, and available data and products together
- Improving branding, attribution, and user awareness of U.S. IOOS and its many contributors and participants
- Developing common design processes and common data/product standards
- Increasing the level of integration across the U.S. IOOS enterprise, moving from cooperative to more coordinated approaches
- Maintaining forward momentum and continuing to grow U.S. IOOS, while addressing needed improvements.

2. Recommendations

The “we” in the recommendations presented below represents the broader ocean observation community that attended the 2012 U.S. IOOS Summit. The co-chairs of the Summit have endorsed these recommendations.

GOVERNANCE

The Integrated Coastal and Ocean Observation System (ICOOS) Act of 2009 defines ‘Federal Assets’ as “all relevant non-classified civilian coastal and ocean observations, technologies, and related modeling, research data management, basic and applied technology, research and development, and public education and outreach programs, that are managed by member agencies...” The legislation designated NOAA as the lead agency for Federal ocean observation efforts, and created a new Interagency Ocean Observations Committee (IOOC) for oversight. Despite these high-level steps, there is still insufficient coordination and oversight of unclassified ocean observing efforts across the 18 Federal member agencies of IOOS.

Recommendation #1.

We recommend the IOOC consider options for strengthening the leadership and oversight of U.S. IOOS, to include:

1.1. Convene an ad-hoc group to decide priority, order and timing for addressing the many recommendations of this report

1.2. Establish ad-hoc Working Groups under IOOC to address the highest-priority near-term recommendations of this report

1.3. Develop a mechanism/funding to encourage more Federal Agency interaction, especially exchange of personnel between the IOOS Program Office in NOAA and the 17 other IOOS Federal agencies

Recommendation #2.

We recommend the U.S. IOOS Program Office, IOOS Association, and U.S. leadership of the Global Ocean Observing System (GOOS) jointly prepare and brief a report twice annually to the Interagency Ocean Observing Committee (IOOC) on plans for/progress made on all of the recommendations in this Summit report.

Recommendation #3.

We recommend the IOOC arrange annual briefings on progress and needs of the U.S. IOOS program to the senior leadership of the 18 Federal agencies involved, to the Deputy-Level of the National Ocean Council, to the Office of Management and Budget, and to the House and Senate Ocean Caucuses.

Recommendation #4.

We recommend the Office of Management and Budget review all Federal agency ocean observation programs as a whole, to identify overlaps and gaps in the process of preparing the President's Budget.

Recommendation #5.

We request the House and Senate Ocean Caucuses review the President's Budget for all ocean observing activities in the 17 participating U.S. IOOS Federal agencies; and provide recommendations to their associated Authorization and Appropriations Committees to develop an optimized investment in national ocean observations.

Recommendation #6.

We recommend the U.S. IOOS Advisory Committee consider potential mechanisms to strengthen the leadership and consolidation of U.S. IOOS efforts.

FUNDING

The funding available for U.S. IOOS efforts falls far short of what is required to address all of the identified high-priority user requirements. The ocean observing community at the Summit agreed that increased Federal funding is needed, but investigation of alternate funding mechanisms must also be pursued:

Recommendation #7.

We recommend the Administration and Congress consider marginally increased funds for the 17 U.S. IOOS Federal Agencies to address recommendations of this report.

Recommendation #8.

We recommend the U.S. IOOS Advisory Committee provide guidance on whether/how to proceed with potential mechanisms for additional funding, such as:

8.1. Public/private partnerships, including the legalities, liability, and intellectual property issues of federal U.S. IOOS program participation/investment in private ocean observation, product preparation and dissemination companies

8.2. The legalities/liabilities of the U.S. IOOS program commercializing and charging for some products

8.3. The development of business case(s) to support private investment in U.S. IOOS

8.4. A U.S. IOOS Foundation; crowd-sourcing for individual projects

8.5. Established cooperative mechanisms, like DoD Cooperative R&D Agreements

USER ENGAGEMENT and OUTREACH

The profound value of the U.S. IOOS network to the general public is not well understood, despite its critical support in emergency response to major disasters, and daily support to a broad range of business and civil users nationwide. The regional, national, and global ocean observing efforts have diverse and uncoordinated user engagement strategies and public-facing websites for dissemination of U.S. IOOS data and products, which hampers both awareness and access of business, emergency, and general public users. And the U.S. IOOS community at the Summit agreed that education and training issues need more focus.

Recommendation #9.

As a near-term significant step, we recommend the IOOC direct all Federal agencies, all Regional Associations (RAs), and the U.S. component of GOOS to include the U.S. IOOS logo on all U.S. civil ocean observation products, along with any logo(s) of the product originators.

Recommendation #10.

In a major effort to work toward increased integration, we recommend the IOOC encourage all U.S. IOOS participants to engage fully in development and maintenance of a consolidated, web-based "market-place" that includes:

10.1. All known U.S. IOOS users (regional, national, global)

10.2. All documented user needs (The 27 common products identified across the 11 Regional Associations must be integrated with national and global product needs)

10.3. User-friendly tools that facilitate user inputs and connections/collaboration between users and providers

10.4. Initial focus on a narrow, "proof-of-concept" set of users and activities, such as biological/chemical observations, and higher-resolution coastal models, and on-land applications of ocean data

Recommendation #11.

We recommend the IOOC direct and oversee development of a comprehensive communications and advocacy strategy, with goals and milestones, that:

11.1. Highlights small business job creation as part of U.S. IOOS growth

11.2. Includes a comprehensive cost/benefit analysis every two years

Recommendation #12.

We recommend the U.S. IOOS Program Office and IOOS Association work together to:

12.1. Conduct a workforce analysis for U.S. IOOS to identify what jobs will be needed, and where the necessary education and training can be found or established

12.2. Establish an interdisciplinary U.S. IOOS Education Team to provide a comprehensive review of IOOS education efforts and develop a ten-year U.S. IOOS Education Plan.

DESIGN PROCESSES & INTEGRATION

It is necessary in the coming decade to move from loose cooperation to more effective coordination of IOOS efforts as a system-of-systems with common and well-defined processes, self-governance, and oversight.

DESIGN PROCESSES

Recommendation #13.

We recommend the IOOC direct the U.S. IOOS Program Office, IOOS Association and U.S. component of GOOS to work together to develop a draft plan, by August 2014, of clear, common, repeatable processes for the basic work of IOOS

13.1. A process to define observation requirements across the many uses and scales of the U.S. IOOS enterprise. We recommend the Framework for Ocean Observations (FOO) approach of addressing essential ocean variables (EOVs) be considered as a way of spanning the many users and scales of U.S. IOOS requirements. For process implementation, consider starting with sea surface temperature (SST), winds, and surface currents

13.2. A census of all existing U.S. IOOS observation programs (with sites and variables measured), observation technology development efforts (with variables and accuracy of measurement), modeling efforts, data analysis and product development efforts

13.3. A process for identifying and endorsing key “indicator” measurements for ecosystem health, regional climate change for input to global models, water quality indicator observations co-located with physical and biological measurements, and similar cross-cutting issues.

13.4. A process of comprehensive, periodic assessments of the collection of core variables to identify unnecessary duplication and high-priority gaps; and a workable process for eliminating the duplications to free up resources for the gaps.

13.5. A process to test and assess the maturity of new technologies for inclusion in the U.S. IOOS system-of-systems.

13.6. A process for aligning data reporting standards across the U.S. IOOS enterprise to improve efficiency, accessibility, and costs.

13.7. A process to optimize the design of U.S. IOOS by consolidating efforts and maximizing variables observed at each site, including improved accuracy and sampling.

Recommendation #14.

***We recommend the IOOC and the U.S. IOOS Advisory Committee jointly provide a timely review and critique of this plan; recommend a few common priorities for initial implementation; and assess implementation of the new processes*.**

ALIGNMENT OF SYSTEM DESIGN AND MODELING

Modeling can be used to: optimize the IOOS observing system design, support assessment of the impacts of sensor placement, and improve the identification of gaps and duplications.

Recommendation #15.

We recommend the IOOS community continue to more fully utilize modeling in the assessment and design of the observing system

15.1. Consider the Global Climate Observing System (GCOS) observing principles in the design of the observing system, recalling that the time series of observations is also very useful for assessing model accuracy.

15.2. Use modeling to optimize the observing system design to support the data requirements and input needs for coupled, nested, and ensemble models across the time- and space-scales required for the full range of U.S. IOOS users.

ASSESSMENTS

Assessments prepared for the Summit showed impressive progress in many areas of U.S. IOOS activity, but they also highlighted the need for more communication and integration across the partner organizations, the various data types, geographic locations, and time- and space-scales of the U.S. IOOS efforts. Clear examples of this are the separate progress assessments in Chapter 2 for national and regional programs, and the assessment of satellite observations that focuses only on climate monitoring, and does not address observations of these variables from other technologies.

Recommendation #16.

We recommend the IOOC direct the development of, and oversee the preparation of, periodic U.S. IOOS-wide assessments, based on observations of defined EOVs across all observing technologies and for all uses.

16.1. The assessments should include metrics of users and usage of various U.S. IOOS data and products

16.2. The assessments should highlight progress, and roadblocks, toward linking the global/national/regional/local components, and the biogeochemical and physical components of U.S. IOOS

16.3. The metrics should identify under-performing or under-used parts of the system to support funding decisions

SYSTEM INTEGRATION PROJECTS AND DRILLS

There are numerous Federal and State entities that organize disaster response drills, often without adequate knowledge of the data and resources available from various U.S. IOOS programs.

Recommendation #17.

We recommend the U.S. IOOS Program Office, IOOS Association, and U.S. components of Global Ocean Observing System work together to choose and organize IOOS participation in at least one large-scale disaster response drill annually, with IOOC oversight.

There are efforts in technology and user-product development throughout U.S. IOOS, but they are not well coordinated. The enterprise requires a robust, broadly coordinated series of U.S. IOOS systems integration projects that will respond to user needs, develop and test new observation technologies, and develop new approaches to wider data/product sharing across the U.S. IOOS enterprise. The regional efforts of U.S. IOOS need to improve the integration with global observing systems and global modeling and assimilation efforts to address regional climate impacts (including the effects of large-scale climate variability on regional extremes).

Recommendation #18.

We recommend the IOOC Committee direct and oversee planning, implementation, and assessment of a ten-year series of annual U.S. IOOS system integration projects that:

18.1. Identify an end-to-end unifying issue/theme/specific challenge for each year

18.2. Focus on integration of national, regional, global, government, industry, academic, observations, data management and modeling efforts for that theme

18.3. Develop metrics to assess success, provide lessons learned

18.4. Work through a Steering Team appointed by IOOC

18.5. Include assessment of support to both rapid response and long term issues

18.6. Test high-level policy issues like payment for products

OBSERVATIONS AND TECHNOLOGY

First and foremost, there is an important need for both more traditional observations, and for observations in a wide variety of new data types, scales, and geographic areas.

Recommendation #19.

We recommend that the new processes for U.S. IOOS observing system design address the following gaps identified at the 2012 U.S. IOOS Summit:

19.1. Biological, geochemical, and ecological observations

19.2. More observations in the near-shore environment

19.3. A dedicated observing effort in the boundary between coastal and global models

19.4. Deep ocean, under ice, coastal winds, biological/geochemical/ecological, primary and secondary productivity, long-term climate, water quality monitoring, climate change indicators, ice, wind, waves, bathymetry, surface currents, seafloor changes, sub-surface oceanography, passive acoustic monitoring of animal movements.

Recommendation #20.

We recommend that the new processes for U.S. IOOS technology development address the following gaps identified at the 2012 IOOS Summit:

20.1. Ocean pH (acidity) at depth, calcium saturation, passive acoustics, animal tagging, high resolution bathymetry, biomass, sea ice, water quality monitoring, and biological/ecological observations

20.2. Miniaturization, improved power sources, and vandalism protection

20.3. Hardened sensors for extreme events

20.4. Coordinated efforts to inform industry of desired data standards/reporting formats are required

20.5. Co-location of biological sensors as often as practical on platforms also collecting other EOVs within the U.S. IOOS enterprise

20.6. Available ship time, which is critical for observations, validation data, and launch/maintenance/retrieval of observing technology

20.7. Further develop extended duration repeat-transect observations in coastal and estuarine systems to capture dynamics (e.g. ferries, gliders)

20.8. Influences of instrument lifetime and servicing needs on the effectiveness of the observing system

DATA MANAGEMENT & COMMUNICATION

The Data Management and Communications (DMAC) efforts of U.S. IOOS have made impressive progress, but require expansion and stronger integration across the U.S. IOOS community.

Recommendation #21.

We recommend the IOOC direct and oversee the following near term initiatives related to emergency events:

21.1. Develop easier-to-use common tools across the U.S. IOOS enterprise for data description, access, and visualization

21.2. Improve the timeliness of information delivery; develop social media tools

21.3. Address data/product dissemination in extreme-event power outages

21.4. Improve the scale of products to personal-scale decision products; ensure interoperability that allows rapid combining of freshwater and sea surge in coastal flooding forecasts

21.5. Develop U.S. IOOS data response teams to react quickly to major emergencies, but also to participate in nationally-coordinated emergency response drills, participate in IOOS system integration projects, and to perform in-person installations, testing, and training with regional IOOS Data Access Centers (DACs)

Recommendation #22.

We recommend the IOOC direct and oversee the following initiatives by the IOOS Program Office, the DMAC Steering Team, the IOOS Association, and the RAs, related to integration across the U.S. IOOS enterprise:

22.1. Expand data and product standards across new data types and new user groups

22.2. Develop and adopt key data standards and protocols across the entire U.S. IOOS enterprise to greatly improve the exchange of observations across local, regional, national and global programs

22.3. Improve access and interoperability of ocean observation data dissemination and storage across the 18 participating U.S. IOOS Federal agencies; and develop common formats and exchange protocols between DMAC and regional U.S. IOOS DACs

22.4. Ensure appropriate local observations make it into global data sets and global observations are available to inform local and regional analyses and products

22.5. Make Web services the primary standard for disseminating U.S. IOOS information

22.6. Develop a common look and feel for user access to U.S. IOOS data and products across the enterprise

22.7. Engage the observation technology industry to report data to U.S. IOOS standards

22.8. Increase engagement with 'middleman' small businesses to address their data needs for expanding their products for end users

22.9. Integrate satellite data better with other U.S. IOOS observations

Recommendation #23.

We recommend the following data and product issues be addressed by the broad U.S. IOOS community, with guidance and oversight by the IOOC:

23.1. Make data from Marine Protected Area (MPA) monitoring available to U.S. IOOS, and ensure the full range of IOOS data are available to MPA managers

23.2. Integrate more private sector data into the U.S. IOOS enterprise

23.3. Develop more complete standards for monitoring/reporting biological data, and make much more biological data available to U.S. IOOS users

23.4. Increase the amount of biological data, and coastal data of all kinds, available on the Global Telecommunication System (GTS)

Recommendation #24.

We recommend the IOOC direct the regional, national, and global data storage, analysis, and dissemination personnel to work together on the following:

24.1. Increase the focus on common calibration, Quality Assurance and Quality Control (QA/QC) approaches for all IOOS data and products

24.2. Adopt Quality Assurance of Real-Time Ocean Data (QARTOD) as the U.S. IOOS QA starting point

24.3. Consider the calibration and QC "best practices" of the global climate observation community for use across the U.S. IOOS enterprise

24.4. Increase U.S. IOOS data use by adding data quality flags and resolving liability issues

24.5. Develop automated processes for collecting metrics on users and usage on standardized websites across the U.S. IOOS enterprise

24.6. Assess -- through design exercises or other means -- the number, type, and functionality of regional DACs needed; estimate future storage needs across the U.S. IOOS enterprise; consider cloud solutions for storage and analysis

MODELING & ANALYSIS

Recommendation #25.

We recommend the greater U.S. IOOS modeling community work together and with academia, under direction and oversight of the IOOC, on the following:

25.1. Develop a ten-year plan for merging regional, national, and global ocean modeling efforts into coupled, nested, and ensemble models across the time and space scales required for the full range of U.S. IOOS users

25.2. Develop improved, and more localized nowcast/forecast products for the location and movement of Harmful Algal Blooms (HABs), and for the location and movement of protected/endangered species

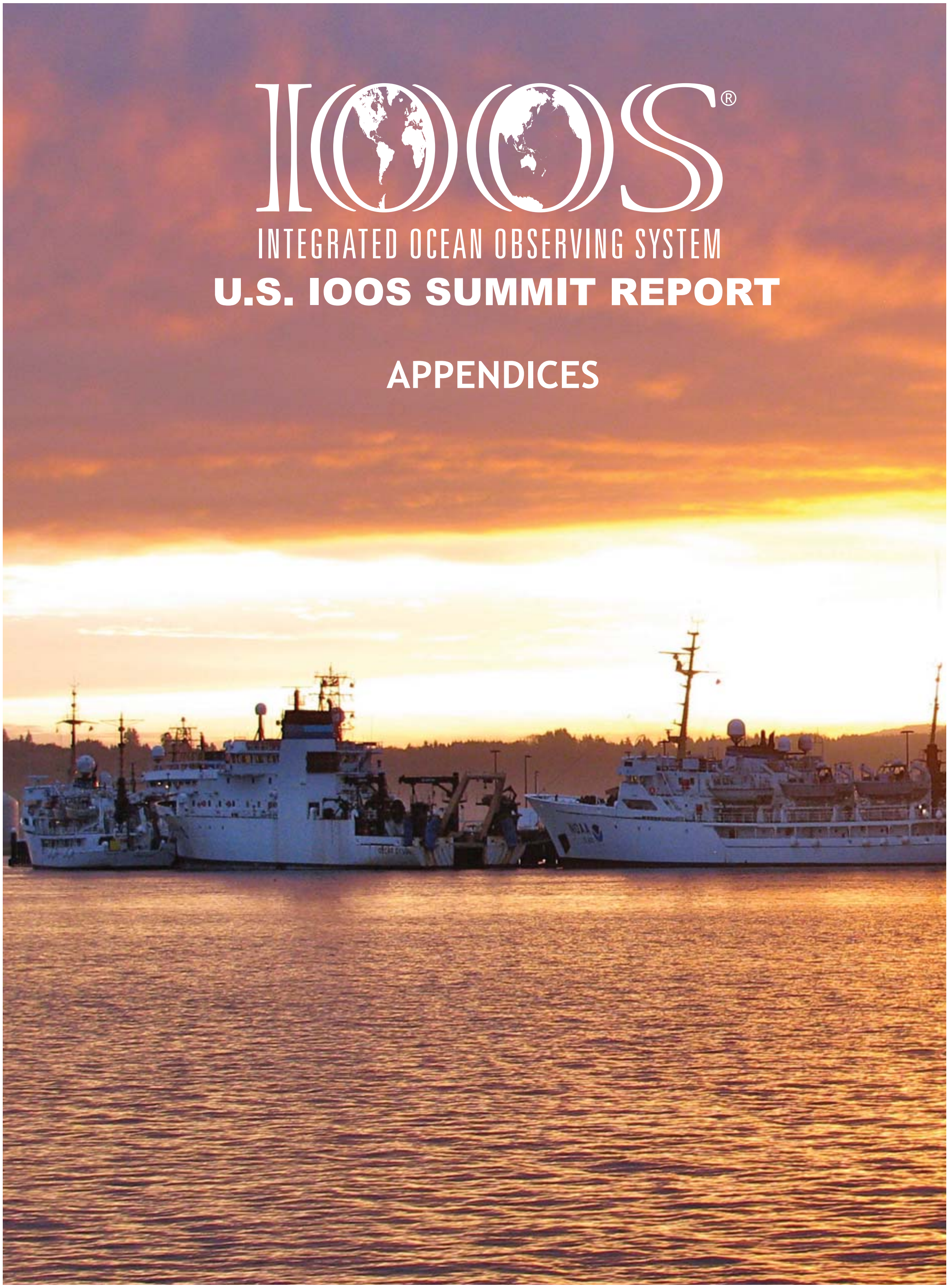
25.3. Develop appropriate measures of success, including efficiency of the U.S. IOOS collection/processing/delivery systems and the usefulness of products, so that improvements in system performance can be measured

25.4. Increase the focus on integrating biological/ecological observations into nested models that address broader ocean issues

25.5. Expand the U.S. IOOS modeling test bed nationally, with broad participation by multiple RAs; use the National Science Foundation's Ocean Observatories Initiative (OOI) for sampling density studies

25.6. Use modeling more in the design/assessment of the U.S. IOOS Observation Subsystem

25.7. Consider developing a process for U.S. IOOS approval/certification of models



U.S. IOOS SUMMIT REPORT

APPENDICES

APPENDIX A: SUMMIT AGENDA

INTEGRATED OCEAN OBSERVING SYSTEM

2012 SUMMIT AGENDA

A NEW DECADE OF THE INTEGRATED OCEAN OBSERVING SYSTEM

November 13-16, 2012 • Hyatt Dulles, 2300 Dulles Corner Blvd., Herndon, VA

DAY 1 - TUESDAY, NOVEMBER 13, 2012

CELEBRATING A DECADE OF PROGRESS AND PREPARING FOR THE FUTURE

These sessions will celebrate the decade of progress in the ocean observing system since the 2002 Ocean US Workshop, Building Consensus: Toward an Integrated Ocean Observing System, which provided the foundation for an Integrated Ocean Observing System (IOOS). In 2012, a decade later, government, industry, and academic leaders can look back and provide intelligent perspectives and present a vision for IOOS moving forward.

9:00 Session 1A: Opening and Welcome to the Summit

Dr. Eric Lindstrom, IOOS Summit Co-Chair and Physical Oceanography Program Scientist, NASA Headquarters

The purpose and expected outcomes of the Summit, the Summit design, and post-Summit actions.

9:15 Session 1E: Keynote Addresses: Celebrating Success and the Path Forward

Vice Admiral Paul G. Gaffney II, U.S. Navy, (Ret.), President, Monmouth University

10:00 Session 1B: IOOS and The Opportunity Ahead

Dr. Kathy Sullivan, Assistant Secretary of Commerce for Environmental Observation & Prediction and Deputy Administrator and Acting Chief Scientist, NOAA

The opportunities for IOOS in the next decade, making the "system of systems" work from the watershed, to the coast, to the Great Lakes, to the global oceans.

10:30 Break

11:00 Session 1C: Panel Discussion: Linking the Regional, National, and Global Components of IOOS Through the Next Decade

- *National IOOS: Zdenka Willis, Director, U.S. IOOS Program Office*
- *Global IOOS: Dr. Albert Fischer, Chief of the Global Ocean Observing System Project Office (invited)*
- *Regional IOOS: Julie Thomas, Executive Director, SCCOOS - Southern California Coastal Ocean Observing System*

11:35 Session 1D: IOOS in 2022: A Vision for the Future

Dr. Rick Spinrad, Chair of the IOOS Federal Advisory Committee and Vice President for Research, Oregon State University

12:00 Lunch

1:00 Session 1F: Visionary Vignette: Accessing, Fusing and Sharing Data within a Real-Time Decision Making Collaborative Environment: The Future of IOOS is Here

Dave Jones, Founder, President & CEO, StormCenter Communications Inc.

1:15 Session 1G: Panel Discussion: From the User's Perspective

Session Moderator: Molly McCammon, Executive Director, AOOS – Alaska Ocean Observing System

Remarks from IOOS users on how they currently use observing products and what they would like to see in the future. Comments will represent the IOOS themes of marine safety, sea level rise, fisheries, ecosystems and hazards.

3:30 Break

3:45 Session 1H: Panel Discussion: Developing Support for IOOS, Politics, Policies, and Personalities

Session Moderator: Dr. Bob Gagosian, President, Consortium of Ocean Leadership

Remarks from Congressional representatives and other on the national election and the outlook for 2013 Legislative Session.

5:00 Adjourn

5:15 Reception

2012 SUMMIT AGENDA

A NEW DECADE OF THE INTEGRATED OCEAN OBSERVING SYSTEM

November 13-16, 2012 • Hyatt Dulles, 2300 Dulles Corner Blvd., Herndon, VA

DAY 2: WEDNESDAY, NOVEMBER 14, 2012

USER REQUIREMENTS AND OBSERVING SYSTEM NEEDS

Day 2 will examine technical and scientific requirements for delivering products to users. This includes observing system components (observations, models, data management, product development) needed to address those requirements. The draft Summit Proceedings will set the stage for the discussions. Facilitated breakout sessions will identify priorities for post-summit actions to move IOOS forward.

8:30 Session 2A: Opening: Charge for the Day

Dr. Jan Newton, IOOS Summit Co-Chair and Executive Director, NANOOS - Northwest Association of Networked Ocean Observing Systems

8:40 Session 2B: Celebrating the Past: Chapter 1

Session Moderators: Zdenka Willis, Director, U.S. IOOS Program Office and Dr. David Martin, Associate Director and Senior Principal Oceanographer, Applied Physics Laboratory, University of Washington

Session Topic: New capabilities and successes for our ocean, coastal and Great Lakes environments resulting from IOOS activities. Discussion will focus on Chapter 1 of the Draft IOOS Summit Proceedings.

9:45 Session 2C: The Next Decade: User Requirements: Chapter 2

Session Moderators: Debra Hernandez, Executive Director, SECOORA - South East Coastal Ocean Observing Regional Association and Cara Wilson, Research Oceanographer, NOAA Fisheries Service

Session Topic: Users and Requirements. Discussion will focus on Chapter 2 of the Draft IOOS Summit Proceedings.

10:45 Break

11:15 Session 2D: Evaluating the Risk: Can IOOS aid the Insurance Industry?

Presenter: TBD

12:00 Lunch

1:00 Session 2E: Visionary Vignette of the Day: Navy Innovations

Rear Admiral Jonathan W. White, Oceanographer and Navigator of the Navy

1:15 Session 2F: The Observing System Required to Fulfill User Needs

Session Moderator: Dr. Harvey Seim, Professor, University of North Carolina

Session Topic: The required observing system elements needed to address future needs. Discussion will focus on Chapter 3 of the Draft IOOS Summit Proceedings

3:00 Break

3:20 Session 2G: Break Out Session 1: Products to Fulfill Future User Needs

Break Out Session 1 will define actions for developing relevant and effective use-products.

Break Out Sessions:

1. *Marine Operations - offshore energy, safe navigation*
2. *Climate Concerns - ocean acidification, carbon*
3. *Ecosystems and Fisheries - adopting an ecosystem approach to IOOS*
4. *Water Quality - harmful algal blooms, hypoxia, drinking water*
5. *Hazards - inundation, storms, water level changes (sea level rise, lake decrease)*

5:00 Adjourn

2012 SUMMIT AGENDA

A NEW DECADE OF THE INTEGRATED OCEAN OBSERVING SYSTEM

November 13-16, 2012 • Hyatt Dulles, 2300 Dulles Corner Blvd., Herndon, VA

DAY 3 - THURSDAY, NOVEMBER 15, 2012

SYSTEM INTEGRATION AND THE VISION FORWARD

Sessions this day are devoted to integrating the system into a unified vision that spans the local, regional, national and global scales.

9:00 Session 3A: Opening Session: Recap of Day 2 and Charge for the Day 3

Dr. Ru Morrison, IOOS Summit Co-Chair, Executive Director, NERACOOS - North East Regional Association of Coastal Ocean Observing Systems.

Recap of the previous day's activities including overview of the break out session discussions

9:10 Session 3B: The "I" in IOOS: A Truly Integrated Ocean Observing System: Chapter 4

Session Moderator: Michael Bruno, Sc.D., Dean, Schaefer School of Engineering and Science Professor, Stevens Institute of Technology

Session Topic: Integration Challenges and Opportunities. Discussion will focus on Chapter 4 of the Draft IOOS Summit Proceedings

10:30 Break

10:45 Session 3C: Break Out Session 2: Implementation Prioities and Plans

This session will build on Break Out Session 1 that identified user needs and products for the next decade by defining the priorities for the system elements. Each session will identify near, mid, and long term actions.

1. *Product development and stakeholder engagement*
2. *Integration through data management*
3. *Observation system*
4. *Modeling and assimilation*
5. *Research and development*

12:00 Lunch

1:00 Session 3D: Visionary Vignette of the Day - TBD

1:15 Session 3E: The Way Forward: Chapter 5 of the Draft IOOS Summit Proceedings

Session Moderator: Dr. Rick Spinrad, Chair of the IOOS Federal Advisory Committee and Vice President for Research, Oregon State University

Session Topic: A Vision for IOOS. Discussion will focus on Chapter 5 of the Draft IOOS Summit Proceedings.

2:45 Break

3:00 Session 3F: Break Out Session 3: Cross-cutting Issues

These break out sessions will focus on developing actions for cross-cutting issues critical to moving IOOS forward.

1. *Integration of ecosystem parameters into IOOS*
2. *Emerging technologies*
3. *Education and training*
4. *Advancing development of a business model*
5. *Advancing IOOS through advocacy*

5:00 Adjourn

DAY 4 – FRIDAY, NOVEMBER 16, 2012

THE NEXT DECADE FOR US IOOS

Sessions this day will review the results of the Breakout Sessions and the IOOS 2012 Summit Proceedings. Discussion will focus on Post-Summit Actions, summarizing accomplishments and expectations for follow-up after the 2012 Summit.

8:30 Session 4A: Opening: Recap of Day 3 and Charge for Final Day

Dr. Paul DiGiacomo, IOOS Summit Co-Chair and Chief of the Satellite Oceanography and Climatology Division, NOAA Satellites and Information

8:45 Session 4B: The Way Forward: Actions for the Next Decade

Session Moderator:

Findings from the break-out sessions, priorities for Post-Summit Actions - Reports by Break Out Session Chairs

10:30 Break ** SIGNING OF SUMMIT DECLARATION ******

10:50 Session 4C: Reactions to the Summit: Panel Discussion

Presenters: Representatives from National IOOS, Global IOOS, Regional IOOS, IOOS Federal Advisory Committee, IOOC, Congress, Users, and the Private Sector

Session Topic: Each presenter will provide a summary of their reactions to the Summit

12:00 Session 4D: Vision for Next Year: Post Summit Actions

Presenters: IOOS 2012 Summit Co- Chairs

Final remarks, next steps and action plan.

12:30 Adjourn – Summit Closes

APPENDIX B: U.S. IOOS SUMMIT ATTENDEES

Steven Ackleson
Consortium for Ocean Leadership

Charles Aleander
U.S. IOOS Program Office

Jonathan Allan
Oregon Department of Geology/NANOOS

Thomas Altshuler
Teledyne Webb Research

Rafael Ameller
Stormcenter

Don Anderson
Woods Hole Oceanographic Institution

Jon Andrechik
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Larry Atkinson
Old Dominion University

Becky Baltes
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David Balton
U.S. Department of State

Holly Bamford
NOAA National Ocean Service

Molly Baringer
NOAA/AOML

Catherine Barrett
U.S. Senate

Jack Barth
Oregon State University

Alan Barton
Whiskey Creek Shellfish Hatchery

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Marine Technology Society

Kenneth Boda
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Univ. of Maryland CES/MARACOOS

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Mark Bourassa
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Stevens Institute of Technology

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NAVOCEANO

Russell Callender
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Gabrielle Canonico
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Garden State Seafood Association

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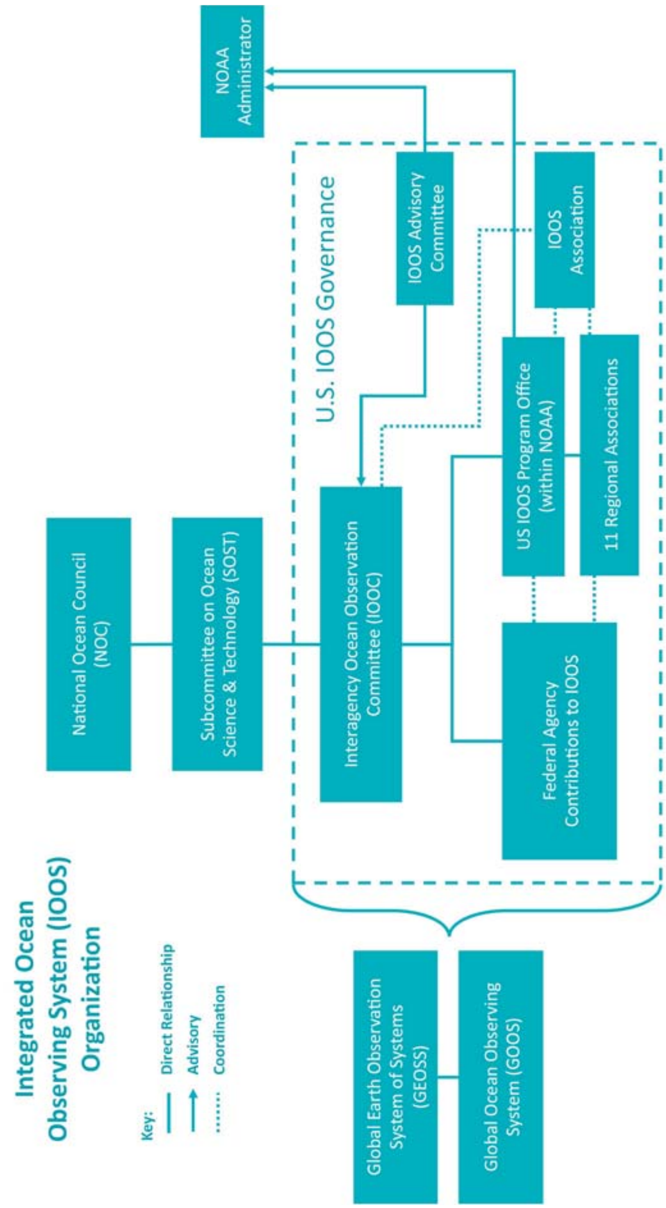
APPENDIX C: U.S. IOOS SUMMIT REPORT AUTHORSHIP TEAMS

Chapter	***Chapter Title***	Chapter Lead	Chapter Writing Team
One	***A Vision for the Future***	Rick Spinrad *Oregon State University*	Margaret Davidson Jack Dunnigan Dave Jones David Martin
Two	***Progress During the Past Decade***	Zdenka Willis (Co-lead) *NOAA/IOOS Program Office* David Martin (Co-lead) *University of Washington*	Jack Dunnigan Kate Lambert
Three	***User Engagement and Requirements***	Debra Hernandez (Co-lead) *SECOORA* Cara Wilson (Co-lead) *NOAA/NMFS*	Ann Jochens Ralph Rayner Ray Toll Richard Crout Steve Weisberg
Four	***Observing System Capabilities: Gap Assessment and Design***	Harvey Seim *University of North Carolina*	Ed Harrison Derrick Snowden Rich Signell Paul DiGiacomo
Five	***Integration Challenges and Opportunities***	Michael Bruno *Stevens Institute of Technology*	Rich Signell Chris Mooers Eoin Howlett Scott Glenn Leslie Rosenfeld Richard Edwing Jennifer Ewald Robert Gisiner Mitchell Roffer Bruce Bailey Ray Toll
Six	***Major Themes and Recommendations***	IOOC Co-Chairs: Eric Lindstrom *NASA* David Legler *NOAA* Bauke Hauptman *NSF*	Linda K. Glover Andrea McCurdy Kate Lambert

APPENDIX D: U.S. IOOS ORGANIZATION CHART



APPENDIX E: ASSESSMENTS OF THE U.S. IOOS PROGRAM

The U.S. IOOS Program Office produced the 2012 IOOS Blueprint Version 1.0, which can be found at *http://www.ioos.noaa.gov/about/governance/welcome.html*. The Blueprint's architectural framework does not prescribe specific system or technical solutions, infrastructure/facility material solutions, detailed business process steps, funding mechanisms or an organizational/management structure for the U.S. IOOS Program Office. It provides an architectural framework for describing a full capability (FC) for U.S. IOOS, including partnership roles and responsibilities and implementation requirements. An architectural framework provides a structured approach for organizing and describing discrete activities and components of U.S. IOOS that can be uniformly and repeatably applied to all U.S. IOOS-related capabilities and participants. The architectural guidance and documentation in the Blueprint are used to:

- Establish initial requirements
- Describe what needs to be accomplished, who executes it, and in what order
- Provide functional descriptions, including working relationships among IOOS components

Core Functional Analysis

The U.S. IOOS Program Office conducted an assessment of the Federal Agencies and RAs that are part of U.S. IOOS to determine which functions and activities are currently being performed by which U.S. IOOS Federal and non-Federal partners, and which activities remain to be developed. The Blueprint identifies core functional areas (CFA) that describe the U.S. IOOS program management products and services. The CFAs were derived from stated or implied requirements in the ICOOSA and the IOOS Development Plan. CFAs are the minimum capabilities required for an effective U.S. IOOS and represent, at a high level, the contribution required of U.S. IOOS to produce a cohesive suite of data, information, products, and services related to our coastal waters, Great Lakes, and oceans. Each core functional activity has subordinate activities.

The U.S. IOOS Program Office used a system of capability readiness symbols, to represent the assessment of the ability of U.S. IOOS to perform required activities at a given point in time. The symbols do not convey the effectiveness or efficiency with which the activity is conducted, but focus on the readiness to perform an activity.

Figure E1. Capability Readiness Symbols

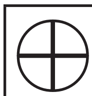
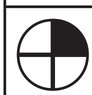
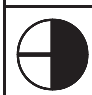
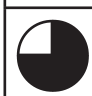
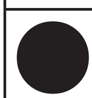
	**PRE-DEVELOPMENTAL.** New partner is recognized as a member of U.S. IOOS and has established preliminary partnership development plans, to include assigning resources and tools.
	**DEVELOPMENTAL.** Partner has begun development process leading to Initial Capability (IC) for assigned roles.
	**MINIMUM ESSENTIAL FUNCTIONALITY.** Partner has achieved IC—accomplished minimum critical function associated with IC for assigned role(s).
	**SIGNIFICANT FUNCTIONALITY.** Partner has begun development process leading to Full Capability (FC) for assigned role(s).
	**FULL FUNCTIONALITY.** Partner has achieved FC—accomplished critical functions associated with FC for assigned role(s).

Figure E2. Core Functionality Activity Findings Federal Partners

	U.S. IOOS Program Office Functional Capabilities (Current)	Federal Partners with Gap-Filling Capabilities in These Core Functions	Composite Across All Federal Partners (Possible)
A.1 Governance & Management *(8 core functions)*	◕		◕
B.1 Observing Systems Subsystem *(4 core functions)*	◔	USACE, Navy/ONR	◑
B.2 DMAC Subsystem *(9 core functions)*	◑	USACE, USGS, NOAA	◕
B.3 Modeling & Analysis Subsystem *(4 core functions)*	◑	USACE, USGS	◕
C.1 Research & Development *(6 core functions)*	○	USACE, USGS, NOAA, Navy/ONR, BOEM	◑
D.1 Training & Education *(6 core functions)*	◔		◔

○ No Capability ◔ Some Capability/Less Than Half ◑ Some Capability/More Than Half ◕ Some Capability In All ● Full Capability In All

Results of the analysis of readiness of the Federal Agencies

What this tells us is there are opportunities to pursue growth in U.S. IOOS capability through partner contributions. For example:

Observing Subsystem: Pursue partnership agreement opportunities with USACE and Navy/ONR in core functions within the Observing Subsystem in the area of optimization studies and asset management.

DMAC Subsystem: Pursue partnership agreement opportunities with USACE, USGS, and NOAA in core functions within the DMAC subsystem such as utility services development and configuration control.

Modeling & Analysis Subsystem: Pursue partnership agreement opportunities with USACE and USGS in assessment and management of sponsored models.

Research & Development: Pursue partnership agreement opportunities with USACE, USGS, NOAA, Navy/ONR, and BOEM in core functions within the R&D subsystem for requirements determination, coordinated pilots.

Figure E3. Core Functionality Activity Findings: Regional Partners

U.S. IOOS Subsysem	Minimum Regional Capability	Maximum Regional Capability
A.1 Governance & Management	◔	◕
B.1 Observing Systems Subsystem	◔	◕
B.2 DMAC Subsystem	◔	◑
B.3 Modeling & Analysis Subsystem	◔	◕
C.1 Research & Development	◔	◕
D.1 Training & Education	◔	◑

○ No Capability ◔ Some Capability/Less Than Half ◑ Some Capability/More Than Half ◕ Some Capability In All ● Full Capability In All

The assessment of readiness of the Regional Associations

From this we assess that RAs are active in all of the subsystems, and collectively display a solid foundation of IOOS capability. Overall, while the RAs have capability in some of the sub-activities in each subsystem, no region has “full capability” in any subsystem.

General Assessment

A U.S. IOOS Assessment, conducted by the U.S. IOOS Program Office, evaluated U.S. IOOS capability as it existed in 2010 among U.S. IOOS partners for the coastal component. Future assessments of progress will be based upon the Summit Vision and associated implementation guidance. Below are the results from the Assessment regarding assets that contribute to the Observing, DMAC, and Modeling and Analysis subsystems.

Observing Subsystem

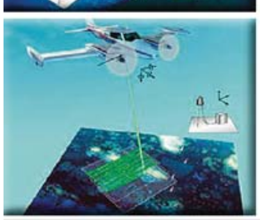
Figure E4 depicts the observing programs and assets that contribute to U.S. IOOS, as part of the Blueprint assessment. Next steps should focus on identifying how they fit together and where gaps in capability exist against requirements.

Some federal programs do not have sustained programs or systems, but still provide valuable contributions to the Observing Subsystem. The Bureau of Ocean Energy Management (BOEM) has played an important role in regard to increasing observing assets by issuing a Notice to Lessees (NTL) requiring oil & gas platforms to collect and transmit current data in near real time and provide it as non-proprietary data transmission into the federal U.S. IOOS data stream. Through their ocean studies program, in anticipation of drilling in the Arctic, BOEM has been funding University of Alaska to provide HF Radar, drifters and gliders for data collection there.

The RAs have the responsibility not only for deploying observing assets but also providing access to ocean, coastal and Great Lakes data collected by State, Local, Tribal governments, academia, industry and non-governmental organizations, as funding allows. The RAs provided an initial inventory of assets, stood up Regional Data Assembly Centers (DACs), and completed Regional Build Out Plans. Based on many years of interaction with users in their regions and nationwide, the RAs identified priority user needs in four primary categories: marine operations; coastal, beach and near shore hazards; ecosystems, including fisheries, and water quality; and long-term trends in ocean and Great Lakes conditions. The process for developing the Regional Build Out Plans began with each individual RA identifying user needs, products and required assets for their own region. This information was then synthesized to identify common elements across the nation as well as unique regional circumstances. A national synthesis document, *http://www.ioosassociation.org/documents*, defines 27 common products and services that should be provided in all the regions after a 10-year implementation period.

A foundation for all U.S. IOOS activities and products is effective, accurate, precise and reliable in situ and remote sensing instruments to quantify key parameters and to document environmental conditions and changes over time. The Alliance for Coastal Technologies (ACT) was developed, in large part, to fulfill one aspect of these U.S. IOOS technology requirements, by providing an understanding of sensor performance and data quality, while facilitating the maturation of novel technologies. Since 2004, ACT has evaluated 49 sensors from 25 international companies; overall, ACT has conducted 235 tests of instrument performance in the laboratory and in the field, under a wide range of environmental conditions and in different deployment applications. These Technology Evaluations have helped manufacturers improve their technologies and users make informed technology choices. The online Technology Information Clearinghouse now connects users with over 300 companies and nearly 4,000 commercial instruments.

Figure E4. Observing Platform Types from Synthesis of the Regional Build Out Plans

	PLATFORM TYPE AND USE	TYPICAL NUMBER PER REGION
IN-SITU FIXED PLATFORMS		
	**Shore stations** with meteorological and/or oceanographic instrumentation used to measure a variety of variables, most commonly water level and temperature	• 10–30 ocean or Lake shore stations • 12–45 meteorological shore stations
	**Multi-purpose moorings** used for time-series measurements of a variety of variables	5–32 multi-purpose moorings
	**Specialty observing** platforms, moorings (e.g. wave buoys) or seafloor-only (e.g. temperature sensors on lobster traps), used to measure a small number of variables; also region-specific platforms (e.g. oil rigs)	Due to the range of platform types in this category, there are no typical numbers
IN SITU MOBILE PLATFORMS		
	**Ships** used for repeat transects, event response, process studies, and to deploy and recover other platforms	UNOLS vessels, ships of opportunity, contract vessels, and small boats are all used
	**AUVs** used for bottom surveys and for water column measurements	1–4 AUVs
	**Vertically profiling gliders** measure a variety of variables as they execute a sawtooth trajectory	5–7 profiling gliders
REMOTE SENSING PLATFORMS		
	**Land based HF radar systems** Measure surface currents	11–50 HF radars
	**Satellite sensors** Measure a number of ocean and atmospheric variables from space, including sea surface temperature and ocean color	Satellites are part of Federal backbone
	**Airborne LiDAR** Used to map shallow water bathymetry	Aircraft contracted as needed

Data Management & Communication Subsystem

DMAC is the central mechanism for integrating all U.S. IOOS data sources into compatible formats. At the Global level individual programs such as Argo and OceanSITES have global data assembly centers. In addition to the efforts of the U.S. IOOS Program Office to provide a national consistent data management picture of U.S. IOOS, the data must also be provided in formats that serve communities. For example, the World Meteorological Organization (WMO) and national meteorological services rely on the Global Telecommunications System (GTS) for ocean data dissemination to support atmospheric modeling, and the U.S. IOOS Data Assembly Center at the NWS's NDBC provides this service. Since the number of ocean data records being sent to the GTS has risen from less than 500,000 in 2003 to over 11 million in 2011. At the Regional level, each of the RAs established DACs which have significantly increased user access to ocean data. For example Central and Northern California (CeNCOOS) provides real-time ocean and coastal information from 183 assets and 23 partners while the Northwest Association of Networked Ocean Observing Systems (NANOOS) provides information from 167 assets and 25 partners.

Modeling and Analysis Subsystem

NOAA's National Ocean Service (NOS) applies hydrodynamic models for the development, transition and implementation of Operational Forecast Systems (OFS) in U.S. estuaries, ports, lakes and the coastal ocean. These models and systems have applications in the support of safe and efficient marine navigation and emergency response as well as marine geospatial and ecological applications on synoptic time scales (hours to several days). There are currently thirteen water bodies in which OFSs are functioning and new OFSs are under development. Once tested, fully evaluated, and deemed accurate by NOS standards, experimental forecast systems are transitioned into the operational environment.

A new strategy of transitioning from individual port or estuarine models to a regional modeling approach is being developed and implemented to enhance the efficiency of development and operations. The first NOS regional model was recently implemented for the northern Gulf of Mexico and includes a high resolution model of the continental shelf as well as higher resolution grids (nests) in up to six ports in Texas, Louisiana, Mississippi and Alabama. A similar approach is planned for the U.S. West and East Coasts. Current OFS coverage is ~30% of the coastal continental U.S.

In 2010, U.S. IOOS established the Coastal and Ocean Modeling Testbed (COMT) to accelerate the transition of scientific and technical advances from the coastal and ocean modeling research community to improve certain operational ocean products and services. Initially addressing chronic issues of high relevance in the Atlantic and Gulf regions such as flooding from storm surge and seasonal depletion of oxygen in shallow waters, this project has established a robust infrastructure to facilitate model assessment, and detailed scientific investigation of both model output and data. Through the COMT, methods will also be explored for effectively delivering model results to regional centers, scientists, and managers relying on U.S. IOOS. Results from phase I of that effort include:

- Development of skill metrics for specific issues of societal importance
- Development of standards, web services and standards-based tools that work across a variety of different model types and conventions, enabling interoperability and software reuse by following U.S. IOOS DMAC principles.
- Improvements to all models through comparisons with others.

For example, the Estuarine Hypoxia team reported that the Chesapeake Bay ROMS Community Model (ChesROMS) model realized a 40% overall reduction in RMS difference between predicted and observed bottom dissolved oxygen concentration due to improvements identified during the Testbed project;

Research and Development

A major development is the funding of the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI), a long-term program to provide 25-30 years of sustained ocean measurements to study climate variability, ocean circulation and ecosystem dynamics, air-sea exchange, seafloor processes, and tectonic plate-scale geodynamics. The OOI will enable powerful new scientific approaches for exploring the complexities of Earth/ocean/atmosphere interactions, thereby accelerating progress toward the goal of understanding, predicting, and managing our ocean environment. The OOI is expected to foster new discoveries that will move ocean research in unforeseen new directions.

APPENDIX F: COMMON PRODUCT REQUIREMENTS OF U.S. IOOS RAs

A national synthesis document, www.ioosassociation.org/documents, defines 27 common products and services that should be provided in all the regions after a 10-year implementation period.

USER NEED/ GOAL	PRODUCTS/ SERVICES	KEY VARIABLES/ DATA STREAM
MARINE OPERATIONS		
Vessels		
Safe and efficient coast and ocean transit and operations--shipping, fishing, recreation, ferries, etc.--includes scheduling and routes	Nowcasts and forecasts with visualization tools for coast and open ocean, Great Lakes	Near real-time offshore wind, wave, temperature (air and sea), atmospheric visibility, bathymetry, AIS vessel tracking, navigation charts
Safe passage into and inside ports, harbors, marinas, passages--includes scheduling, routes, keel clearance, pilot boarding decisions, port status designations	Nowcasts and forecasts with visualization tools near and in major ports, harbors, passages	Above variables but at higher resolution for nearshore and harbors, plus surface and subsurface currents, water level and water density
Search and Rescue		
Where to focus search efforts, and optimize safety and efficiency of operations	Hindcasts, nowcasts and forecasts for visualizations, modeling and delivery into tactical SAR decision tools	Near real-time wind, wave, surface and subsurface currents, temperature (air and sea), atmospheric visibility and cloud cover
Spill Planning and Response		
Rapid effective response to spills or floatable debris, including decisions re type and location of containment efforts, clean up and wildlife rescue. Determine origin.	Hindcasts, nowcasts and forecasts formatted and delivered to NOAA OR&R spill modelers and responders	Near-real time winds, waves, surface and subsurface currents and water density
	Spill trajectory tools as requested by users for spills not covered by OR&R, e.g. small spills, some contaminants, planning and drills	Same as above
	Satellite imagery and contaminant maps to further define and track spills	Synthetic aperture radar; oil and contaminant distributions throughout water column

Offshore energy		
Assess conditions for feasibility and cost-effectiveness of energy generation; compare alternative locations	Climatologies—historical average conditions	Historical wind, wave and/or currents
Maximize efficiency and safety of energy operations	Nowcasts and forecasts	Near real-time winds, waves, currents
Evaluate potential impact of energy facility on coastal processes, wildlife, and other ocean users for permit review	Predictions of impacts	Acoustics, wave fields, sediment transport, nutrients, habitats, wildlife distribution, migratory pathways, etc.

COASTAL, BEACH and NEARSHORE HAZARDS		
Emergency response and preparedness		
Timely hazard and disaster information to coastal communities to protect public and infrastructure	Observations, nowcasts and forecasts of extreme weather, high water, storm surges and erosion events, inundation and waves	Near real-time water level, waves, shoreline, bathymetry
Long term planning for future responses	Climatologies and long-term forecasts of frequency and intensity of extreme weather, high water, storm surges, erosion events, inundation and waves	Historical data on above variables and related atmospheric drivers
Enhance public safety and use of beaches	Beach conditions web portal	Rip currents, waves, presence of jellyfish or HABs, water quality including fecal bacteria indicators

WATER QUALITY		
Nonpoint and point source pollution		
Predict and minimize impacts from discharges of pollutants, including nutrients and fecal indicator bacteria	Early warnings of the presence/prediction of pollution events, including plume / particle tracking	Near real-time nutrients and fecal bacteria indicators, currents, point source and stormwater inflows
Improve management based on water quality conditions and trends, identifying and mitigating sources of pollution	Portal for integration of regional water quality monitoring data, freshwater inputs, restoration efforts	Historical and current nutrient, pesticide, sediment, fecal bacteria concentrations, salinity, currents, oxygen, point source and stormwater inflows, program activities

HABs		
Protecting public health and aquaculture facilities from HAB impacts and preparing for wildlife rescue	Maps showing spatial distribution of HABs and long-term patterns of occurrence	Historical HAB biotoxin concentrations, species distribution and abundance
Early warnings to coastal managers and businesses when conditions are conducive to HAB formation and when HABs present	Early warnings to coastal managers and businesses when conditions are conducive to HAB formation and when HABs present	Near real-time temperature, currents, chlorophyll (chl), nutrients, HAB biotoxin concentrations, species distribution and abundance
Hypoxia and eutrophication		
Improve adaptation and mitigation of harmful impacts association with low oxygen (hypoxia) and high nutrients (eutrophication)	Maps showing spatial distributions and long-term patterns of occurrence	Historical oxygen, nutrients, chl
	Early warnings for when conditions are conducive to hypoxia and/or eutrophication or they are present	Near real-time temperature, currents, water column density, oxygen, nutrients, chl

ECOSYSTEMS AND FISHERIES		
Healthy and Productive Ecosystems and Sustainable Fisheries		
Improved understanding, use, management and conservation of coastal, marine and Great Lakes ecosystems. Restore and protect healthy ecosystems and sustainable fisheries, and the cultures and economies that depend on them.	Integrated maps and displays linking diverse variables, with spatial analyses tools to support regional planning	Habitats, fish and wildlife distributions/migrations, invasive species, dynamic physical/chemical variables (currents, temperature, nutrients), bathymetry, etc.
	Seasonal and annual climatologies	Historical physical and chemical variables (currents, temperature, nutrients, etc.). and biological responses (chl, zooplankton, fish, wildlife, etc.)
	Ecosystem and health indices integrating physical, chemical and biological variables	Same as above two rows
	Current modeling and virtual particle tracking for larval fish transport	Surface and subsurface currents

LONG TERM CHANGE AND DECADAL VARIABILITY		
Acidification		
Long term planning for mitigation and adaptation to respond to acidification and impacts on ocean life and fisheries	Status and trends of acidification, including mapping of particularly sensitive habitats	pH, CO2, habitat distribution
Effective and safe operation of facilities, e.g. for shellfish aquaculture, short term planning/responses such as suspending, moving operations, changing timing of releases or harvest	Warnings sent to interested parties when conditions unfavorable due to acidification	CO2, pH, temperature, salinity, oxygen, turbidity, chl, river discharges
Shoreline and water level changes		
Long term planning to ensure safety and protection of coastal community and natural resources, evaluate proposed development or coastal protections (also see emergency response above)	Long-term trends and forecasts of beach and shore erosion sea level rise, land subsidence, and coastal flooding and inundation	Water level, waves and winds, precipitation and runoff, nearshore Laser Interferometry Detection and Ranging (LIDAR)/ bathymetry, shoreline position
Ecosystem conditions		
Increased understanding of changes in ocean/lake conditions over time and planning for mitigation and adaptation strategies	Climatologies and long-term forecasts	Historical physical, chemical, biological and geological variables (e.g. currents, temperature, oxygen, nutrients, chlorophyll, zooplankton, fish, wildlife, shoreline)
	Regional climate indices	Primary productivity, C02, shelf-slope exchange, El Niño Southern Oscillation (ENSO), freshwater inputs, etc

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APPENDIX H: ACRONYMS

ACT . . . . . .Alliance for Coastal Technologies
AOOS . . . . .Alaska Ocean Observing System
Argo . . . . .Array for Real-time Geostrophic Oceanography
ATN . . . . . .Animal Telemetry Observing Network
Blueprint . . .Blueprint for Full Capability
BOEM . . . . .Bureau of Ocean Energy Management
BON. . . . . .Biodiversity Observation Network
BSEE . . . . .Bureau of Safety and Environmental Enforcement
CaRA . . . . .Caribbean Regional Association
CEOS . . . . .Committee on Earth Observation Satellites
CeNCOOS . . .Central and Northern California Ocean Observing System
CFA . . . . . .Core Functional Areas
CILER . . . . .Cooperative Institute for Limnology and Ecosystems Research
Chl . . . . . .Chlorophyll
CO-OPS . . . .Center for Operational Oceanographic Products and Services
CODAR . . . .Coastal Ocean Dynamics Applications Radar
CO2. . . . . .Carbon Dioxide
COMT . . . . .Coastal and Ocean Modeling Testbed
CSREES . . . .Cooperative State Research, Education, and Extension Service
CWP . . . . .Community White Paper
DAC. . . . . .Data Assembly Centers
DART . . . . .Deep-ocean Assessment and Reporting of Tsunamis
DIF . . . . . .Data Integration Framework
DMAC . . . . .Data Management and Communications
DOE. . . . . .Department of Energy
DOS. . . . . .Department of State
DOT. . . . . .Department of Transportation
ECV. . . . . .Essential Climate Variable
eMOLT. . . . .Environmental Monitors on Lobster Traps
ENSO . . . . .El Niño Southern Oscillation
EOV. . . . . .Essential Ocean Variable
EPA . . . . . .Environmental Protection Agency
FC . . . . . .Full Capability
FDA. . . . . .Food and Drug Administration
FOC. . . . . .Full Operating Capability
FOO. . . . . .Framework for Ocean Observations
GAO. . . . . .Government Accountability Office
GBIF . . . . .Global Biodiversity Information Facility
GCOOS . . . .Gulf of Mexico Coastal Ocean Observing System
GCOS . . . . .Global Climate Observation System
GEO. . . . . .Group on Earth Observations
GEOSS. . . . .Global Environmental Observation System of Systems
GHRSST . . . .Global High Resolution Sea Surface Temperature
GIS . . . . . .Geographic Information System
GLOS . . . . .Great Lakes Observing System
GOCO . . . . .Government Owned

Contractor Operated

GODAE . . . . .Global Ocean Data Assimilation Experiment

GOOS . . . . .Global Ocean Observing System

GOSUD . . . .Global Ocean Surface Underway Data

GTS . . . . . .Global Telecommunications System

GTOS . . . . .Global Terrestrial Observing System

HAB . . . . . .Harmful Algal Blooms

HFR . . . . . .High Frequency Radar

IA . . . . . . .IOOS Association

ICE . . . . . .Independent Cost Estimate

ICOOSA . . . .Integrated Coastal and Ocean Observation System Act of 2009

IDIQ . . . . . .Indefinite Delivery/Indefinite Quality

IMOS . . . . .Integrated Marine Observing System

IOOC . . . . .Interagency Ocean Observation Committee

IOOS . . . . .Integrated Ocean Observing System

JCOMM . . . .Joint Commission for Oceanography and Marine Meteorology

JCS . . . . . .Joint Chiefs of Staff

K-12 . . . . .Kindergarten through 12th Grade

KML . . . . . .Keyhole Markup Language

LIDAR . . . . .Laser Interferometry Detection and Ranging

MADIS . . . . .Meteorological Assimilation Data Ingest System

MARACOOS . .Mid-Atlantic Regional Association of Coastal Ocean Observing System

MBARI . . . . .Monterey Bay Aquarium Research Institute

MAST . . . . .Modeling and Analysis Steering Team

MBG . . . . .Marine Biogeographic

MMC . . . . .Marine Mammal Commission

MPA . . . . . .Marine Protected Areas

NANOOS . . . .Northwest Association of Networked Ocean Observing Systems

NASA . . . . .National Aeronautics and Space Administration

NCDC . . . . .National Climatic Data Center

NMP . . . . . .National Mesonet Program

NDBC . . . . .National Data Buoy Center

NERACOOS . . .Northeastern Regional Association of Coastal Ocean Observing Systems

netCDF . . . .Network Common Data Format

NFRA . . . . .National Federation of Regional Associations

NGDC . . . . .National Geophysical Data Center

NGO . . . . .Non-Governmental Organization

NHS . . . . . .National Hurricane Center

NMP . . . . . .National Mesonet Program

NOAA . . . . .National Oceanic and Atmospheric Administration

NOC . . . . . .National Ocean Council

NOPP . . . . .National Ocean Partnership Program

NORLC . . . .National Ocean Research Leadership Council

NPS . . . . . .National Park Service

NSF . . . . . .National Science Foundation

NTSB . . . . .National Transportation Safety Board

NWLON . . . .National Water Level Observation Network

NWS . . . . .National Weather Service

OBIS . . . . .Ocean Biogeographic Information System

OceanSITES . .Ocean Sustained Interdisciplinary Time series Environmental observation System

OFS . . . . . .Operational Forecast Systems
ONR. . . . . .Office of Naval Research
OOI . . . . . .Oceans Observatories Initiative
ORR. . . . . .Office of Response and Restoration
OSSE . . . . .Observing System Simulation Experiment
PacIOOS . . . .Pacific Islands Ocean Observing System
pCO2 . . . . .partial pressure of Carbon Dioxide
pH . . . . . .Acidity
PICO . . . . .Panel for Integrated Coastal Observation
PIRATA . . . .Prediction and Research Moored Array in the Atlantic
PORTS. . . . .Physical Oceanographic Real-Time System
QA/QC . . . .Quality Assurance/ Quality Control
QARTOD . . . .Quality Assurance of Real Time Oceanographic Data
R2O. . . . . .Research to Operations
R&D. . . . . .Research and Development
RA . . . . . .Regional Associations
RAMA . . . . .The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction
RCOOS . . . .Regional Coastal Ocean Observing Systems
SAROPS . . . .Search and Rescue Optimal Planning System
SCCOOS . . . .Southern California Coastal Ocean Observing System
SECOORA . . .Southeast Coastal Ocean Observing Regional Association
SLOSH. . . . .Sea, Lake, and Overland Surges from Hurricanes
SoS . . . . . .System of Systems
SOS . . . . . .Sensor Observational Service
STEM . . . . .Science, Technology, Engineering, Mathematics
SWE. . . . . .Sensor Web Enablement
TOA. . . . . .Tropical Ocean-Atmosphere
TOPP . . . . .Tagging of Pacific Predators
TRITON . . . .Triangle Trans-Ocean Buoy Network
USACE. . . . .United States Army Corps of Engineers
USARC. . . . .United States Arctic Research Commission
USCG . . . . .United States Coast Guard
USGS . . . . .United States Geological Survey
WHOI . . . . .Woods Hole Oceanographic Institution
WMO . . . . .World Meteorological Organization
WOCE . . . . .World Ocean Circulation Experiment