A Collaborative Portal for Ocean Observatories

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Abstract— **A Collaborative Ocean Observatory Portal (COOP) has been developed to enable distributed investigators to collaboratively operate ocean observatory systems. COOP is being created within the Autonomous Ocean Sampling Network program to support the Adaptive Sampling and Prediction (ASAP) field experiment that occurred in Monterey Bay in the summer of 2006. ASAP involved the day-to-day participation of a large group of researchers with ties to geographically diverse institutions throughout North America. These investigators had to interact on a continual basis to optimize data collection and analysis. While some investigators needed to be physically present to launch and retrieve their assets, the long duration of the observatory made sustained co-location of researchers difficult. Likewise, future ocean observatories and observing systems (such as moored arrays and cabled observatories) will operate 24 hours a day, 7 days a week over many years or even decades. Since sustained co-location of researchers for situational awareness and decision-making will be impractical, there is a need for collaborative data distribution and situational awareness tools appropriate for the ASAP experiment, and eventually, for all ocean observatories.**

As implemented for the ASAP team, the COOP tool set consists of several components, starting with a publicly viewable, web-based tool for reviewing the day's progress and proposed actions. Registered scientists are able to discuss the day's progress (and attach illustrative data), propose actions (and back-up those proposed actions with supporting data), and discuss and vote upon proposed actions. The tool provides links to other system components, such as a database of data collections in both original and common formats, interactive data access and manipulation tools, and pages of automatically generated graphical summaries of observational results and model forecasts.

I. INTRODUCTION

Distributed operations which enable real-time situational awareness are a reality in industry (refinery operations for large conglomerates, airline operations, utility companies), defense, and civilian government agencies (National Oceanic and Atmospheric Administration [NOAA], Federal Emergency Management Agency [FEMA] and National Aeronautics and Space Administration [NASA]). Even academic and quasi-academic institutions (e.g. NASA's Virtual Astrobiology Institute [1], NASA's SkyView Virtual Observatory [2], and the National Science Foundation's (NSF's) National Virtual Observatory [3]) have made substantial investments in allowing geographically distant researchers to collaborate on mission operations.

However, the needs of an ocean observatory differ from those of other collaborative ventures [4]. The primary differences are the heterogeneity and time-varying nature of the data sources involved in an ocean observatory, and the wide breadth of the decision space. For example, while most of the existing, non-oceanographic collaborative efforts manage a variety of semi-independent components, the set of components is well defined and varies slowly (if at all) over the life of the program, and decisions that affect these components are well defined. Conversely, ocean observing systems will consist of a wide range of mobile platforms including drifters, autonomous underwater vehicles and ships, fixed measurement assets such as moorings and radar, and remote measurements from satellites and aircraft, all of which may be reconfigured at will to respond to observational opportunities and changing objectives. Further, there can be variability in the number and presence of observational assets at disparate locations in the observation area.

II COLLABORATIVE SCIENCE PORTALS

An important step in designing COOP was to examine how co-located researchers make collaborative, operational decisions. In fields other than Oceanography, tools and processes now exist and with substantial maturity, which allow individuals to be situationally aware of the environment in which such scientific work is taking place. For example, in NASA's Mars Exploration Rovers (MER) mission, for the planned 90 Martian-day duration of surface exploration mission 250 scientists from the US and Europe were co-located in at the Jet Propulsion Laboratory (JPL). Co-location of scientists and operational personnel was deemed necessary so that the daily commanding of the two robotic assets would allow scientists on earth to understand how the vehicles behaved in a hostile environment, and how operators on earth would capture the scientific intent and engineering constraints. In addition, co-location was deemed tolerable over the short (approximately 92 Earth-day) design life of each rover.

However, the rovers exceeded their design lives, and the mission continued for years, not months as expected. In the second year of the mission, some MER personnel were allowed to return to their home institutions while collaborating via the Internet. Now in its third year of operation, the team has the ability to command the vehicles with less than 50 operations personnel at JPL and most of the science team distributed (Arizona, Ithaca, Pasadena, Washington DC, Germany and Denmark). To enable such an operation to be a success, a number of MER-specific support tools were designed and built in place by the agency [5]. With the goal of multi-year missions from the outset, collaborative Ocean Observing efforts can model their efforts on the latter part of the MER mission.

III COLLABORATIVE OCEANOGRAPHY

In August 2003, the Autonomous Ocean Sampling Network (AOSN) field program leveraged a highly heterogeneous set of observational components to realize its mission of using oceanographic models to assimilate data from a variety of platforms and sensors into synoptic views of oceanographic fields and fluxes in an area of approximately 10,000 km^2. In operation, the system relayed information from platforms and sensors to shore in near real-time (hours) where it could be assimilated into numerical models. The model output could then be used to visualize ocean properties in four dimensions, predict future conditions, and achieve another AOSN goal: adaptive deployment of mobile assets to improve performance and optimize detection and measurement of fields and features of particular interest.

The 2003 experiment highlighted the intensively collaborative nature of AOSN operations, which involve a large number of individual elements operated as an integrated system. The experiment used two classes of gliders, three types of propeller-driven autonomous underwater vehicles, ships, aircraft, moorings, drifters, surface-current mapping radar, and satellites. Three models, one atmospheric model and two ocean models, provided nowcasts and forecasts. The combination of data and models provided a very large and diverse volume of data. Management of the data streams included quality control of the data, visualization of results from individual observation elements, synthesis of observations and models, validation of models, and creation of derived products. Individual elements of this process were highly demanding of specialized talent. In practice, problems with individual data streams and models were not apparent until the synthesis and intercomparison stages, and insights frequently came from the interaction of team members bringing different expertise to the problems.

To achieve its goals, the 2003 AOSN experiment required that participants share data and collaborate on a regular basis. Given the transient nature of oceanographic processes and need to adapt observation plans to evolving conditions, the interactions were forced to operate at a high tempo. Every 24 to 72 hours, depending on the state of the experiment and conditions in the field, investigators held "Real-Time Operations Committee" (RTOC) meetings. The agenda was fixed and progressed from providing routine situational data, to reports on observation, to model results, to discussions of observational alternatives. These meeting provided the team updates on logistical issues such as ship and asset availability and evolving atmospheric conditions, as well as reviews of accumulated observational data, synoptic ocean forecasts, evaluation of performance and reports on specialized studies. The RTOC meetings were held in a common meeting room whereby researchers orally and visually presented their reports, usually in the form of PowerPoint briefings. It was during these meetings that results were discussed, model needs were recognized, and adaptive sampling plans were made. Observational assets were then redeployed based on decisions made during the RTOC meeting. These meetings were a focal point of the experiment, and grew in size as the field program progressed.

The challenge for the 2006 experiment was to replicate and improve on the function of the RTOC meetings with a distributed team. Efficient and effective decision-making depends on maintaining a common situational awareness of the distributed team. At the same time, leveraging the considerable diversity of expertise represented on the distributed team demands an environment flexible enough to allow specialized products produced by individual team members to be efficiently shared. The give and take of the RTOC discussions must be supported, as must more formal proposals of action and voting methods intended to build consensus. All of this rests on a foundation of a strong and flexible data system. Access to data for all is essential for synthesis and development of new analysis products.

The system that was designed to meet the goal of providing a collaborative, on-line RTOC environment is herein called the Collaborative Ocean Observatory Portal (COOP). The starting point for COOP was a collaborative publication web site created for coordinating publications from the 2003 experiment. This site allowed members to post proposals for papers, provided a forum for discussion of individual papers, and allowed the upload of relevant documents including various drafts of the paper. Some of the building blocks for COOP thus existed in prototype form. Combining this with a prototype data system, a series of experiments called virtual pilot experiments, or VPEs, were run. Initially these were intended to test the data systems and collaborative environment, but as COOP became more functional, they became forums for collaboration and planning of the experiment for the ASAP team. Through the five VPEs that were run, COOP evolved substantially, eventually abandoning the original collaborative publication site software base for the more modular and flexible architecture described in this paper.

IV DESIGN AND EVOLUTION OF COOP

To be successful, the COOP design would have to allow users to have an experience like attending an RTOC meeting, but from their computers wherever they happen to be located.

In designing COOP, researchers defined desirable functionality and experimented with prototype versions of COOP. A survey of ASAP Principal Investigators identified a hierarchy of needs, revolving around four central requirements: access to observational data and model outputs, data-sharing tools, on-line meeting spaces, and tools to facilitate decision making processes.

In the winter and spring of 2006, the ASAP participants used COOP (and its first prototype, the ASAP Virtual Control Room [6]) to run several VPEs. The VPEs used an analysis run of the Harvard Ocean Prediction System of the AOSN 2003 data sets as a virtual ocean. The virtual ocean is "sampled" by virtual assets. In the case of autonomous underwater gliders, the Princeton Glider Coordinated Control System controls the virtual gliders and simulates their movement in the virtual ocean flow field [7]. The results are packaged in data files as though from the actual observational assets, and placed in appropriate repositories at the various institutions. The "observations" are then collected from these repositories by the MBARI data system, converted to a common format, and made available. Various partner institutions (for example, the real-time modeling groups) then access these observations and generate outputs that are also placed in the MBARI data repository. In its current incarnation, COOP provides a portal to standard data and modeling products (visualizations) from the central data set, to web pages containing specialized products produced by partner institutions, to proposal and discussion pages, and to a voting page used to support collective decision making.

These virtual experiments were intended to test a) shore-side data systems required for the field program, b) data and model visualization for informing decision making, c) collaborative tools for supporting interaction of the distributed team, and d) processes to structure the interaction so that decisions are made in a timely manner. The virtual experiments have proven much more powerful than their original intent, largely because of the effectiveness of COOP at facilitating communication between participants and understanding of the VPE workflow. In effect, COOP had become a powerful medium for interdisciplinary collaboration of the extended team even before the field program had begun.

The VPEs have been instrumental in identifying both unanticipated problems and opportunities. The ASAP team members originally scheduled three VPEs, but have already conducted five, and they have found the VPEs to be a valuable enough tool that they will continue to use COOP to conduct VPEs after the field experiment.

V COOP ARCHITECTURE

The first prototype of COOP used six hypertext markup language (HTML) frames to convey the collection of collaborative information. Of these six frames, two were controlled by the site administrator, so only four were truly collaborative, and users complained that the frames were

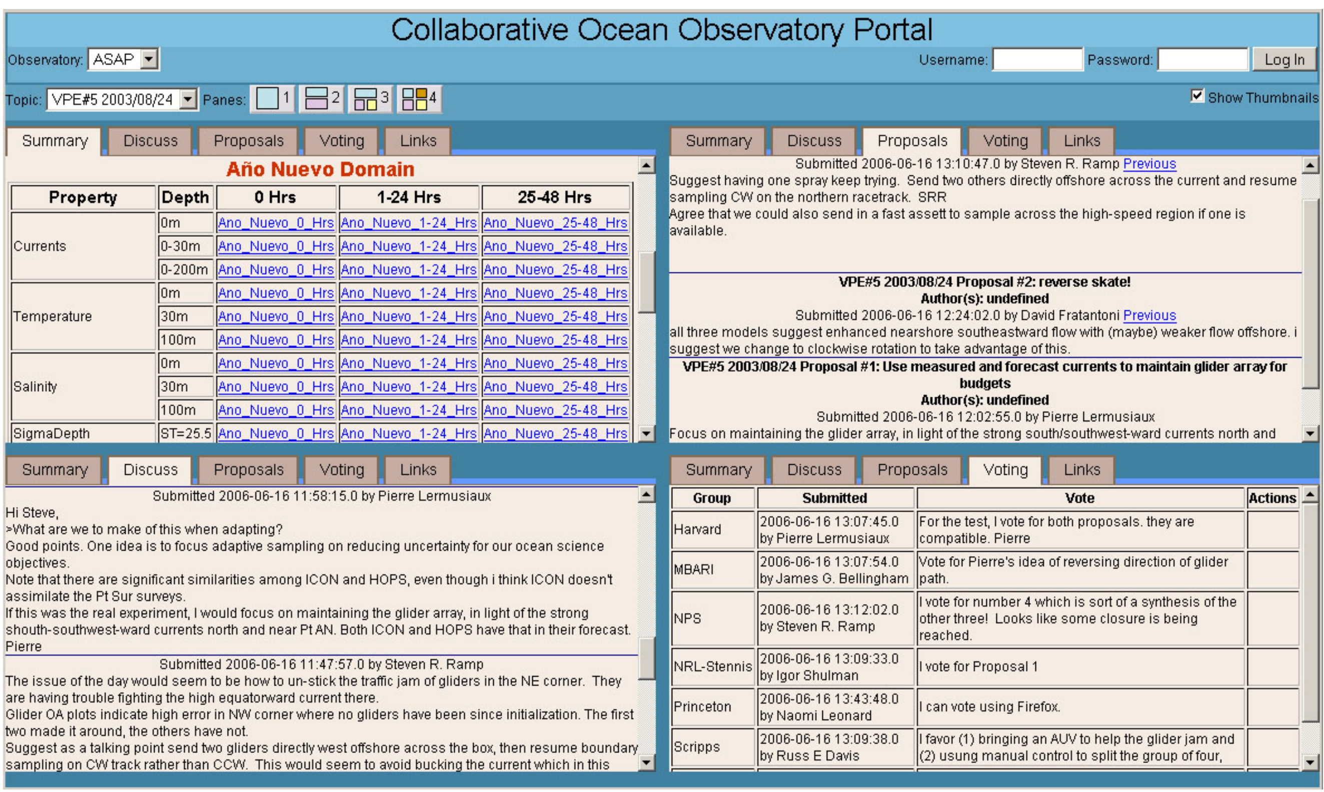

Figure 1 Collaborative Ocean Observatory Portal (COOP), from the Adaptive Sampling and Prediction (ASAP) Virtual Pilot Experiment #5, June 16, 2006. The "Four pane" configuration is selected, and the selected panes are (clockwise from top left) "Summary", "Proposals", "Voting", and "Discuss".

too small while simultaneously requesting additional frames for other forms of collaborative content.

The current version of COOP [8] uses an architecture that allows users to dynamically select what content appears in panes within the portal (see Figure 1). The number of panes that appear in the portal (one to four) can be selected by the user. The sub-portal content that appears within each individual pane is referred to as a "portlet", and is selected by clicking on one of a row of tabs above each pane with the name of the desired portlet. The COOP web page uses embedded JavaScript code to asynchronously request information from a COOP web server and refresh its panes with portlet content. The COOP web server uses an open API (similar to web services) that could allow other types of web applications and stand-alone applications to access and manipulate COOP collaborative content without going through the COOP graphical user interface.

There are currently seven portlets defined in the COOP application. Six of these ("Summary", "Links", "Discuss", "Live Docs", "Proposals", and "Vote") are normally publicly viewable, while the "Contacts" portlet contains confidential contact information that is viewable only by observatory participants. The content of all seven portlets are specific to a selected observatory, and are editable by participants of the selected observatory Hence several independent observatories may use COOP simultaneously and maintain independent collaborations, while keeping informed by the collaborations occurring in other observatories.

The "Summary", "Discuss", "Proposals" and "Voting" portlets are linked to the selected "Topic" under the observatory heading. So for example, a new topic could be created each day to manage a dynamic, rapidly evolving observatory, or alternatively, topics could correspond to areas of interest in a more established observatory. In either case, when a new topic is selected, the displayed summary, discussion, proposals and voting results correspond to that topic. The "Links", "Live Docs", and "Contacts" portlets do not change as different topics are selected, but do change if a different observatory is selected.

The "Summary" portlet is essentially a blank slate for each new topic until content is added by an observatory participant. It is also possible to provide a list of universal resource locator (URL) links to external documents that will be merged into the summary displayed to users.

The "Links" portlet is also a blank page until an observatory participant adds the HTML links to other documents. Actually any kind of HTML content is allowed, but links to external documents are encouraged.

Likewise, the "Live Docs" portlet is initially a blank page until an observatory user adds an HTML image link, (nominally to an image on a remote machine) that is updated in real time to provide situational awareness.

The "Discuss" portlet is used for general discussion as well as discussion focused on the proposals that observatory members have made. Text and attachments can be posted. There are three buttons at the top of the "Discuss" portlet. Users may click the "All" button to see all discussion entries for the selected topic in chronological order. Clicking the "Main" button displays all discussion except for that dedicated to the proposals. Clicking the "Proposal" button and selecting a proposal shows only discussion on a particular proposal.

The "Proposals" portlet is where proposals are made and posted. Proposals are numbered in order received and can be given a title. Text and attachments can be posted.

The "Voting" portlet is used to vote on the proposals for the selected topic. For each observatory, voting teams are defined, and each team may have one or more participants. Each participating team in the observatory has a vote and the vote is submitted as text. Each participating team can revise their vote as more information comes in and is made available.

As content in any portlet is revised over time, earlier content can be viewed using the "Previous" link that appears with the revised content.

VI COOP IN THE ASAP EXPERIMENT

In the ASAP 2006 field experiment, the COOP tool was used to facilitate a decision making process every other day. Team members were able to participate from any internet-accessible location, and any team member could add to the day's "Summary" portlet, point out trends and discuss observations in the "Discuss" portlet, and make an adaptation proposal using the "Proposals" portlet. If a team member submitted a proposal, team-wide discussion and voting followed using the "Discuss" and "Voting" portlets. All interactions were archived so that future experiments can be made more systematic with increased automation.

Each day, a new "Topic" was created, and with it, a new "Summary" portlet was also created and was updated with announcements on schedule, system status, voting results from previous day, ocean, atmosphere, hardware, adaptive sampling and coordinated control and forecast. For daily (and in some cases more frequent) summaries of atmosphere, hardware, adaptive sampling and coordinated control, model uncertainty, users were encouraged to follow the "dynamic links" in the "Summary" and in the "Links" portlet. Plots of observed and predicted currents, temperature, and salinity were updated daily on the "Summary" portlet. These plots were organized in a convenient grid with a link for every plot.

The ASAP "Links" portlet lists both static links and dynamic links. The static links include the ASAP home page, the Monterey Bay 2006 (MB2006) page which links to documents that provide overview and logistics on several field experiments running during the summer of 2006 in Monterey Bay, links to other Monterey Bay data, links to participating institutions, and links to archived data from all virtual pilot studies. The dynamic links are to participating scientists' sites that were continually updated and contained additional information that was not included in the COOP.

The "Proposals" portlet is where adaptation proposals are made and posted. Proposing and voting schedules are listed on the "Summary" portlet. The "Voting" portlet is used for

ASAP participants to vote among the adaptation proposals of the day. For the ASAP observatory, each participating institution has a vote and the vote is submitted as text.

VII CONCLUSION

Lowering the barriers to participation will be important to the success of future ocean observatories. As demonstrated in the ASAP experiment, COOP allows scientists to coherently and collaboratively manage an ocean observatory, without being co-located at the observatory. Using COOP, a team of observatory scientists is able to manage complex data sets and complex collaborations in an intuitive and useful way. The underlying structure of COOP may have a wide range of utility in realms outside of ocean observatories.

ACKNOWLEGEMENTS

The authors would like to thank Dr. Russ Davis at Scripps Institute of Oceanography and Dr. Pierre Lermusiaux at Harvard University for helpful discussions. This work was supported by the Office of Naval Research (ONR) Grant No. N00014-02-1-0856, by the David and Lucile Packard Foundation, and through the National Science Foundation (NSF) Laboratory for the Ocean Observatory Knowledge Integration Grid (LOOKING).

REFERENCES

[1] National Aeronautics and Space Administration Virtual Astrobiology Institute [Online]. Available: http://nai.arc.nasa.gov/

[2] National Aeronautics and Space Administration SkyView Virtual Observatory [Online]. Available: http://skyview.gsfc.nasa.gov/

[3] National Science Foundation National Virtual Observatory [Online]. Available: http://www.us-vo.org/

[4] J. Graybeal, J Bellingham, and F Chavez, "Data Systems for Ocean Observation Programs," *Sea Technology*, September, p. 23-25, 2005.

[5] J. Wick, J. Callas, J. Norris, M. Powell, M. Vona, "Distributed operations for the Mars Exploration Rover Mission with the science activity planner," Aerospace, 2005 IEEE Conference, 5-12 March. p. 4162-4173, 2005.

[6] ASAP Virtual Control Room [Online]. Available: http://aosn.mbari.org/asap/

[7] D. Paley, F. Zhang and N. Leonard, "Cooperative Control for Ocean Sampling: The Glider Coordinated Control System," preprint [Online]. Available: http://www.princeton.edu/~naomi/publications/2006/TCST06.html

[8] Collaborative Ocean Observatory Portal [Online]. Available: http://aosn.mbari.org/coop/