RCOOS and Ocean Information Tools for Decision Makers

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Abstract-**The nascent Regional Coastal Ocean Observing Systems (RCOOS) are expected to provide enhanced awareness of the coastal environment through the deployment of new sensors and the communication of user-driven information products. Successful utilization of RCOOS information will require close interaction with the intended user communities. The planned information systems and decision aids can benefit from Human Factors research. With the adoption of human-centered design principles and the employment of web-based technologies, RCOOS information can be quickly transmitted to those who need it, and visualized in ways that help users make critical decisions. We describe three web-based decision tools that identify the opportunities of this approach.**

I. INTRODUCTION

The U.S. Integrated Ocean Observing System (IOOS) is a federally sponsored program that supports the development of regional coastal associations (RCOOS). RCOOS will deploy new marine sensors and create an infrastructure to combine present-day sensors from a variety of marine activities and incorporate future sensors into a shared information system. The regional focus of the individual RCOOS organizations will help serve the needs of the individual stakeholders in their geographic area. The IOOS strategic vision is to foster a host of new products useful to a variety of decision makers, "designed to be user-driven and provide sustained data and information in forms and at rates required by decision makers [1]." The types of user communities envisioned include: maritime operations, ecosystem monitoring, fisheries, and marine recreation. These communities need information that helps them gain knowledge and make decisions. Water quality personnel, for example, may need to predict the movement of an oil spill by comparing a variety of wind and ocean forecasts with historical observations from marine sensors. The present mechanisms for locating and displaying ocean information are inadequate to meet IOOS goals. IOOS developers should focus on designs that are human-centric, that is, systems that are powerful yet flexible, easily deployable and rapidly upgraded with the evolving needs of the user. We believe that the emerging capabilities of web-based systems offer opportunities to meet these objectives.

II. HUMAN FACTORS AND WEB TECHNOLOGIES

A. Lessons from Human Factors Research

Human Factors' literature has documented the impact of complex systems on human performance. When the human component is incorporated late into the design phase, the resulting system can require the human operator to perform functions that impede rather than improve the performance of the assigned task, or the system itself may become an impediment. The adoption of a user-centered design methodology is one way to explicitly place the needs of the human at the forefront of the design process. Ref. [2] has shown how UCD applied to information systems helped large software organizations improve their products. UCD principles include: the study of user needs through task analysis, rapid prototyping, iterative evaluation, and usability assessments. Another interesting aspect noted by some UCD proponents is the inclusion of non-engineers in the design team, specifically, individuals with experience in graphic design and technical communication, or as [3] describes, the soft side of system concerns.

The concern for users' needs leads directly to a focus on system interfaces. "From the point of view of the user, the interface is the system [4]." Through the interface the user navigates to all of the information within the system. The clearer the organization the easier it is for users to proceed. Interface design principles, which were derived from the research of the Human-Computer Interaction (HCI) discipline, have proven extremely effective and popular. One well-known example is the rapid adoption of computer windowing environments, which was based on cognitive research done at the XEROX research center in Palo Alto, CA (PARC) [5].

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Human Factors research provides insight into more than just the actions taken at the computer interface. There is extensive literature on how people make decisions and how they use information in their decision-making process. Studies of humans in naturalistic situations, such as, weather forecasting, military command and control, and firefighting, have led to recommendations for the design of decision aids. Ref. [6] developed a principle that states—decision aids need to assist in active organization, search, and exploration of information. Additionally, decision aids should help decision makers reflect on the meaning of the information, while also allow them to evaluate and choose among different options.

B. New Trends in Web-based Information Systems

The technology to transfer, share, and display information via the World Wide Web continues to advance swiftly. The web browser itself has become ubiquitous. We can look at it as the new operating system since so much can be achieved using just a browser that in the end it could be the only application running on a personal computer.

Web technologies offer opportunities to implement many of the principles that have been put forward by the Human Factors community. When one compares the general public's use of computers, before and after the Internet, it can be argued that the Web has already made computing more human-centered. Prior to the web, computers were typically thought to be the domain of scientists and engineers. Today, computers are an important source of information and entertainment for many people. The opportunities of web technology go beyond improving the computer interface. When compared to the typical client/server applications, the adoption of a web solution increases the speed of software development because of its use of open source technologies, which results in sharing and re-use of software components (often done over the Web). Additionally, web systems are easier to deploy, easier to update, and easier to learn--people already know how to use their browser. There are a variety of promising web technologies, three of which we will focus on here: web portals, web applications, and web services. Specific applications will follow this discussion.

Web portals were once thought to be sites that simply organized information in a consistent way and provided users with links to the information. Many environmental information websites have adopted this paradigm. These sites provide a centralized location for searching information and a cascading array of linked pages that display pre-rendered images. These information as presented does not lend itself to search or investigation. New technologies such as the Java Portlet Specification standards (JSR 168, JSR286) [7] increase the dynamic nature of a web portal. Portlets are small interface components that can have access to different back-end data systems yet to be aggregated into a unified portal. Liferay is an open source framework for creating dynamic portals and is being used by a variety of organizations, e.g., www.ncsa.uiuc.edu.

Some tasks may have a more specific need for interactivity with information than can be achieved in a portal. Google's many examples of browser-oriented web applications (Mail, Calendar, Maps, Reader) have proven that web browser functionality is rich enough for all but the most complex tasks [8]. Javascript is the key component in allowing highly interactive web pages, while the emergence of Ajax-style dynamic web page manipulation allows richer user-data interaction and investigation. One shortfall of Javascript is its poor drawing capabilities within the web browser. A solution to this is the use of Flash. The Flash plug-in allows significant enhancement in vector graphic rendering.

The technology of web services is rapidly evolving and making an impact on many software development projects. The World Wide Web Consortium (W3C) states:

> Web services provide a standard means of interoperating between different software applications, running on a variety of platforms and/or frameworks. Web services are characterized by their great interoperability and extensibility, as well as their machine-processable descriptions thanks to the use of XML. They can be combined in a loosely coupled way in order to achieve complex operations. Programs providing simple services can interact with each other in order to deliver sophisticated added-value services [9].

Access to data is provided without human-as-reader oriented formatting (e.g., html tags for browser presentation). True web services include a formal specification of the services provided. Clients use this 'self-description' to formulate service requests. Registries following the Universal Description Discovery and Integration (UDDI) model provide a way for data producers to advertise and for data consumers to discover services.

Web services have yet to gain widespread acceptance. Effort is required by data providers to append web service functionality to legacy systems. Real Simple Syndication (RSS) [10] is, however, one example of a web service technology that has been successful. RSS deals with the distribution of frequently updated content, typically news headlines. The key to the success of RSS is its accepted formatting standard (RSS 2.0) used by both publishers and consumers (so-called RSS readers) to communicate information.

In the following section we describe three examples of web-based systems that were developed at the University of Washington (UW) for different user communities. Each application provides users with environmental information, but each design is different due to the results of user studies and user evaluations.

III. EXAMPLES OF UW WEB SYSTEMS

A. Probcast

A team of scientists at the UW studied the development and visualization of probabilistic weather information [11]. One aspect of the work was to test the mechanism that best conveys probabilistic information. The initial intent was to provide newspaper-like weather graphics on a web page. The innovation was to add probability information in ways that would be useful to the general user. Psychological literature has shown that people often have difficulty comprehending probabilistic information. For example, most people do not need to know the confidence interval of a temperature forecast, but they may need to know the highest temperature possible for a particular day. Project investigators conducted controlled experiments on different ways to describe and visualize probabilistic information. The wording used to convey the information is important and was tested prior to deployment of the website. All of the results of the experiments were incorporated into a web-based system called Probcast.

The probabilistic information in Probcast is derived from the UW Mesoscale Ensemble (UWME). The UWME uses the fifth generation mesoscale community model (MM5) to generate multiple forecast members, each using different starting conditions [12]. These forecast members are combined with observational data and relayed to a post-processing system that uses a Bayesian Model Averaging technique [13], which outputs calibrated and bias corrected probabilistic forecast parameters [14]. These data are made available to the public via the website www.probcast.com.

Fig.1 shows a Probcast visualization for a period in August 2007. Probcast provides a display of five forecast periods, with a total range of approximately 60 hours. Probcast uses a mix of numeric, text, and graphic maps to convey information about the uncertainty in the weather predictions for temperature and precipitation. The text was chosen carefully to describe the most likely

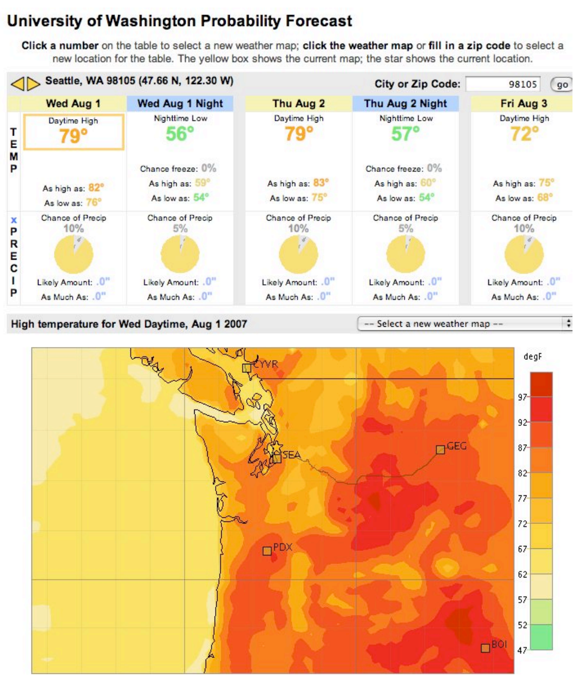

Figure 1. Probcast display of temperature information for Seattle, WA

scenario and possible extreme conditions. The numerical forecasts displayed are based on the Probability Distribution Function (PDF) produced during the post-processing. Because the intended user is assumed to be the general public, Probcast uses more understandable descriptions for probability information, for example, Probcast employs the text “as high as…” instead the more statistically correct yet less clear “the upper 90% bound is…”

Probcast can be thought of as a focused web portal. Most of the visualization work is done at the data facing side with only a small amount of interactivity on the user facing side. Users can select specific locations for the forecasts by entering a zip code or a city name. Users can also click on a specific numerical forecast number and see the related map graphic below the five-panel forecast window. The benefit of employing web-based technology is the ease of deployment. Since the general public is the intended user, UW needed a mechanism that provided the application to a large and anonymous audience. When Probcast went operational in Fall 2005, it had an average of 2,700 page views per month. In 2006, the monthly page views increased to 18,700 and in the first half of 2007 there have been an average of 21, 480 monthly page views.

B. Boater Information System

The Boater Information System (BIS) was a research effort to improve the communication of critical environmental information to Puget Sound boaters (sailors, power boaters, windsurfers, kayakers, and fishers). To arrive at full representation of the boaters in Puget Sound, we contacted local yacht clubs, marinas, marine supply stores and boat shows. We also conducted a survey over a four-month period (July-September, 2006) in which we contacted boaters in person or via the web and asked questions such as boating experience, boating frequency, and environmental information needs. [15]. We received 610 surveys.

Based on our analysis of these boaters and through an 18-member advisory board, we learned that boaters needed more than static visualizations. They need a tool that helps them visualize the impact of weather and water conditions, and how they will change over time [16]. Boaters also need the ability to interact with the information to help them make voyage decisions based in part on their boat and their crew's level of experience.

A web browser alone cannot achieve this level of map interactivity. The BIS web-based effort (http//bis.apl.washington.edu), employed Flash, which extends the browser's ability to display vector graphics. This provides a high level of interactivity for the client while the server collects and processes extensive environmental data. BIS interactivity includes: toggling data layers, moving backwards and forwards in time, setting warning thresholds for wind speed, and inputting voyage routes. Users create their own visualizations and data fusions such as defining medium (yellow) and high (red) wind thresholds (Figure 2) or viewing tides at specific points (Figure 3). Based on tides and winds boaters can see at a glance if they need to change their departure time.

User involvement in design decisions affected not only the way data is made available, it also drove changes in data visualization. For example, when boaters were shown the weather community's commonly accepted icon for wind, (the wind barb) many boaters did not realize that the tip of the barb pointed in the direction the wind was heading. BIS designers chose to move away from the use of a wind barb and used an arrow instead.

BIS was released as a beta version in May 2007. During the first month of operations, BIS averaged 38 individual visits per day and 1,182 visits per month. In three months this has increased to an average of 88 visits per day and 2,727 visits per month. It is interesting to note that the highest daily usage in May, June, and July, was 101, 202, and 170, respectively, and each of those peaks occurred on a Thursday. One explanation for this, which appears to be supported by user comments, is that BIS is most often used to plan weekend trips that typically begin on a Friday, thus indicating that BIS is being used as a decision-planning tool.

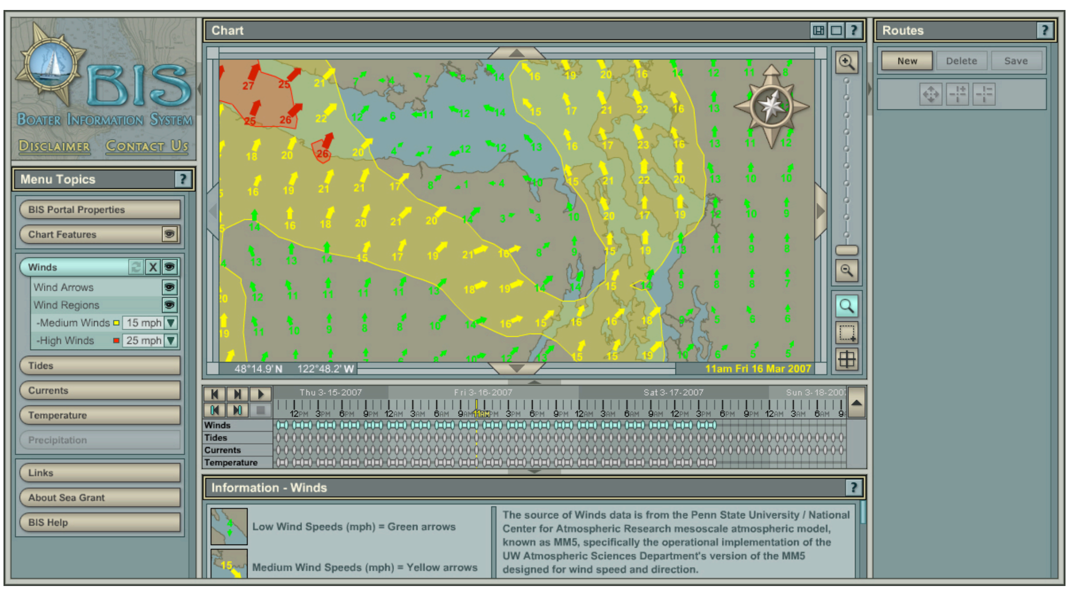

Figure 2. Medium and High Wind Thresholds

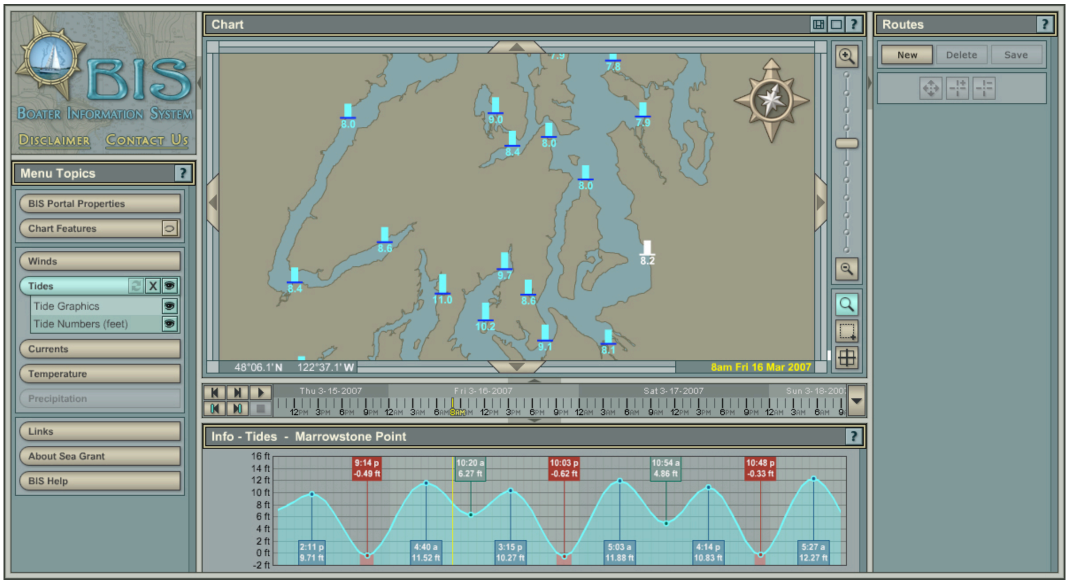

Figure 3. Tidal Information

C. Glider Monitoring, Piloting and Communication (GLMPC) System

The Glider Monitoring, Piloting and Communication system or GLMPC involves a far more complicated decision task than either BIS or Probcast. The University of Washington has developed buoyancy-driven ocean sensors that move autonomously through the water http://www.apl.washington.edu/projects/seaglider . These Seagliders spend most of their operational life under water collecting ocean observations. At the end of each dive, they return to the surface, use a satellite link to transmit the observations and vehicle data (such as battery level), and check to see if their operating instructions have changed.

Webb Research Corporation manufactures a similar, buoyancy-driven instrument, Slocum, http://www.webbresearch.com/slocum.htm while Scripps Institute of Oceanography has developed the Spray glider http://spray.ucsd.edu/ . Each has its own mission specific strength. Though all use Iridium for glider-to-shore communications, the message/file formats are all proprietary, as are the actual pilot-glider interactions. Seaglider uses a store-and-forward approach where commands are left in specific text files on Unix systems. Slocum uses a real-time chat model, with scripting support to enable unattended pilot control, while Spray also uses store-and-forward via email.

The Glider Consortium, sponsored by the Office of Naval Research (ONR), has been charged with the creation of software systems for the purpose of a unified command and control interface for multiple glider operations, including those employing gliders from the different manufacturers mentioned above. UW is the technical lead in this effort, and the GLMPC system is the realization of the piloting interface for these multi-vendor glider systems. Given the number of gliders envisioned for operational use (up to as many as 50) and given that the three types of gliders operate differently, ONR recognized the need for a universal interface. In fact, Human Factors research cautions against mental overload in people performing complicated tasks. GLMPC was designed to simplify the pilots' already demanding task.

The GLMPC application (http://glmpc.apl.washington.edu/) presents the pilot with a (2D) GIS canvas, upon which historical glider movements are shown and future glider routes can be composed and assigned to individual gliders. The canvas covers an operational area of arbitrary size. Pan, zoom, and layer visibility features are standard GIS. Glider data can be supplemented by basemap layers such as coastline, bathymetry, model output data, ship locations, etc.

During operational use both the pilot and the glider can initiate data transfer. For pilots, selection of a new route, for example, will result in the submission of this request into the GLMPC system. Once the data has been processed accordingly, some form of response is expected. Similarly, new data from a glider must be relayed to the pilot. Thus, the system was organized to accommodate this peer-to-peer communication. Figures 4 and 5 show the interface with a few of the GLMPC capabilities.

GLMPC is an integrated solution in that pilots view glider data (graphical, tabular views) and command glider operations from within a single application. For Seaglider at least, this functionality did not exist a priori. Furthermore, the piloting interface is an interactive web page rather than a specialized client application. Local data structures, e.g., planned glider routes, are edited within the browser and 'written' over the network back to the web server for conversion into specific glider file formats.

The decision to deploy the piloting interface as a web-browser hosted application ensures high availability and usability. It avoids the problem of client-side plug-in requirements, which plague technologies such as Java Web Start. By maximizing the utility of the web's underlying protocols (http, ssl), we leveraged existing solutions in security (authentication, integrity, confidentiality), bandwidth optimization (reuse of downloaded data deemed unchanged), versioning (the application is identified by its URL).

We chose not to use the possible existing solution of Google Earth for several reasons. Although it is a rich interactive GIS application and supports the creation and visualization of geospatial paths and could show glider tracks plus act as an editor for route creation, Google Earth does not have charting capabilities. Thus it could not be the basis for an integrated glider command

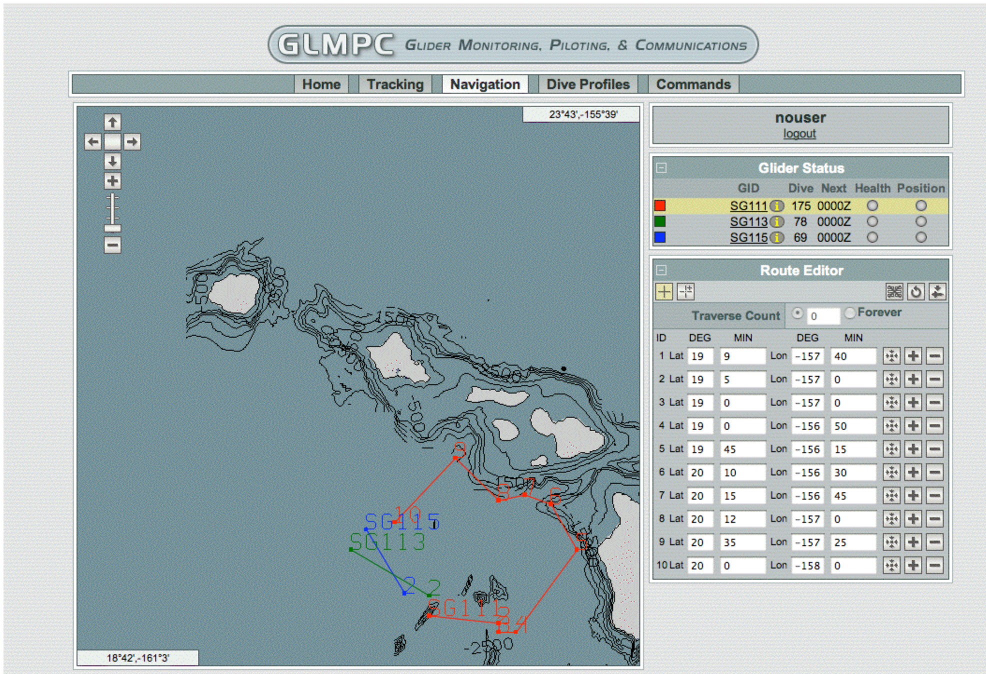

Figure 4. GLMPC Glider Tracking and Route Editor

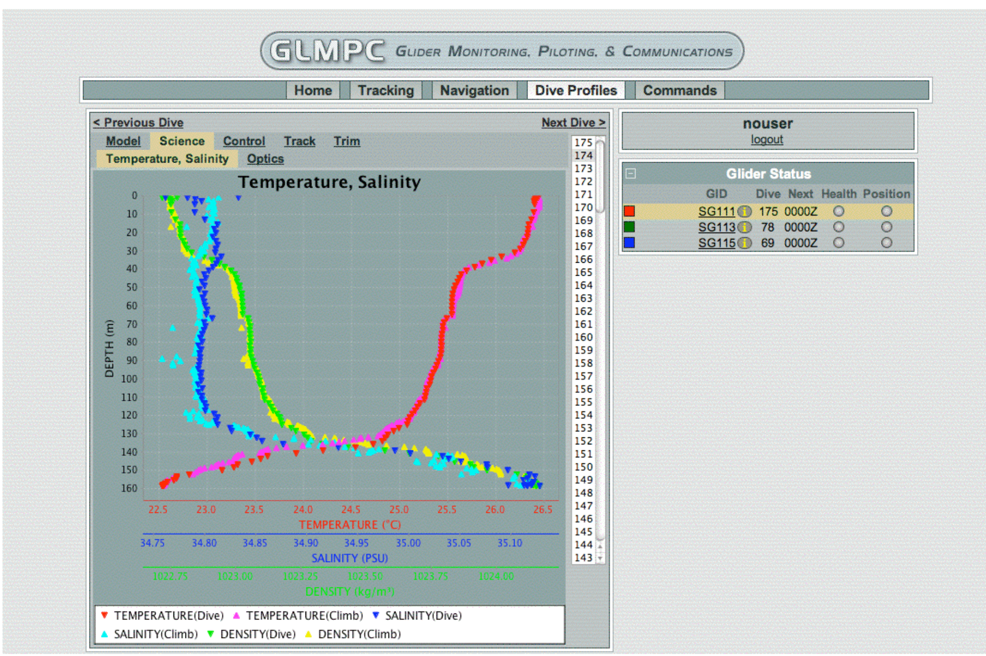

Figure 5. GLMPC Glider Dive Profile Visualization

and control solution. Further, it requires online access to fixed address servers for underlying GIS data. Security restrictions and operational requirements dictated the need for an application to be delivered and installed at the target site. In other words, GLMPC serves up its own maps without dependency on external, public sites.

IV. CONCLUSION

The examples given here present varying levels of user interactivity made possible by the adoption of web technologies. Probcast performs significant computing processing at the server side, but presents a unified and constrained data visualization in the web portal. In BIS, boaters use their browser to view information, but are given greater control over the display of the data to help them make decisions. GLMPC is a web application for a more complex, multi-tier interaction. Glider pilots need to visualize data from a remote vehicle, use the data to make decisions, and then communicate changes to the vehicle's commands. Each system meets its users' needs in different ways, but each is web-based and requires only a web browser at the client interface. Web-based technologies will continue to be important for the transmittal of user-defined data. RCOOS will require an even greater number of decisions by a far greater variety of users than those presented here. This demand places more emphasis on the need to tailor interface visualizations and allow greater navigation through different information layers. The demand also means increased interactivity. More users will require the ability to do different things with the same data. Canned visualizations or static charts of data are of little real use. Future RCOOS sensors could require remote monitoring and control via a distributed information network. Web applications and services will continue to be reinvented to meet RCOOS demands for ocean information that can be used to solve real-world problems.

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