A National Science Foundation-funded Research Coordination Network called the “Research Coordination Network: OceanObs” (RCN) is addressing approaches for improving interdisciplinary research capabilities in the ocean sciences. In addition, the RCN continues tasks that focus on improved observation capabilities and on community outreach and education. A working group has addressed issues and challenges of open data. Another working group is focused on improvements in observations where both in situ and remote sensing provide essential information. A use case for the discussion is considers observation of coastal waters. There is also a monthly webinar, “Blue Marvel - Ocean Mysteries” that supports Capacity Building and Outreach. The ultimate goal of these activities is to identify and encourage better ways to make earth observations and to improve availability to society as knowledge and understanding for improved policy and decision-making. This paper reviews the status of the RCN developments.

Introduction
The oceans provide many important functions within the Earth system including strong coupling with weather and climate dynamics, providing food and energy resources, supporting trade and commerce, offering extensive stabilization for variations in our environment and being a resource for biodiversity. The need for improved coordination in ocean observations is more urgent now given these issues of climate change, sustainable food sources and increased need for energy. Ocean researchers must work across disciplines to provide policy makers with clear and understandable assessments of the state of the ocean.

New technologies and approaches are emerging to vastly improve ocean observations. Cabled observatories are an example of a paradigm shift, providing a relative abundance of power and bandwidth for observations covering scales from cm to km and times from seconds to decades [1]. Sensors traditionally only available in laboratories can now be adapted for in-situ observations. Gliders are demonstrating a level of maturity that enables them to support new opportunities for observations [2].

The potential for interdisciplinary collaboration is significant. Addressing the ocean as an “ecosystem”, there are needs to understand the interactions of the physical, biological and chemical environments. In a recent RCN webinar, the climate change impacts on fish spawning grounds and therefore the productive viability was given as an example of needing integrated multi-disciplinary assessments for understanding ocean ecosystems [3]. The “Research Coordination Network: OceanObs” (RCN) is a forum to address these issues and develop recommendations on key topics of ocean observation and information.

The goal of the RCN is to foster a broad, multi-disciplinary dialogue, enabling more effective use of ocean observing systems to inform societal decisions. This is a very broad goal and, practically, it is necessary to identify specific areas on which to focus. The RCN has therefore defined a series into a series of objectives to support the goal. These include:

- Motivate commitments to sustaining ocean and marine observing systems
- Stimulate inter-disciplinary cooperation for both observations and analyses
- Facilitate open exchange of ocean data
- Promote interoperability
Within these objectives, the RCN considers specific areas such as issues of open data policy, integration of space-based and in-situ measurements, innovative concepts in sensors and education. Additional subjects may be proposed by the network members in topics such as citizen science. In achieving these objectives, the RCN will motivate new research outcomes, provide wider visibility for the value and impacts of ocean observations and encourage a new generation of scientists to focus on the oceans and their challenges. This paper will provide status and outcomes of three areas that have been active in the last two years.

Open Data Policy and Practices

The topic of open data has been receiving a lot of attention recently. This ranges from important changes in European policy through the adoption of the Horizon 2020 digital agenda [4] to recent debates on peer review and access to data in order to replicate published results [5]. Countries as diverse as Denmark [6] and Burkina Faso [7] have announced open data policies for government data. The Open Data Institute’s director Gavin Starks believes there is a strong business case to be made for governments, organizations and businesses to make most of their data open – that is, share it online to unlock its potential [8].

Many of these pronouncements and policy changes have focused on government data. When addressing open data for research, the issues are a complex mix of three factors: infrastructure for effective sharing, cultural changes providing incentives for sharing and policy changes to enable sharing. For the third, in the US, NSF announced on February 22 2013: “Today, the National Science Foundation (NSF), along with federal partners, announced its commitment to expand public access to the results of its funded research. Public access is intended to accelerate the dissemination of fundamental research results that will advance the frontiers of knowledge and help ensure the nation's future prosperity.” At the same time, the NSF Director, Subra Suresh, pointed out that "full public access will require changes in policies, procedures and practices from the many stakeholders who participate in NSF’s broad research portfolio spanning all scientific and engineering disciplines" [9].

An RCN working group looked at the broad range of issues relating to open data and the challenges to creating a practical open data environment in a report of the Research Coordination Network RCN:OceanObsNetwork, entitled “Facilitating Open Exchange of Data and Information” authored by J. Gallagher, J. Orcutt, P. Pissierssen, L. Raymond, and P. Simpson [10]. The RCN working group on open data addressed three core issues of open data: (1) discovery and access, (2) data quality and (3) fitness for purpose and sustainability. Following detailed discussion and examination of the issues, the working group developed a series of recommendations that are summarized as follows:

● In its implementation, Open Data must, among other things, improve the efficiency, the collaborative nature and impacts of scientific research. This will be achieved when Open Data implementation and Policy:
  ● Is sustainable;
  ● Preserves the peer review attributes of science and of publications and expands it to include data;
Assures scientists of recognition for their research;
- Maintains data attributes such as provenance, metadata, quality attributes, etc;
- Allows easy discovery and access to data and information, particularly supporting cross discipline research;
- Supports Intellectual Property Rights and licensing protocols;
- Is compatible with evolving national and international policies; Motivates participation and contributions;
- Minimizes negative impacts on existing disciplinary systems; Works across physical, social and economic sciences; and Promotes access and use by the public and policy makers.
- Metrics should be established to monitor status and progress in the above areas.
- Policies should be adopted that support the sustainability of an Open Data environment.
- Broadly inclusive collaborations across scientific disciplines need a more formal way to make data generally available. Translators (brokers) for formats should be developed as middleware.
- Collaboration between international repositories of ocean science and other data should be encouraged both to improve efficiency and reduce costs.
- Adoption of Digital Object Identifiers or equivalent “globally unique persistent identifiers” should be expanded and widely implemented.
- A peer review methodology for datasets and/or data repositories should be implemented.
- Journal publishers should have a clearly stated data policy regarding supplemental material and related datasets.
- Outreach and Capacity Building is needed for general users to be comfortable in a cross-domain data environment; such activities should be built into an Open Data initiative.

Further examination of these recommendations is provided in a recent paper “Facilitating Open Exchange of Data and Information” which acknowledges that a “broad consensus exists that Open Data presents great value [11]. However, beyond that simple statement, there are a number of complex, and sometimes contentious, issues that the science community must address.” Thus, any comprehensive policy on Open Data will require compromises that are best resolved by broad community input. The paper provides recommendations that serve as a starting point for these discussions.

In Situ and Remote Sensing Observations
Much of the ocean environment remains poorly characterized - constrained by observing feasibility limitations. Ocean processes cover a wide range of spatial and temporal scales, typically many orders of magnitude. For example, dynamic processes can range from global scale oscillations to eddies of a kilometer or less. To understand and predict the full range of ocean processes requires significant improvements in our ability to make and analyze observations, effectively combining multiple observations into model predictions that can help manage or adapt to our changing environment. This is particularly true for biogeochemical cycling of oxygen, carbon, nutrients and metals and the resultant microbiological response that dominate ocean productivity and influence fisheries and carbon sequestration potential [12]. In addition certain geospatial ocean environments such as the near shore regions offer greater challenges for both measurements and understanding due to their large dynamic variations [13, 14].
During the last century, many of the observations focused on ship-based measurements. These were point or sequential measurements along a track and provided insight into the oceans, but were not comprehensive enough to give a broad view of the ocean dynamics. Two advances in the last 50 years have changed observations – the advent of space-based remote sensing and the use of new sensors, electronics and communications to provide a broader range of in situ measurements [15]. The examples of ARGO floats [16] and glider platforms [17] are two such advances. Sensors for these and other platforms are expanding to include both physical and biogeochemical observations. Aquatic sensors can use a range of techniques from optical techniques (e.g. optical fibers, hyperspectral imaging, spectroscopy), wet chemical, electrochemical, biosensors, and acoustic techniques [18]. These offer important advances.

However, more comprehensive end-to-end capabilities are necessary. Remote sensing observations are improving in their ability to capture high-resolution images, but are not always well correlated with in situ observations. Model validation with observations can be routinely done but model predictions vary when examined at the local level, particularly in the coastal regions [19]. Thus there are still significant challenges.

An RCN working group is looking correlations of satellite observations and in situ measurements in the complex near shore environment. The purpose is to identify gaps and requirements and provide recommendations for how ocean-observing systems of the future could use satellite measurements to complement in situ measurements for the coastal environment. The goal of combining these different types of measurement is to make the whole greater than the sum of the parts. In the study, a use case is chosen of river plumes (fresh water) entry into the coastal ocean environment. In this context, in addition to the sensor synergies, the question of correlation with numerical models is considered in order to quantify sub-seasonal time scale transport of freshwater and its constituents from terrestrial water storage bodies across and along continental shelves, as well as its impacts on some key biological/biogeochemical properties of coastal waters. [13]. Fresh water also affects stratification and thus can influence rates of primary production, as well as the vertical distribution of oxygen. Influx of freshwater is generally time-dependent, particularly at temperate and higher latitudes, with important influences at days to seasonal time scales. Calculations and models based on geostrophy show that river plumes should hug the coastline and move to the right of the initial flow direction in the northern hemisphere. However, simple models do not always capture the important modes of variability owing to tidal impacts, topography, winds, coastal waves, and other influences. Recent studies also show the importance of “bulge” circulation near river mouths. High discharge rates coupled with upwelling favorable winds can stimulate bulge circulation, which can keep large amounts of freshwater near river mouths for extended periods of time [20].

The components of a fully integrated future observing system to determine the fate of major river plumes once they reach the U.S. continental shelf requires a combination of observations, models, and analyses of the background data of the watershed and adjacent coastal ocean. To focus assets at crucial times during the year and at key locations requires knowledge of the
historical patterns of subseasonal to interannual variability in freshwater storage in terrestrial reservoirs within the coastal region of interest. A regional-scale numerical model for the region of interest that is forced by realistic tides and winds, has realistic bottom topography, vertical and horizontal resolution appropriate for its application, and is capable of producing the fields of interest, including ecological and biogeochemical tracers, is required as an integrative and predictive tool. The model will be particularly useful if it can be run in near real-time and is capable of assimilating basic meteorological fields and some ocean physical observations such as vertical structure. To support such a model, buoy winds, surface air temperature, and incoming solar radiation are the minimum meteorological measurements required as a complement to the physical and biological ocean measurements. Current satellite systems can monitor ocean color, ocean topography and sea surface environment. New satellite systems such as PACE [21] and HyspIRI [22] will expand these measurements with refined spectral sensing. These will provide significant improvements for resolving in-water constituents beneath the complex atmospheres of coastal regions. Resolving taxonomic composition at the phytoplankton class level, as well as determining dominant phytoplankton size classes will also be possible. New ocean color measurements with more rapid observations from GEO orbits can improve elements of the coastal regions with fresh water inflow [23].

The working group is examining recommendations for near coastal measurements. A new technology is needed for monitoring the fate of river plumes and their impacts in shelf water – one possibility is an instrument such as an ARGO float for shallow water. Such a float is under development but not yet operational [24]. A critical feature is that the float senses the bottom by striking it, so that profiles from the surface to the bottom are possible. One operational scenario to optimize collecting high priority data is to release floats in at different stages of river discharge events or high discharge seasons. In addition to temperature and salinity sensors, coastal ARGO floats could also include bio-optical sensors [25], such as transmissometers (water clarity), chlorophyll fluorometers (phytoplankton biomass), and scattering meters (back-scattered solar spectral irradiance to compare with satellite-derived measurements). The measurements need then to be combined with models of both the onshore hydrology (SWAT) and the ocean forecast models such as RTOFS and MERCATOR with the goals of having improved forecasts on a short time scale so that impacts of large water discharges can be better understood and predicted.

Education and Outreach.

With all the advances in sensor and data management, there are still mysteries in the seas and below the ice that intrigue not only scientists, but also the public. Appreciation of these brings an understanding of the impact of the ocean on our lives. The RCN, in collaboration with other organizations, sponsors a webinar series, appropriately titled “Ocean Mysteries” which offers new ideas for ocean observations and understanding [3]. The series started with a discussion of the ocean and its impacts on human health by Rita Colwell, explored with Don Walsh the depths, probed under the ice with Matt Mowlem and Bob Bindschadler and looked with Lorenzo
Ciannelli at fish spawning in the context of climate change. A list of the presentations is given in Table 1.

Table 1: Blue Marvel Ocean Mysteries Webinar

<table>
<thead>
<tr>
<th>Topic</th>
<th>Presenter</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Oceans, Climate and the Cholera Paradigm</td>
<td>Rita Colwell</td>
<td>October 16 2012</td>
</tr>
<tr>
<td>Chemistry to Antarctica to Scripps Oceanography</td>
<td>Tony Haymet</td>
<td>November 8 2012</td>
</tr>
<tr>
<td>Going the Last Seven Miles, a Personal Odyssey</td>
<td>Don Walsh</td>
<td>January 8 2013</td>
</tr>
<tr>
<td>Our Changing Ocean</td>
<td>Margaret Leinen</td>
<td>February 18 2013</td>
</tr>
<tr>
<td>Evolution of Robots for Exploring the Deep Sea</td>
<td>Dana Yoerger</td>
<td>March 12 2013</td>
</tr>
<tr>
<td>What Ice Sheets Hate</td>
<td>Robert Bindschadler</td>
<td>April 2 2013</td>
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<tr>
<td>Microbial Oceanography – Potential and Challenges</td>
<td>Levente Bodrossy</td>
<td>May 21 2013</td>
</tr>
<tr>
<td>An Ocean of Data: Diving into the Virtual Ocean</td>
<td>Simon Allen</td>
<td>June 25 2013</td>
</tr>
<tr>
<td>Environmental Impact of the Arctic’s Shrinking Sea Ice</td>
<td>Mark Serreze</td>
<td>July 16 2013</td>
</tr>
<tr>
<td>A Century of Discovery</td>
<td>Gwynn Griffiths</td>
<td>September 10 2013</td>
</tr>
<tr>
<td>A probe for Subglacial Lake Ellsworth, Antarctica</td>
<td>Matthew Mowlem</td>
<td>December 12 2013</td>
</tr>
<tr>
<td>Understanding our Planetary Life Support System</td>
<td>John Delaney</td>
<td>February 20 2014</td>
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<tr>
<td>Climate, Carbon and the Ocean Nitrogen Budget</td>
<td>Robinson (Wally) Fulweiler</td>
<td>March 25 2014</td>
</tr>
<tr>
<td>Where Do Fish Like to Spawn?</td>
<td>Lorenzo Ciannelli</td>
<td>July 15 2014</td>
</tr>
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In addition to the webinars, the RCN has sponsored sessions on international collaboration in the context of new initiatives.

Summary
The RCN facilitates tasks that focus on improved observation capabilities and on community outreach and education. A working group has addressed issues and challenges of open data. Another working group is focusing on improvements in observations where both in situ and remote sensing provides essential information, using freshwater influx into the coastal ocean to examine key challenges and formulating recommendations for future observations. As part of the outreach activities, there is also a monthly webinar, “Blue Marvel - Ocean Mysteries” and reaches a wide audience. The ultimate goal of these activities is to identify and encourage better ways to make ocean observations and to improve availability to society as knowledge and understanding for improved policy and decision-making.

References


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24. Personal communication from vendor.