National Marine Sanctuary

West Coast Observations

Sanctuary Network Study

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Executive Summary

The five West Coast National Marine Sanctuaries (Channel Islands, Monterey Bay, Gulf of the Farallones, Cordell Bank, and Olympic Coast) have each been collecting environmental observations for several years. The sanctuaries span the range of the West Coast, from southern California through northern Washington State. Their observations have historically been used to help with the multiple missions of the sanctuary system: to understand the unique environment of each sanctuary (research), to protect and manage the resources, and to educate the public about each sanctuary and environmental concerns in general. Many of the observations are available over the World-Wide-Web (WWW).

This report focuses on the single question: "How (or can) the five sanctuaries be turned into a unified network?" In other words, in this era of large-scale planetary changes, can (or should) the sanctuaries coordinate their research efforts and observations to address larger-scale issues? Can the large geographic range of the sanctuaries be used to some advantage in studying large-scale environmental processes? The authors of this report believe that such a network is both possible and desirable, with fairly minimal reorganization of the current observational system.

The following constraints have influenced the development of the proposed plan:

(1) Given the limited funding for observations, there is a potential conflict between obtaining observations for studying large-scale processes, and obtaining "local" observations for sanctuary management purposes. The best use of funds occurs with overlap of the two, i.e., when unified observations across the west coast can also be used to help with local management issues.

(2) Detection of long-term trends from time series can take years (or decades). The ideal situation is to make measurements that can have more immediate applicability, because: (a) the measurements are used to detect "events", or (b) the observations can be used to understand the underlying physical processes.

(3) The core network observations for the "network" should be in the form of physical (as opposed to biological) time series. This option is less costly and labor intensive, and provides a consistent reference frame or backbone for other NOAA or outside researchers to link into.

(4) When possible, it is desirable to make use of other large-scale

observing efforts (such as the NDBC buoys or satellites). The incorporation of these measurements can provide a context for changes at the sanctuaries that are not possible from single-point measurements alone.

(5) It is assumed that the immediate users of the networked observations are sanctuary personnel, ecosystem managers, and research scientists. As such, it may be adequate to synthesize the observations on an annual basis. If needs dictate, however, it is possible that a real-time data display and analysis network may be necessary or preferable, particularly in responding to events or for public education.

The proposed network represents a two-pronged approach: (1) constructing a "virtual observatory", using remote measurements of sea-surface temperature and winds (from satellites and NDBC buoys), ocean surface currents (from satellites and HF Radar), and potentially currents at depth (from buoys), and (2) a set of oceanographic moorings to detect hypoxia and ocean acidification ("water quality"). The "virtual observatory" will allow local measurements collected by each sanctuary to be placed in a larger-scale context, while the array of water quality measurements would be useful for analyzing both in-sanctuary and larger-scale west coast processes. Each of the options can be implemented independently, although the information gleaned from the combination of the two will be more useful than from either alone.

In terms of the immediate needs of the sanctuaries, data reports need to be generated annually (at least). These include xxxx. Reason is xxxx. This is an additional requirement to the two above, that applies whether or not the decision if taken to implement a network.

This plan should be considered as a "living document". The authors invite comment and discussion.

Authors:

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John Largier is a Professor at Bodega Marine Laboratory. He has been a researcher for many years, most recently investigating the dynamics of upwelling systems and estuaries throughout the world. He is particularly interested in the role that protected marine areas have for conservation and public education.

Dave Lott is the West Coast Regional Operations Coordinator for the National Marine Sanctuaries. He is interested in creating a true network out of the marine sanctuaries to help them further their core missions and to also provide a “backbone” for researchers interested in large-scale and local changes.

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Introduction:

The review represents an attempt to provide perspective on the West Coast Observations of the National Marine Sanctuaries, from the point-of-view of scientists and data users. Although the main focus is on using the observations and sanctuaries in a unified fashion as a "network", the review encompassed other aspects of the observing program. For example, the current methods used to display observations were of necessity investigated during this effort.

Physical observations are currently made across the sanctuary system, although the same observations are not made in each sanctuary. For example, many moorings in CINMS are equipped with ADCPs. Most of the OCNMS moorings are equipped with O2 sensors. In addition, each sanctuary has access to or performs some level of biological monitoring. The OCNMS moorings are owned and operated by the sanctuary. The remaining sanctuaries partner with outside agencies for mooring and instrumentation maintenance.

A typical observational program is based on a well-defined goal. That is, an experimental layout is often designed to address a single well-defined scientific question. The sanctuary program is designed a bit differently. The mission of the sanctuaries includes monitoring and protection of biological resources. As such, programs are required at each sanctuary simply for resource monitoring. Ideally, the programs should also provide insight into the environment of each sanctuary, so that the inevitable biological or physical fluctuations can be put into a larger-scale context.

The footprint of each sanctuary is relatively small compared to the larger scales of (seasonal, climate, etc.) variability in the coastal ocean and along the land-sea interface. Each sanctuary is influenced by these large-scale processes Together, however, the five West Coast sanctuaries form an array that stretches along the U.S. West Coast, representing "ecoregions" ranging from the Southern California Bight to the Washington Shelf [e.g., Spalding, et. al., 2007]. One challenge in this review is how to design an observational program that meets the monitoring needs of the individual sanctuaries while at the same time taking advantage of the combined footprint of the sanctuaries for large-scale monitoring and scientific investigation.

The plan outlined in this document consists of the development of a "virtual observatory", some ocean acidification / hypoxia moorings, and annual reports (see Section 3). It builds on some strengths of the current observational system, although some allocation of resources will have to be made if the full plan is implemented. In particular, modification of the data storage and delivery mechanisms has the potential to greatly enhance the ease of use and value of the proposed network.

The virtual observatory represents an attempt to provide easy accessibility to both local and remote measurements, and to place the local measurements in a larger-scale context. For example, the ability to display and analyze sea-surface currents and sea-surface temperature over the entire West Coast can be coupled with more local "point" measurements to understand variability within and across sanctuaries.

The addition of (at-least) annual data analysis / synthesis reports for each sanctuary and the system as a whole is critical for the sanctuaries to make effective use of the observations. Such reports would not only allow sanctuary staff to understand and communicate changes within their sanctuaries more effectively, but would also allow outside researchers to place their own observations into context without having to "reinvent the wheel" each time that they obtain measurements near a sanctuary. Well-designed reports have the potential to lead to an increased collaboration with outside researchers and a rejuvenated focus on "sanctuary science".

This review is timely given the emphasis placed on understanding and responding to large-scale processes such as climate change by many local, state, and federal agencies, including NOAA [e.g., Office of National Marine Sanctuaries, 2009b]. For example, Daniel Basta (Director, National Marine Sanctuaries) has indicated support for using the sanctuaries as a resource for engaging the public on issues such as climate change, as well as using sanctuaries as bases for long-term monitoring of changes. Jane Lubchenco (NOAA administrator) has indicated support for using sanctuaries as sites for directed research into oceanic processes, especially regarding large-scale issues such as climate change and ocean acidification.

This review benefited from the input of a great many people, most notably the research coordinators and staff at all of the sanctuary sites. Their comments regarding the current state of observational systems in the sanctuary are summarized in a separate section. In addition, the many reports and resources drawn upon to generate this network plan are provided in an accompanying CD.

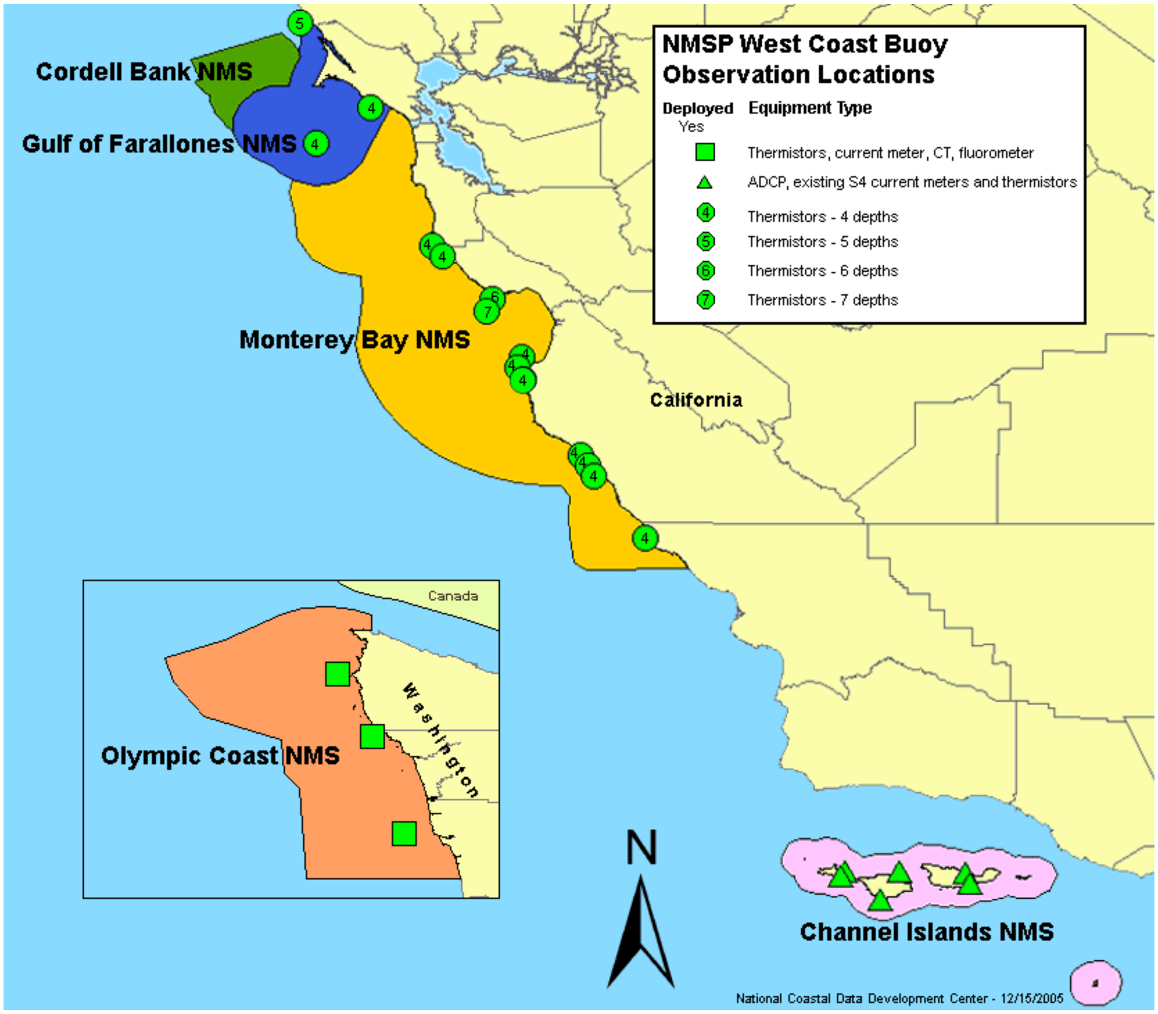
1. Background:

1.1 Background: Sanctuaries

A summary of the West Coast Observational program of the National Marine Sanctuaries is provided in Figure 1. Sanctuary-wide, the moorings typically include thermistors, with more specialized instrumentation on individual sanctuary moorings. For example, moorings in the OCNMS are typically equipped with O2 sensors, while CINMS moorings are often set up with ADCPs.

In addition to the “point” physical data (Figure 1, and listed in Appendix A), many sanctuaries perform transects data on a regular basis and also monitor biological activity and changes . For example, the Cordell Bank Ocean Monitoring Program (CBOMP) is a monthly assessment of seabirds, marine mammals, and other vertebrates. Other sanctuaries have access to other assessments, including intertidal measurements.

Many of the “historical” sanctuary observations have been combined with other observations and interpreted to analyze sanctuary conditions. For example, the latest OCNMS condition report provides an effective demonstration of data interpretation and synthesis [Office of National Marine Sanctuaries, 2008]. Much of the biological survey data is presented, along with some of the physical measurements (for example, a short snippet of DO measurements, Figure 17). However, much of the physical data is simply stored, instead of analyzed or presented. One nice addition to the report is the inclusion of measurements collected by outside agencies, such as domoic acid levels in shellfish (Figure 18), and ship traffic as a proxy for noise pollution (Figure 20).



***<u>Figure 1</u>**. NMSP West Coast Buoy Observation Locations [from West Coast Observing System (WCOS), Phase 1, 2006]. Note that this sensor map does not include more recent additions to the sensor network. For example, new moorings have been established at Cordell Bank and the Olympic Coast. In addition, some of the Olympic Coast moorings have been set up to measure dissolved oxygen. A complete list is provided in Appendix A.*

Outside agencies or partners often use the sanctuary measurements to quantify and understand oceanic processes. For example, some research papers incorporating the MBNMS and CINMS observations are [from DeVogelaere and MBNMS staff, 2009]:

- A related PISCO publication has been submitted: M. Carr, C.B. Woodson, O.M. Cheriton, D. Malone, M.A. McManus, and P. Raimondi. Effective assessment of Marine Protected Areas: Why oceanography matters. Frontiers in Ecology and the Environment.
- A paper was published using the data to investigate how diurnal wind patterns drive a localized, daily patter of upwelling along the northern coast of the Monterey Bay: C.B. Woodson et al. 2007. Local diurnal upwelling driven by sea breezes in northern Monterey Bay. Continental Shelf Research 27: 2289 – 2302.

However, at the moment much of the physical data is simply being archived, because appropriate resources have not been allocated for funding its quality control, analysis, or inclusion in regional studies. In addition, the requirement for instrument calibration (for example, of the OCNMS sensors) is often a low priority, given other sanctuary needs.

The observations are gathered and made accessible through various websites [list from DeVogelaere and MBNMS staff, 2009]:

Sanctuary Integrated Monitoring Network (SIMoN) (http://www.sanctuarysimon.org/regional_sections/obs/).
Geospatial One Stop (http://gos2.geodata.gov/wps/portal/gos),
NCDDC's Regional Ecosystem Data Management Portal (https://ecowatch.ncddc.noaa.gov/).
NODC's Ocean Archive System (OAS) (http://www.nodc.noaa.gov/search/prod/).

- Data visualization and analysis tools, including the WCOS interactive map (http://www.ncddc.noaa.gov/website/NMSP_WCO/viewer.htm) and the WCOS portal (http://portal.ncddc.noaa.gov/wco/) were developed by SIMoN and NCDDC.

A full description of SiMON and "anticipated" (to-be-developed) web services is provided in a West Coast Observing System document [National Coastal Data Development Center, et. al., 2006]. The report describes the need for meta-data management as well as data storage and customized displays.

The requirement to serve as the public repository for data and information of a large array of diverse sanctuaries can be rather challenging, but SiMON performs that function well [Figure 2a]. It does more than simply point the interested user or researcher to physical measurements. It also serves as a clearinghouse for all types of sanctuary information, including oceanography summaries, photos, discussions of habitat types, etc.

Physical observations are available from the WCOS map (Figure 2b), via SiMON. Providing a useful interface for such a large array of measurements can be a challenge. The built-in map represents a nice option for the user to specify a specific region. However, actually obtaining measurements is a bit tiresome. The user must specify a site, a range of dates, and a type of measurement! It would be much easier to obtain measurements, and have confidence that all measurements had been obtained, if a range of dates could be entered and a list of all available measurements were to be displayed. In addition, the ability to obtain a subset of measurements would also be a useful addition to the search mechanism, particularly if a “virtual observatory” (Section 3) were to be developed. This would save the user (or programmer) quite a bit of time in having to stitch the measurements together. One other issue is that the site does not always seem to work well on the Safari web browser (the standard for Apple computers). The behavior is somewhat erratic.

The ability to easily obtain the physical mooring measurements, and overlay them with other observations, is a key requirement emphasized repeatedly by the sanctuary staff. The staff is also “desperate” (not their word, just an impression) to see the observations analyzed / synthesized on a regular basis. The main author of this report believes that at least part of the roadblock in using the observations is due to a few factors: (1) the design of the user interface for the data access websites (SiMON / WCOS), which could be slightly modified to improve ease of use, (2) a lack of resources to analyze the data, and (3) a lack of time of the research coordinators and sanctuary staff to do the analyses given all of the other responsibilities.

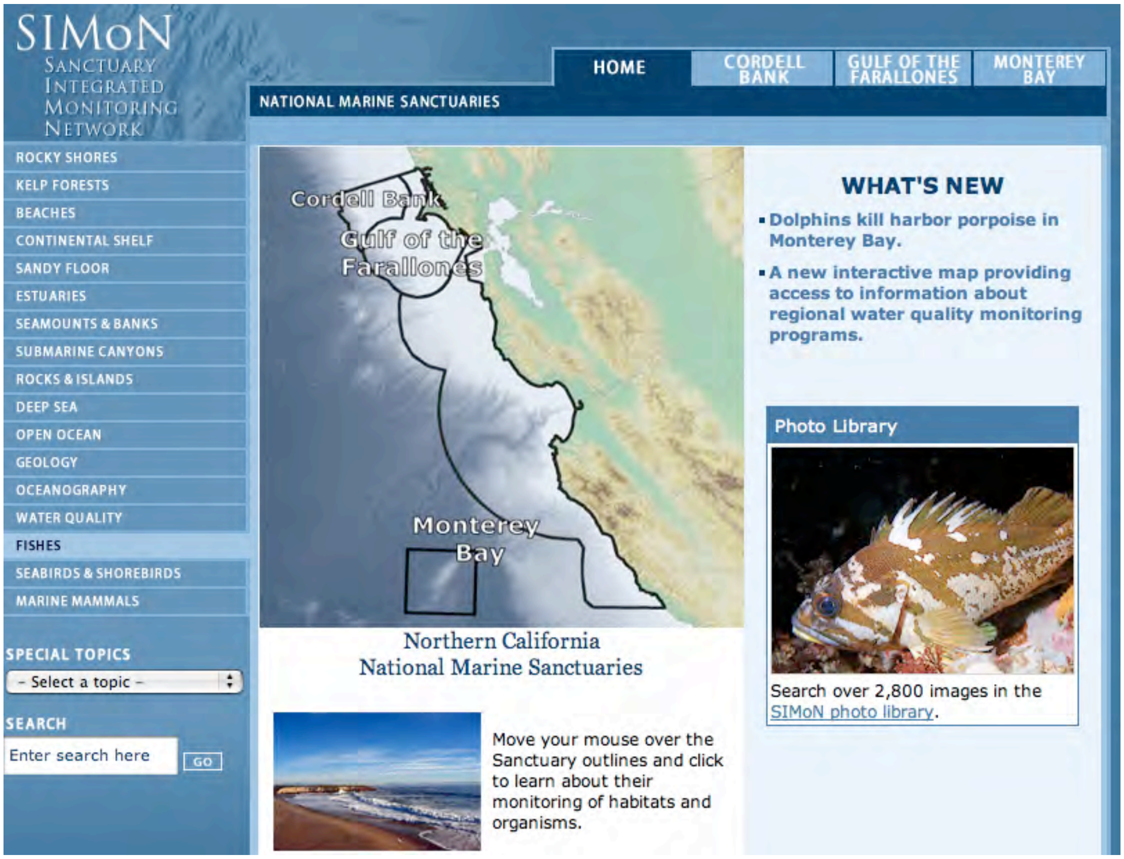
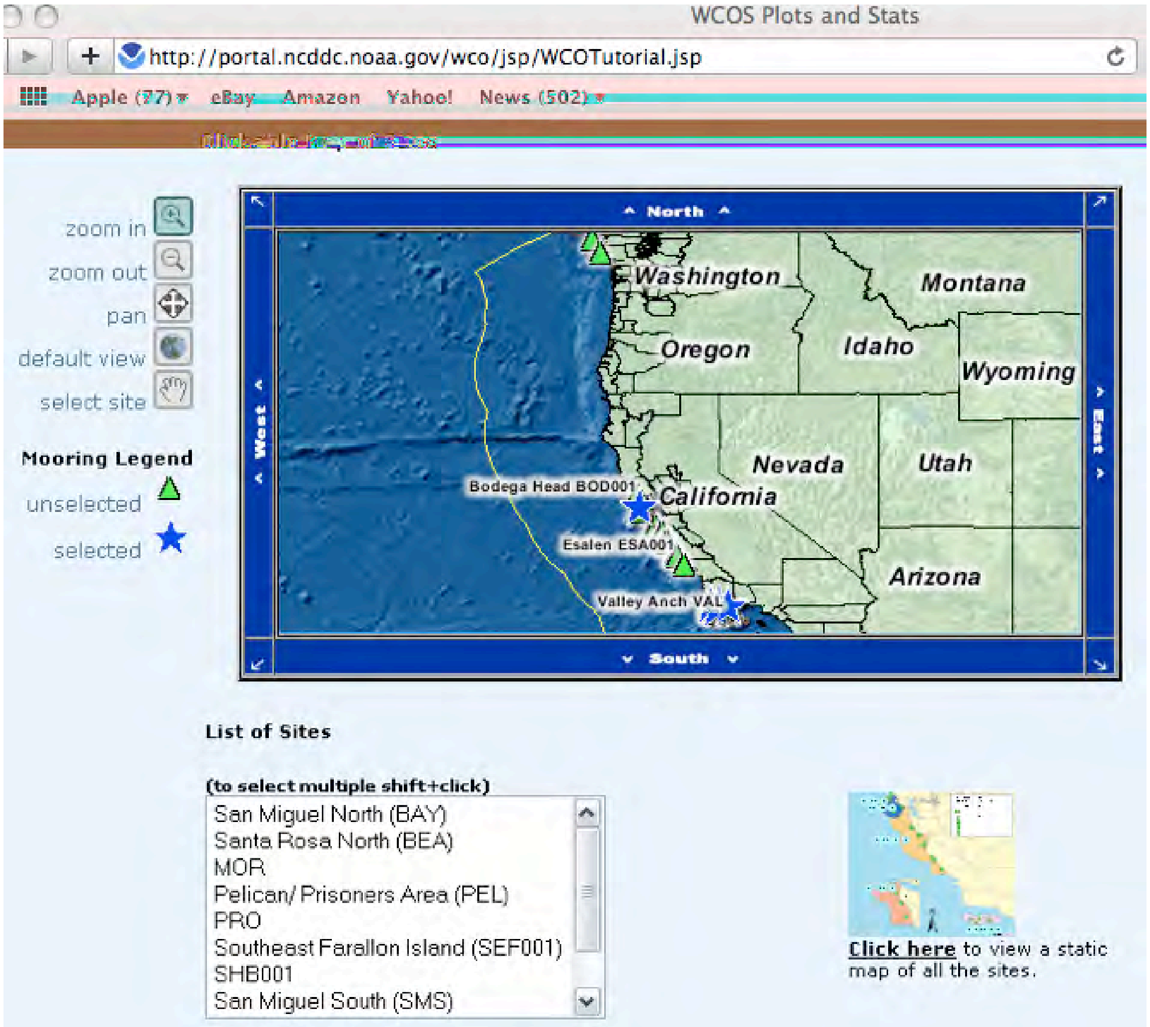


__Figure 2a.__ *Snapshot of SiMON homepage (December 21, 2009).*



<u>Figure 2b.</u> *Access of West Coast Observations (snapshot of WCOS tutorial, December 21, 2009).*

For a full summary of conversations with sanctuary personnel regarding data display and analysis issues, please refer to Appendix B.

The observations collected to date could form the basis of several small-scale research studies, such as process studies at each sanctuary (e.g., how changes in wind patterns relate to sanctuary water quality conditions, describing changes in populations), or cross-comparisons of sanctuaries (e.g., investigating water temperatures across sanctuaries). Both sets of these studies would benefit from incorporating data sets obtained by other organizations (for example, remote measurements of SST or geostrophic currents). The research questions that could be investigated are really endless, although some basic analyses of the measurements collected to date would help to form the backbone of sanctuary characterization and perhaps guide future research.

The ability to perform multiple large-scale cross-sanctuary studies is somewhat limited by the (of necessity?) eclectic nature of the established physical array, as well as the duration of many measurements. The only measurement made consistently across the array is water temperature. Incorporating outside measurements (e.g., SST, winds at buoys, maps of urban growth and influence, etc.) is necessary to provide a larger-scale and longer duration context for sanctuary investigations.

1.2. Background: Outside Agencies

This review is timely. Climate change (or “large-scale monitoring”) is an issue for many agencies. For example, the chief of the U.S. Forest Service has requested forest service units to develop “landscape conservation strategies and action plans” [Tidwell, 2009]. This review does not go as far as conservation strategies (indeed it is unclear what those could be, outside of public education or advocacy). Instead, it focuses on using the sanctuaries as a base for monitoring and understanding large-scale processes.

Along the U.S. West Coast, PISCO (a sanctuary partner) continues to maintain a network of monitoring sites (Figure 3). The measurements at each site are location dependent. Some sites include temperature, or dissolved oxygen, or chlorophyll. PISCO sites are placed in a user-accessible database upon retrieval. The PISCO partnership is an effective means of obtaining sanctuary measurements, although easily obtaining and displaying the PISCO measurements with other sanctuary based measurements is of ongoing concern to the sanctuary staff. PISCO scientists (particularly along the Oregon Coast) are interested in detailed investigations of hypoxia and ocean acidification.

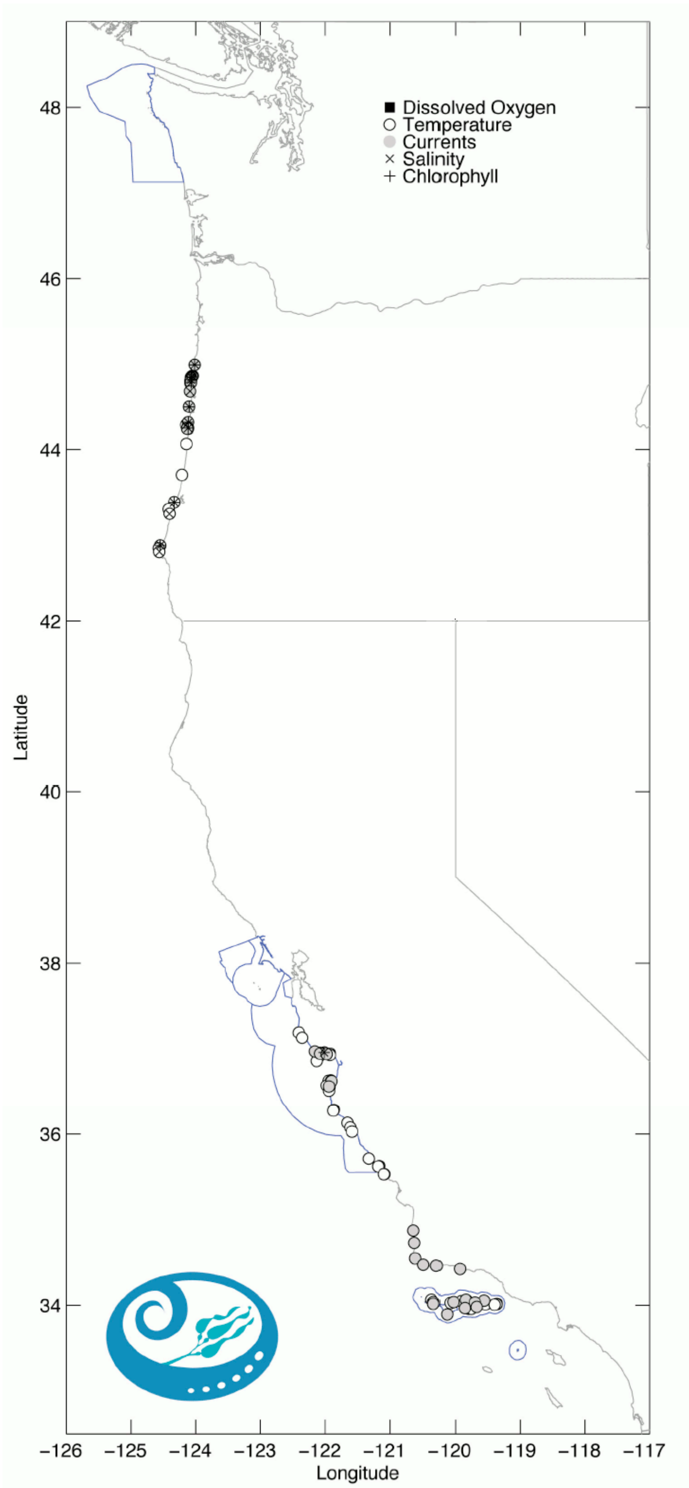


Figure 3. *PISCO mooring locations [figure from the PISCO website, http://www.piscoweb.org/research/coastal-oceans/physical-oceanography, 2009]. The West Coast sanctuaries are outlined in blue*.

The State of California is in the process of defining marine protected areas statewide, and of developing monitoring protocols for the areas that have already been established (Figure 4). The procedures for designing a protocol system are being developed [Ricchia and Whiteman, 2009], although the exact measurements and monitoring methods have not yet been determined. It is currently unknown whether the monitoring will include biological estimates of MPA “effectiveness” (diversity, number of fishes, etc.), or if physical measurements will also be included. As the focus of the MPAs is resource conservation, biological monitoring will presumably comprise the bulk of the observations.

Figure 4. *North-Central California Coast MPA sites, adopted August 5, 2009 (picture from Concur website, article by Scott McCreary, August 27, 2009, http://concurinc.com/wp/2009/08/27/marine-protected-areas-in-california's-north-central-coast/). The MPAs are planned to take effect in January 2010.*

NOAA and the NMFS have developed an ocean acidification plan for the Alaska Fisheries Science Center [Sigler, et. al., 2008]. The researchers claim that the Northeast Pacific is a "sentinel site" for ocean acidification, in the sense that an acidification signal will be detected there first. If funded, species-specific studies will be used to help forecast ecosystem consequences. This is a partnership among agencies, with major funding hopefully coming from NOAA.

The National Data Buoy Center (NDBC) provides an archive of mooring measurements that can be used to place sanctuary measurements in a larger-scale context. Some of the moorings are equipped with ADCPs, although the locations of these can shift depending on funding and priorities. The current configuration of the buoys listed through the NDBC website is shown in Figures 5a - 5d. Different processors / payloads are capable of interfacing with different instruments (such as ADCPs). The buoys and their NDBC payloads are listed in Appendix C.

NDBC is willing to discuss measurement priorities with other organizations and researchers [e.g., Burnett, 2007]. There is an established procedure to get certain buoys listed for instrument additions / upgrades [Burnett, personal communication, 2009, Crout, personal communication, 2009]. The timeline for a "requested" upgrade to be vetted and become operational depends on the complexity of the upgrade. Options exist to provide NDBC with instruments outside of the standard instrumentation available. For non-standard instruments (or for instruments not in the current NDBC inventory), maintenance costs tend to become the responsibility of the user. More detail is provided in Appendix D.

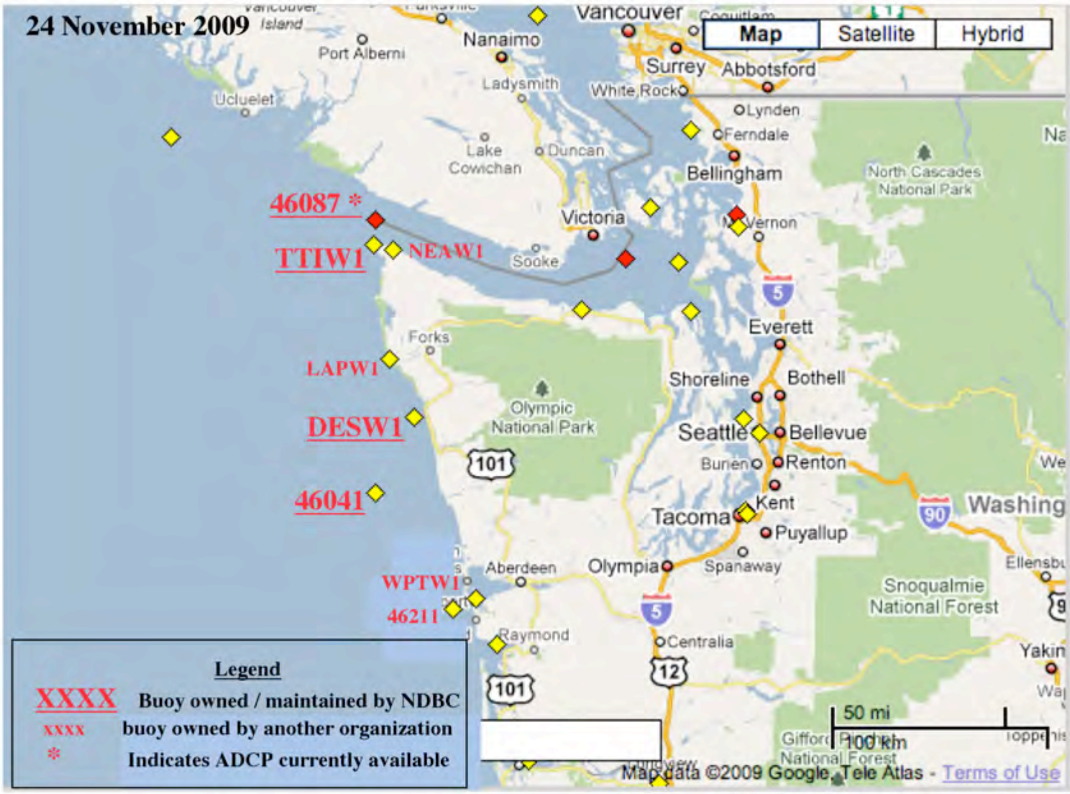


Figure 5a. *Buoys Listed By NDBC, near the Olympic Coast National Marine Sanctuary. Map adapted from NDBC and Google.*

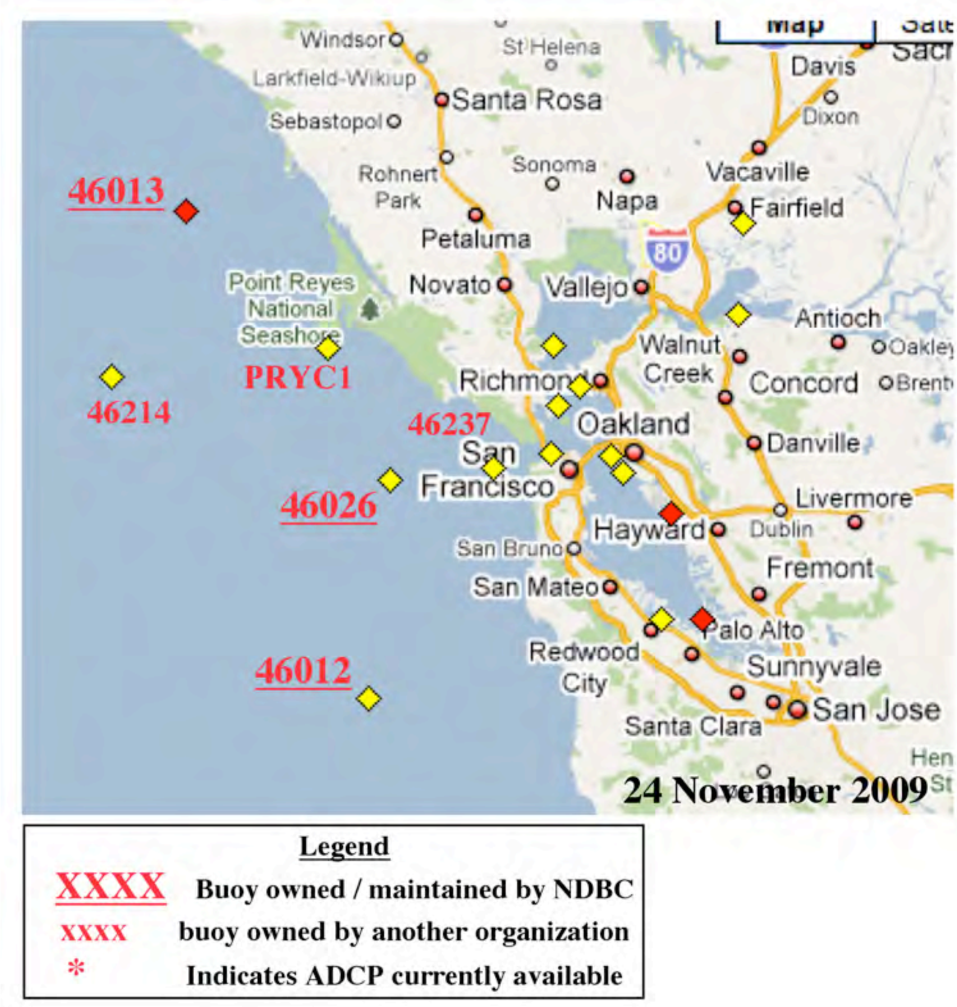


Figure 5b. *Buoys Listed By NDBC, near the Cordell Bank, Gulf of the Farallones, and northern portion of the Monterey Bay National Marine Sanctuaries. Map adapted from NDBC and Google.*

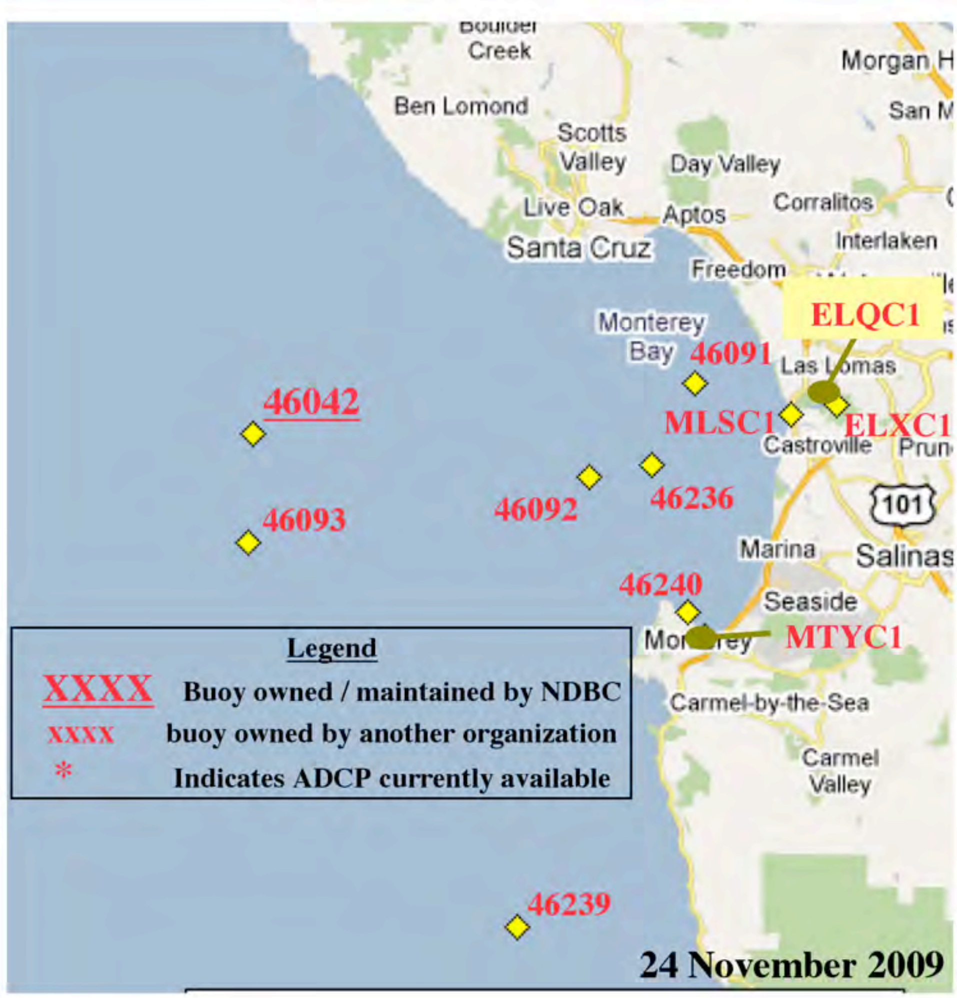


Figure 5c. *Buoys Listed By NDBC, near the southern portion of the Monterey Bay National Marine Sanctuary. Map adapted from NDBC and Google.*

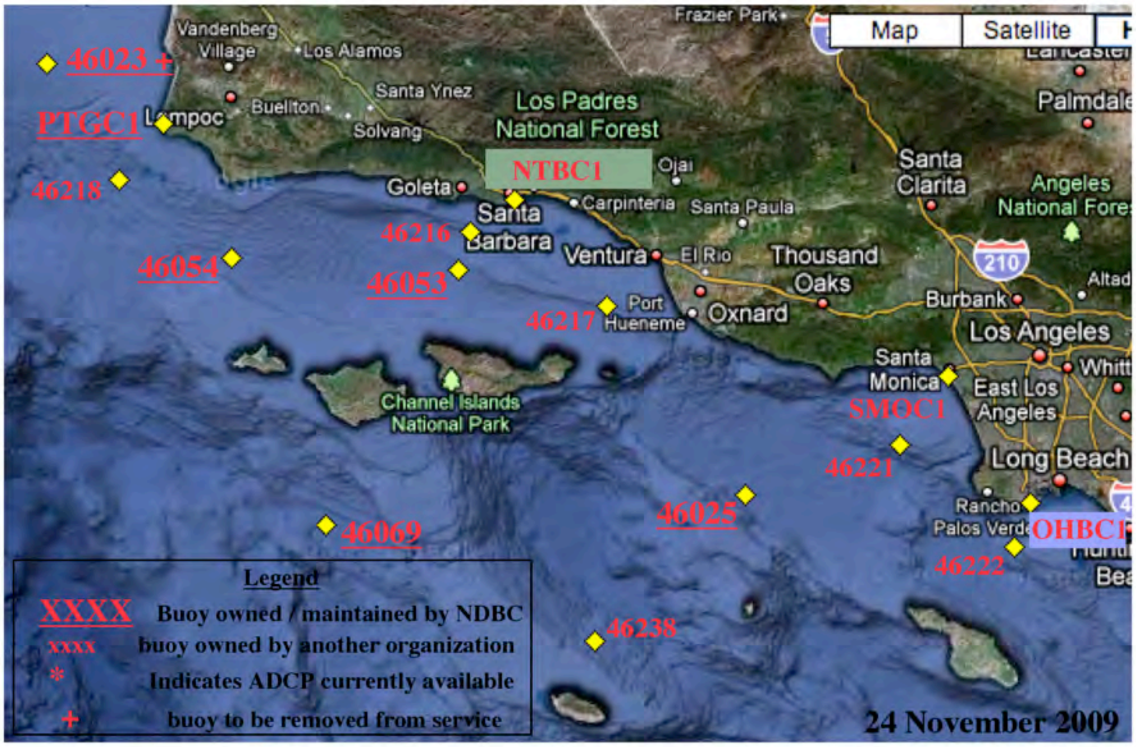


Figure 5d. *Buoys Listed By NDBC, near the southern portion of the Channel Islands National Marine Sanctuary. Map adapted from NDBC and Google.*

1.3. Planetary-Scale Changes

A detailed summary of the possible changes at each sanctuary due to long-term or planetary-scale processes is beyond the scope of this review. An extremely abbreviated discussion is provided here simply for reference.

The large-scale processes that could impact the sanctuaries due to climate change include modification of oceanic temperatures, currents, winds, precipitation patterns, river outflows, and changes in water chemistry (acidification, etc.). More complete discussions are provided in other NMS and PISCO reports [e.g., Office of National Marine Sanctuaries, 2009a, 2009b, Site Scenario Draft Team, 2009].

Detecting large-scale oceanic warming or current regime shifts seems to be beyond the small footprint and point measurements provided by sanctuaries. These signals may be best detected by other long-term observations currently underway, particularly measurements of surface parameters. For example, remote measurements of SST, geostrophic currents, etc., are readily available.

The best use of sanctuary resources, in terms of creating a network, is to design an array that can be used both to fulfill the mission of each sanctuary (monitoring resources, education), and to contribute to the study of large-scale processes and variability. Ocean acidification and hypoxia research seems to fulfill both of these requirements. Hypoxia serves as a good indicator of "regime change" in the ocean, as it reflects both changes in atmospheric / water chemistry and circulation changes [e.g., PICSO, 2009a, 2009b].

The ecological consequences of the changing water chemistry can be quite severe for each sanctuary. A large-scale network would provide a unique opportunity to begin investigating these issues in a large-scale systematic manner. The sanctuaries could also link into current efforts to understand ocean acidification and hypoxia along the West Coast (e.g., PISCO in Oregon, Bodega Bay in California). In addition, OCNMS already has a database of dissolved oxygen measurements, and is continuing its measurement program.

(beef this section up? or is this enough?)

2. Possible Modifications of the West Coast Observational System

In this section, we present a few possible scenarios, including a "do nothing" case. Approximate costs are listed for each. The costs are highly speculative, and should be interpreted as **extremely** rough estimates. Costs will have to be **revised** as the scope of each scenario is refined.

2.1 "Continue Current Efforts"

The current system of physical measurements and data access/display is outlined in Section 1. One of the major strengths of the current system is the leveraging of partnerships with outside agencies, which allows the observational system to obtain many more measurements than the sanctuaries could afford to obtain on their own. The outside agencies also provide readily available expertise that can be used to help interpret conditions in the sanctuaries.

The major drawback of the current operational paradigm is that many of the measurements are simply archived. This is apparently due to a lack of resources (see, for example, the summary of conversations with sanctuary personnel in

Appendix B). Many of the partners are not really paid enough to even provide the current level of service.

Thus, although the measurement program is perceived as necessary to support the mission of the sanctuaries, concern regarding the purpose of the measurement program arises when the measurements are not synthesized on a regular basis. A continuation of this situation seems untenable.

In a “limited-resource” world, one option is to obtain a specified set of measurements for a few years, then interrupt the program for a year and use the observational program funds to analyze the collected measurements. The collection cycle could then begin anew. This option is far less preferable to a consistent, long-term measurement and analysis program.

2.2 Historical Data Analysis

Analysis of previous measurements near the West Coast sanctuaries, including those obtained by outside agencies, would be helpful to provide a longer-term and larger-scale spatial context for the “local “point” measurements. Some of this has already begun [e.g., OCNMS Condition Report, Office of National Marine Sanctuaries, 2008]. As an example of one possibility, estimated geostrophic currents are available along the West Coast dating from 1992, and can be used to quantify variability in surface transport pathways and investigate impacts of these pathways on measurements of water quality.

The time (and hence cost) of to produce such a report can vary widely, depending on the required analyses and goals. It is assumed here that the main goals of such a report are to: (1) collect and synthesize the physical measurements from each sanctuary, (2) include one or two large remote data sets to provide context for the local measurements, and (3) provide some preliminary observations of the state of each sanctuary. The exact scope of work will have to be determined by discussions between sanctuary personnel and the analyst chosen to perform the data synthesis.

With the above (deliberately vague) limitations, the time required to generate such a report is estimated as a total of 4-8 months (1-2 months for data assembly, 3-6 months for analysis). For an oceanographer making 75k per year (including overhead charges), this translates to a cost of between 25k and 50k. Please note that the exact time required could be either much longer (or shorter) depending on the agreed-upon scope of work.

Although such an analysis would aid in interpreting sanctuary observations, and should certainly be strongly considered in the future, an historical synthesis is not believed to be immediately urgent for the sanctuary program. The most immediate questions regard the use of the observations that are currently being collected, and also possible modifications of the observational program.

2.3 Produce Annual Data Reports

The generation of (at-least) annual data reports for all of the sanctuaries could help the sanctuary staff fulfill the missions of monitoring, conservation, and education. A series of such reports would also help establish the context for interpreting future observations and variability. The processing and synthesis required would also help ensure consistent quality control of data sets, and could be used to guide the design of additional observational programs.

The initial cost for such a series of reports could possibly be as large as two months (for all parties to agree to a report format, and to set up the processing / quality control / data display algorithms). After that, it is anticipated that a few months annually to perform an in-depth analysis of the measurements across all sanctuaries should suffice. The generation of such reports would involve basic qa/qc of large data sets, spatial and temporal analysis of patterns, and placing the observations in a larger spatial and temporal context.

For an oceanographer with salary requirements of 75k per year, the cost for two-three months of time is 12.5 - 19k. This represents the amount of time annually after the initial "spin up" the first year to settle on a report format. Please note that this cost is a rough guide. The exact cost will need to be determined after discussions of the report format among all concerned parties.

Analysis of in-sanctuary data (single-point measurements) can be performed fairly easily. Placing data in a larger-scale context would be much easier after the construction of the Virtual Observatory (Section 2.4, below). Importing data from other providers, deriving quality control procedures, and quantifying the relationships with the point measurements can require a large amount of time if the process is not automated in some fashion.

The generation of annual reports is considered to be an urgent need for the sanctuaries, both to understand and monitor changing conditions, and to allow researchers to place future observations in context. This is consistent with the recommendations contained in the recent sanctuary-wide review by the Office of the Inspector General: "The sanctuary program should continue its work with its partners to prioritize research issues and thoroughly analyze the data and information it gathers." [Office of Inspector General, 2008]. The lack of such an in-place process is a source of frustration for sanctuary staff.

2.4 NMS Virtual Observatory

Although the SiMON and WCOS websites do a good job of providing measurements from a large geographical area, the data services and automatic data displays could be much improved. Please note that the thoughts expressed in this section do not imply a criticism of the efforts made to date. Rather, they present one possible roadmap for continued development of the data services. Discussions with the technical staff would help to focus, and possibly revise, some of these suggestions.

The reason for calling this option a "virtual observatory" is that the authors envision a site that is more that simply a repository for observations collected by the sanctuaries. The "virtual observatory" could include storage for measurements from outside agencies, the ability to overlay sanctuary measurements and satellite measurements (for example), automatic analyses of sanctuary trends based on in-situ and remote measurements, and the resources to investigate either one specific sanctuary or perform cross-sanctuary comparisons. The thoughts in this section represent a first step toward that ultimate vision.

Three major improvements would aid both sanctuary staff and researchers: (1) retrieve and store (and possibly display) measurements obtained by other organizations that has applicability to the sanctuaries, (2) provide the ability to easily overlay local observations over larger-scale data sets, and (3) modify the data delivery system so that the user can pull up all sanctuary-wide data by year, instead of performing specific searches on year/location/parameter. Each of these options is discussed separately below.

The first suggestion involves retrieving and storing measurements collected by other agencies. Such measurements include satellite-based estimates of SST and geostrophic currents (among *many* others). These large data sets allow single-point observations to be placed in context. Images can also be automatically generated. As an example, an overlay of sea-surface temperature and locally measured HF Radar currents (Figure 6) is automatically generated at Bodega Marine Lab, using SST measurements obtained through CoastWatch. Satellite-measured geostrophic currents are also readily available (Figure 7). These currents (or HF Radar measured currents) can be integrated in space and time to determine the trajectories of water parcels and hence estimate water-parcel origins or connectivity between regions (Figure 8). If noise pollution is an issue for a particular sanctuary, ship tracks can be obtained and stored for later analysis (Figure 9).

A complete list of readily available measurements is beyond the scope of this report. However, the two organizations with large suites of readily observations are NDBC and CoastWatch. Appendix E summarizes the data available through CoastWatch, and should at least provide an initial starting point for discussions regarding which observations the West Coast Observational Program should incorporate.

Please note that many analyses (for example, connectivity maps, Figure 8) can be automatically performed, and images automatically generated. Obtaining automatic analyses will require more programming effort up-front than simply displaying the images, but has the potential to save significant efforts in future annual data report generation and research. At the very least, all of the measurements (both from the outside agencies and the NMS) should be placed into a common easily read format.

The second suggestion is the ability overlaying observational data from cruises or field campaigns onto maps or larger-scale measurements (such as SST) on request. This would aid sanctuary staff in responding to events, and could also be useful for generating summary figures for the annual data reports. This suggestion can present a bit of a challenge, because such a system needs to be flexible enough to import and plot a wide variety of data, but constrained enough so that an individual user does not require an enormous amount of learning time. It is believed to be possible to design a fairly simple piece of software with some default options that will allow a simple file to imported and overlaid on a larger-scale field. The relative ease of incorporating this option into the current SiMON architecture is not completely known, but will become clearer after the requirements are completely mapped out.

The third suggestion involves modifying the data delivery system. Users should be able to specify a year (and possibly a sanctuary), and pull up a list of all relevant data that they can then select from. This will make retrieving observations for analysis much easier. It would be even more beneficial if such retrieval could be automated.

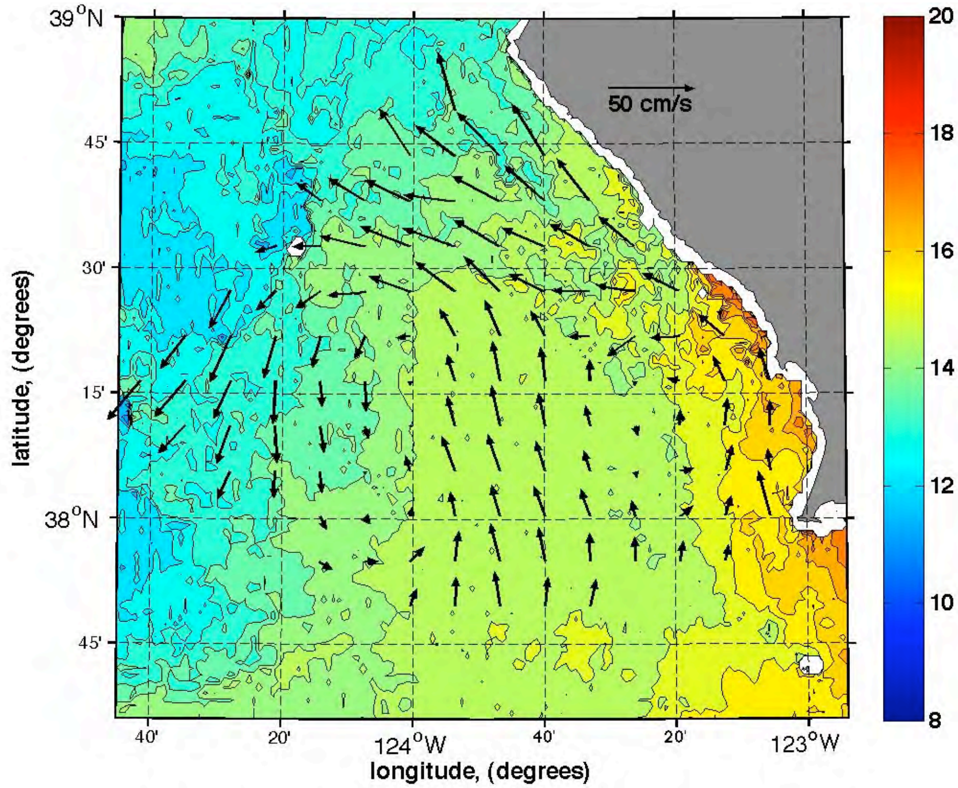


__Figure 6.__ Daily averaged HF Radar surface currents near Bodega Marine Lab on September 5, 2008, superimposed on 3-day composite sea-surface-temperatures (SST) measured from satellite (SST data obtained from NOAA CoastWatch). This figure is generated automatically when processing radar data at BML.

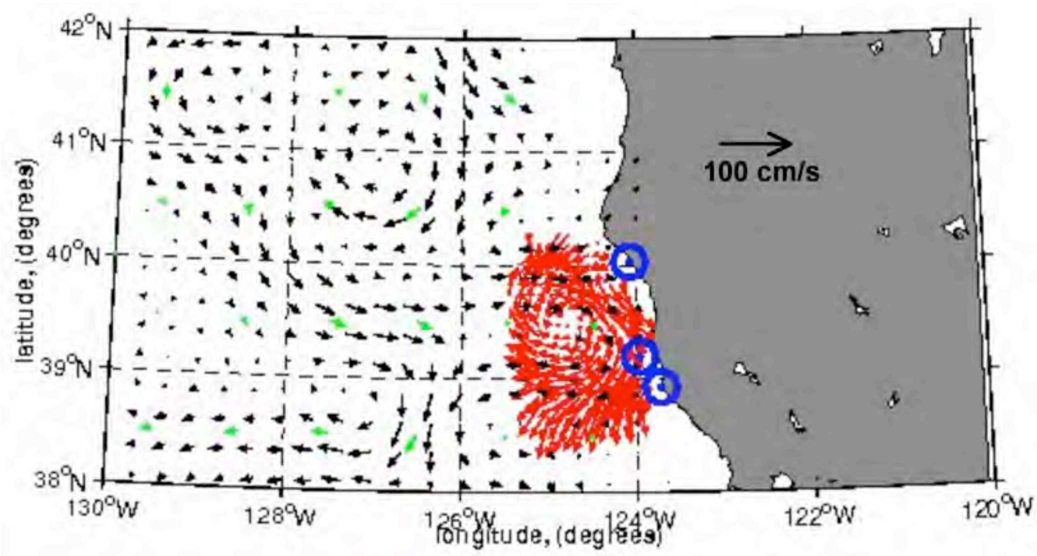
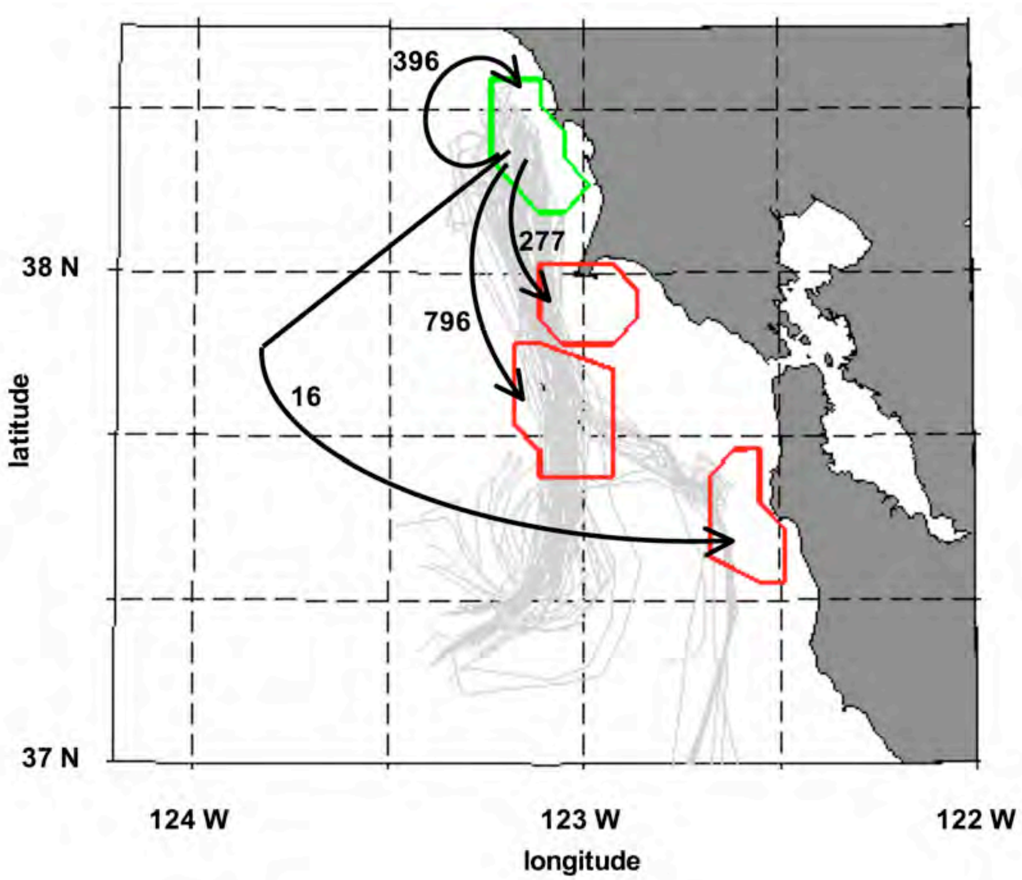


Figure 7. *Daily averaged HF Radar surface currents (red), compared with geostrophic currents estimated using satellites (black), for October 8, 2008. The HF Radar measurements are processed at Bodega Marine Laboratory. The satellite estimates are available on roughly a 1/4 degree grid from AVISO (http://atoll-motu.aviso.oceanobs.com/). Historical estimates for the West Coast are available dating back to October 1992.*



***<u>Figure 8</u>**. Connectivity between North-Central California Coast MPA sites, estimated using HF Radar surface currents. The individual MPA sites have been grouped into 4 regions. Grey tracks represent surface water parcels traveling from the MPA sites near Bodega Bay (in green) to the other regions (red). The numbers of water parcels reaching each site are indicated.*

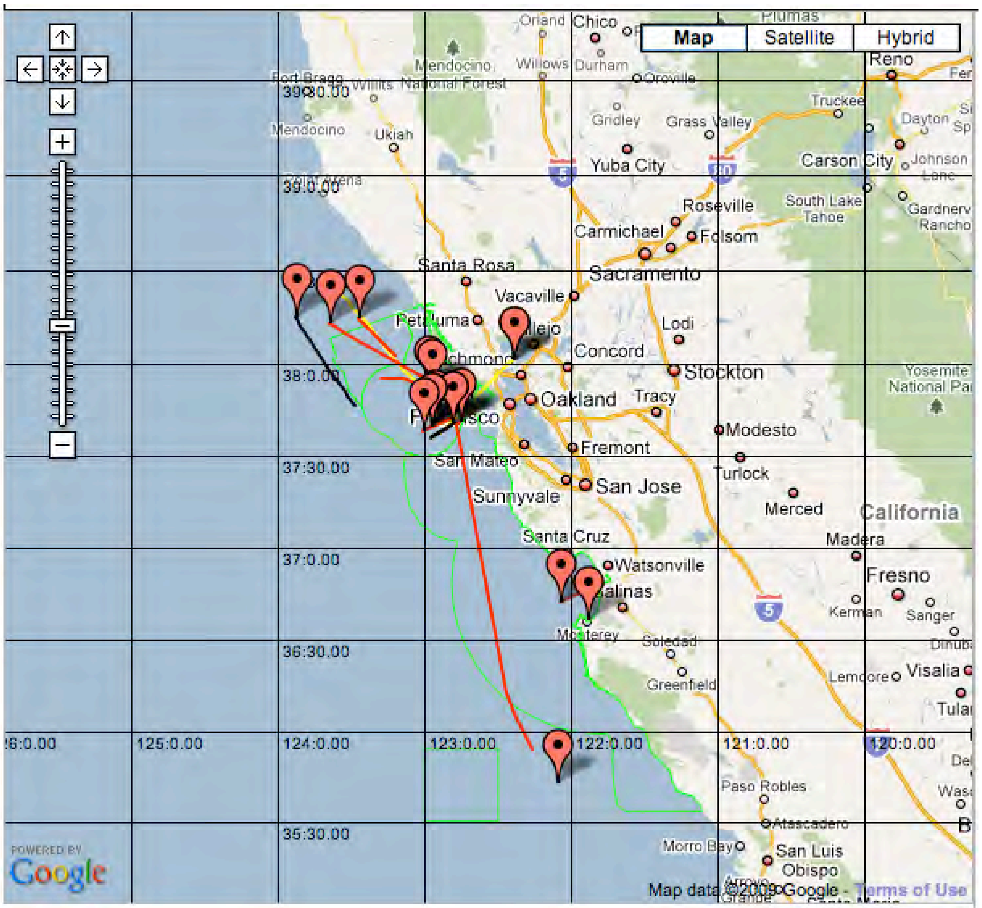


Figure 9. *Real-time ship tracks near San Francisco Bay, using the Automatic Information System (picture from the CeNCOOS website, 9 December 2009, http://www.cencoos.org/sections/ais/aismap.shtml).*

The cost of the Virtual Observatory is difficult to even roughly estimate until the initial system requirements are finalized. The cost will depend on the final design parameters and the organization performing the work. For example, will sanctuary staff implement the changes, or will an outside programmer be required? Given the uncertainties, the net cost could range from zero (for very few changes, or also if sanctuary staff implement the system) to roughly 3-8 months of setup costs for an outside programmer. A couple of months of salary may also be required annually for updating and maintenance.

The cost could increase slightly if new storage systems are required for large amounts of data obtained by outside organizations.

Costs are also difficult to define because NCDDC is willing to work with NMS on data displays and storage needs [Sharon Mesick, personal communication, 2009]. A major geographical focus of NCDDC this year is the U.S. West Coast, so this review into observations and data synthesis is timely. Sharon indicated that she is interested in demonstrating some of recent customized data display projects to interested sanctuary individuals after the start of the year (Jan/Feb 2010), and working with the sanctuaries to define the next steps in this process. The conversation with Sharon is summarized in Appendix F.

Potential cost sharing / synergy with the National Marine Sanctuary Foundation should be investigated. The recent grant received from AT&T [National Marine Sanctuary Foundation, 2009] to develop an "education portal" may have some overlapping interests with the West Coast Observational Program, although this link has not yet been explored.

This option is ranked as relatively urgent because it would help: in the annual interpretation of data, place real-time observations in context, and educate the public about larger-scale issues. Ideally, a well-designed virtual observatory would be fairly easily expandable to other sanctuaries beyond the west coast.

2.5 NMS Oceanographic Moorings

One of the challenges of interpreting the current system of sanctuary measurements in terms of a "network" is the lack of standardization across the sanctuaries. Each sanctuary measures its own selected set of environmental parameters. Ideally, a large-scale process could be identified for the West Coast that also has monitoring implications for each specific sanctuary.

We believe that ocean acidification and hypoxia detection (water chemistry) is that process. Understanding the origin of nutrient-rich waters, their effect on hypoxia, and the challenges of an acidifying ocean continue to be research topics in their own right. Their combined consequences on sanctuary ecosystems could be significant.

The goal is to provide a long-term, standardized set of observations to both monitor the effects on sanctuary resources, and to enable researchers to place their own measurements in context. This concept of an observational "backbone" is similar to the idea of "long-term :reference stations" embodied by the global oceanic observing system [Johnson, 2001]. Each sanctuary should have at least one such mooring (OCNMS has made quite a start on this!). GFNMS, CBNMS, and northern MBNMS could probably do with fewer moorings given their proximity to each other.

If funds are an issue, it might be easier to begin measuring O2 (for hypoxia) first, and add pH and pCO2 as funds become available. An example mooring developed at Bodega Marine Lab for use just offshore is shown in Figure 10. Please note that this is only one possible design for a mooring. It has been optimized for robustness. Hopefully the sensors will function from 6 months - 1 year before needing to be pulled for cleaning. The cost of the water quality sensors on this particular mooring is roughly 60k (20k each for a SAMI-CO2, SAMI-pH, and Wetlabs TQM).

One intriguing possibility, particularly in the lee of upwelling areas, would be to add a gas tension device (~17k) to the mooring [Emerson, 2008, and personal communication, 2009]. Dr. Emerson is working with PMEL on an ocean acidification mooring at Station P, measuring O2, pH, and pCO2. Measurements are transmitted back to shore. With the gas tension device, one can estimate the amount of O2 in the water that is produced due to biological processes, and hence estimate the primary productivity.

Dr. Emerson also indicated that he has had no problem with the SAMI sensors, and that the latest generation of sensors are believed to be more robust. The data from the pH sensors starts to become untrustworthy toward the end of the year (the mooring is serviced annually). Both PMEL and BML (Megan Sheridan) have worked to enable the SAMI sensors to transmit real-time to shore instead of just storing the data internally. Such transmission is a requirement if one desires to be able to identify and immediately correct periods when the instrument may be fouled, which may be a necessity to adequately capture pulsed events such as upwelling.

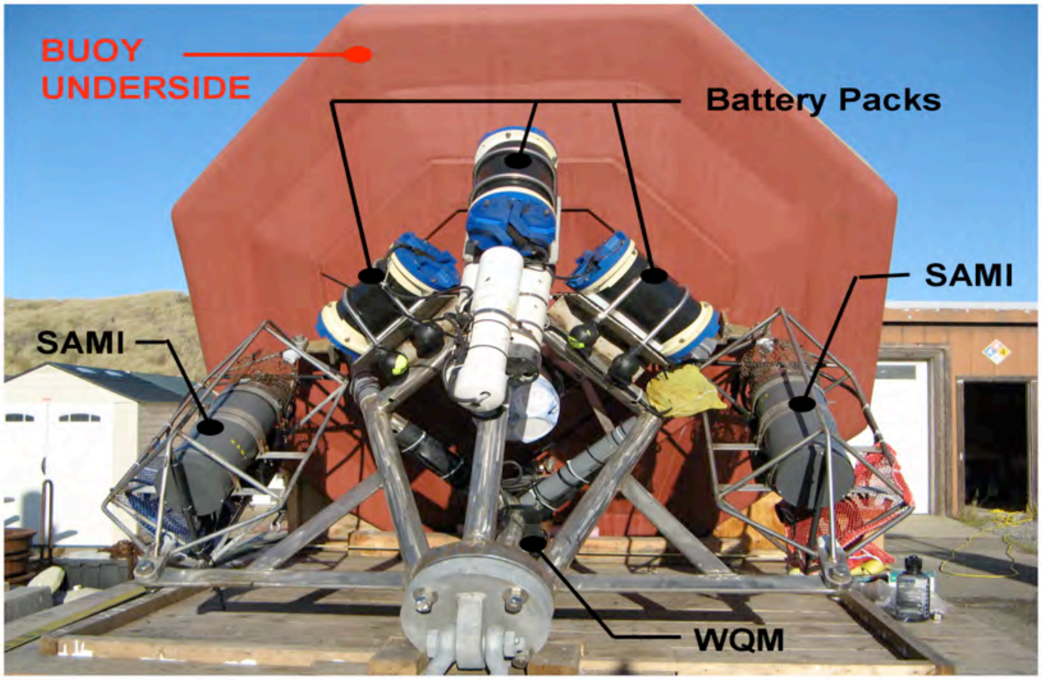


Figure 10. *The Bodega Marine Lab hypoxia / ocean acidification mooring (photo courtesy Megan Sheridan). The sensors are a SAMI-pH, a SAMI-CO2, and a Wetlabs TQM, each costing about 20k. Measurements include C, T, fluorescence, turbidity, pH, pCO2, and O2. This is only an example, other sensors could be added or sensors deleted if not needed.*

We recognize that costs are an issue for the sanctuaries. The instrument cost alone for a single mooring, disregarding maintenance, can range from 20k (for one sensor) to about 80k (for a full suite of sensors, including a gas tension device). Obtaining a full instrument suite for each of several (at least 4?) moorings is a significant cost at a time when the sanctuary system is trying to obtain increased funding through a variety of means [e.g., Office of the Inspector General, 2008]. Some reallocation of resources from the current observational program would help, or partners may be able to contribute. It is of interest that several organizations (e.g., Bodega Marine Lab, Oregon State University, MBARI, etc.) are planning to monitor (or are currently monitoring) water chemistry along the West Coast. These organizations provide both the possibility of collaboration within the sanctuaries, and the ability of the sanctuaries to link their measurements with an even larger-scale network.

Establishing a consistent set of measurements across the sanctuaries may be considered as urgent to make the sanctuaries a true "network". However, the moorings are perhaps less urgent for the immediate needs of the sanctuaries than the annual data reports and the virtual observatory. This ranking should be revisited after the initial set of data reports is issued.

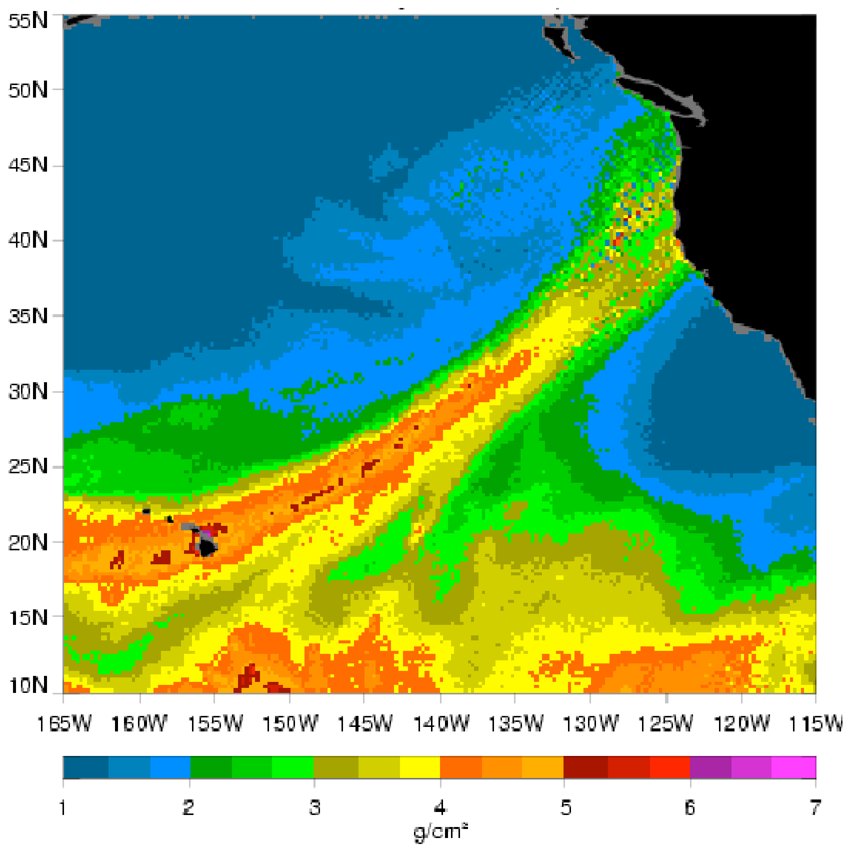
2.6 Future Network Expansion

One challenge with any proposed observational system is deciding when the network is adequate. Before expanding the system beyond its original intent, a series of questions have to be answered: (1) what is the purpose of the extension, (2) what science value is added, and (3) what responsibilities should be assumed by the sanctuaries, and what should be left to outside researchers? In this section, we present some possibilities that should be considered in the future:

> (1) Adding ADCPs near the sanctuary sites (although NDBC has indicated that they are willing to work with other agencies regarding ADCP placement). Estimates of subsurface currents would help in fully quantifying water origins and urban impacts for each sanctuary, and would complement the HF Radar and satellite measured surface currents. Is the spatial variability great enough so that multiple ADCP locations are required in some sanctuaries?

> (2) Extension / collaboration with Hawaii. The climate of the U.S. West Coast is greatly influenced, and sometimes driven, by tropical moisture. For example, all 7 flooding events on the Russian River (north of San Francisco) from 1997 to 2006 were caused by "atmospheric rivers", or the "pineapple express" (Figure 11). In addition, Hawaii continues to be a site of active climate research. For example, CO_2 measured at Mauna Loa tracks oceanic chemistry changes at nearby Station Aloha for the last several years (Figure 12). Inclusion of Hawaii in a "sanctuary network" would expand the spatial footprint of the sanctuaries from just the West Coast into the Pacific Ocean and its associated climate and ecosystem variability. Some of these measurements could "easily" be included in a

"virtual observatory."



<u>Figure 11.</u> *SSMI integrated water vapor, December 3, 2007 [figure from NOAA, http://www.esrl.noaa.gov/news/2008/flooding.html]. Tropical moisture from "atmospheric rivers" impacts the U.S. West Coast on a regular basis [e.g., summary article by Kerr, 2006]. Such "atmospheric rivers" caused all seven flooding events on the Russian River between October 1997 and January 2006 [Ralph, et. al., 2006].*

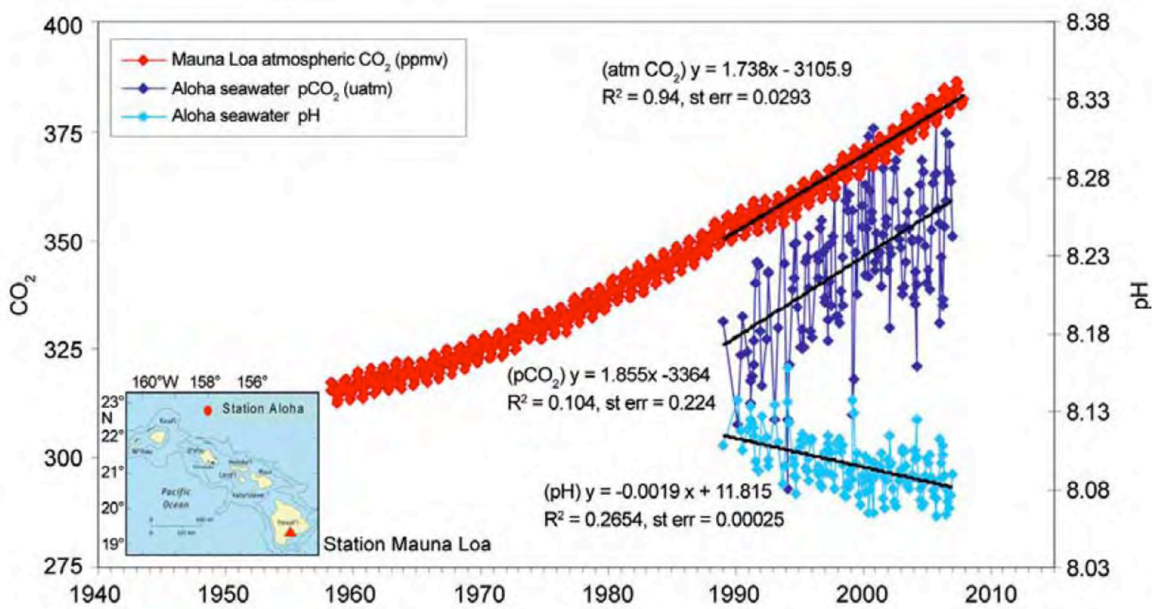


Figure 12. *Ocean acidification measurements from Station Aloha, Hawaii, and comparison to atmospheric CO2 [figure and following caption from Conservation Working Group, Channel Islands National Marine Sanctuary Advisory Council, 2008]:*

"Time series of atmospheric CO_2 at Mauna Loa (ppmv) and surface ocean pH and pCO_2 (µatm) at Ocean Station Aloha in the subtropical North Pacific Ocean. Note that the increase in oceanic CO_2 over the last 17 years is consistent with the atmospheric increase within the statistical limits of the measurements.

Mauna Loa data: Dr. Pieter Tans, NOAA/ESRL, www.esrl.noaa.gov/gmd/ccgg/trends;

HOTS/Aloha data: Dr.David Karl, University of Hawaii, http://hahana.soest.hawaii.edu.

*Graph and caption excerpted from: Feely, R.A. 2008. "Ocean Acidification." In: State of the Climate in 2007. D. H. Levinson and J. H. Lawrimore eds. Bulletin of the American Meteorological Society, **89**, S58. Available at: http://www.ncdc.noaa.gov/oa/climate/research/2007/ann/bams/*

(3) Advocating for other HF Radar sites in Washington State. The addition of these sites would enhance the ability to track water origins and impacts on the OCNMS. Satellite-based estimates of geostrophic currents are available, but smaller-scale temporal and spatial variability can result in significant departures from the geostrophic balance.

(4) Actively working with partners running long-term biological surveys. For example, the well-established “Newport Line” or the more recently established “Bodega Line”, are used to obtain measurements of copepods, physical parameters, etc. These provide opportunities for the sanctuaries to place their point measurements into some larger-scale context, and to look at regional influences that may be of interest for each sanctuary.

(5) Monitor noise pollution (microphones). Noise has been postulated to have a large (unmeasured) effect on various organisms and hence ecosystems. Monitoring noise could be used to investigate this effect, and could also provide a measure of human influence.

(6) Adding moorings. This could be done if needed to quantify spatial variability.

3. Overall Recommendations

Here, we summarize the options (Table 1). The rankings are subjective, but reflect a mix of the need for sanctuaries to meet their current missions, use local observations, and become part of the greater larger-scale monitoring effort. Although this review was conducted independently, many of the conclusions seem to correspond with the findings of the OIG report [Office of Inspector General, 2008]. They are also consistent with the direction indicated from upper NOAA management, and are in line with some of the current large-scale challenges facing the sanctuaries [e.g., Office of National Marine Sanctuaries. 2009b].

Table 1. West Coast Observational Plan options, ranked as: **not desirable**, **not immediately urgent**, **fairly urgent**, and **highly recommended**. Future plans are **unranked**. Refer to the relevant sections for notes on costs and further comments. Note that this ranking should be revisited after some initial data analysis is completed and discussions with the community of research coordinators take place.

Option	**Cost**	**Notes**
Business As Usual	0	The system has strengths , but could be improved. See Section 2.1
Historical Data Analysis	25 - 50 k one time. Cost depends on extent of analysis.	Some of this has been done. See section 2.2
Annual Data Report	12.5 - 19 k annual	Section 2.3
NMS Virtual Observatory	Needs definition to obtain rough cost estimate.	Section 2.4
NMS Oceanographic Moorings	20-80k for instruments, per mooring. Some current instruments on hand could be used. Maintenance required.	Section 2.5
Future Network Expansion		Section 2.6

Many of these needs have already been identified [see, for example, Bowlby, et. al., 1998, Table 7]. Sanctuary staff consistently express a need for both obtaining and interpreting observations to better understand processes at each sanctuary [e.g., see Appendix B]. Such interpretation is also a fundamental requirement for monitoring and assessing change, and allows informed decision or advocacy by the sanctuaries.

Note that the costs listed above are not necessarily additional costs to the sanctuary. Funding could be shifted from current sanctuary observing efforts to some of the efforts listed above. In any case, the annual data reports should begin as soon as possible. The virtual observatory (including the ability to retrieve / overlay data) would also be of great immediate benefit.

4. Next Steps

We suggest the following (near-term) steps for this project:

1. Decide what the annual report should contain, and initiate steps to begin the process. Discussions between sanctuary (and BML) personnel will help to determine the format of the report.

2. Decide what information the “virtual observatory” should contain, how that information should be presented, and who the audience is. Some small meetings / workshops would help to define the requirements.

3. Meet with Sharon Mesick, see her demos, and firm up plans for the sanctuary data display and storage needs. Will NCDDC be able to help, or will the sanctuaries need to do some of the programming and provide their own data storage? The outline of the “virtual observatory? may need to be revisited after the meeting with Sharon.

4. Would the sanctuaries like NDBC to make measurements (or, would the sanctuaries like to make measurements on NDBC-run buoys)? Outline a plan, and initiate discussions with the regional associations and NDBC as needed.

5. Revisit the rankings (Table 1). Ensure that the “lessons learned” to this point are incorporated and the rankings are changed if necessary.

6. Present plan at next sanctuary research coordinators workshop. Ideally, the presentation should be “active”. In other words, specific

feedback should be sought, and possible synergies across the sanctuary system should be explored.

Further steps can be firmed up, and a detailed timeline provided, after the initial meetings / workshops take place.

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Appendix A: List of Current West Coast Sanctuary Mooring Positions

Table A.1 Available measurements at each West Coast sanctuary. Numbers indicate that multiple measurements are available (for example, "X (7)" in the thermistor column indicates that 7 thermistors are recording at a particular location). Please note that the available measurements at some locations may have changed through time. Therefore, this list is not exhaustive, but should give some idea of the available observations. Most of the moorings are maintained through cooperation with local partners. The moorings at OCNMS (highlighted) are owned and maintained by the sanctuary.

Sanctuary	Mooring Location	ADCP?	S4?	Therm?	CT?	DO?	F?
CBNMS	Cordell Bank (note *)			**X**			
CINMS	Willows Area	**X**	**X**	**X**			
	Scorpion	**X**	**X**	**X**			
	San Miguel North	**X**	**X**	**X**			
	San Miguel South	**X**	**X**	**X**			
	Santa Rosa North	**X**	**X**	**X**			
	Santa Rosa South	**X**	**X**	**X**			
GFNMS	Bodega Head			**X (5)**			
	Duxbury Reef			**X (4)**			
	Southeast Farallon Is.			**X (4)**			
	Pigeon Point			**X (4)**			
MBNMS	Ano Nuevo			**X (4)**			
	Terrace Point 7			**X (6)**			
	Terrace Point 8			**X (7)**			
	Point Joe			**X (4)**			
	Sunset Point			**X (4)**			
	South Point Lobos			**X (4)**			
	Esalen			**X (4)**			
	Big Creek			**X (4)**			
	Lopez Rock			**X (4)**			
	Point Sierra Nevada			**X (4)**			
OCNMS	Makah Bay 015			**X (4)**			
	Makah Bay 042		**X (surface meter)**	**X (6)**	**X (2)**		**X**
	Cape Alava 015			**X (4)**			
	Cape Alava 042		**X (surface meter)**	**X (6)**	**X**		**X**
	Cape Alava 065			**X (8)**	**X**	**X**	
	Cape Alava 100			**X (12)**	**X**	**X**	
	Teahwhit Head 015			**X (4)**			

	Teahwhit Head 042		X (surface meter)	X (6)	X (2)		
	Kalaloch 015			X (4)			
	Kalaloch 027		X (surface meter)	X (6)	X		X
	Cape Elizabeth 015			X (4)			
	Cape Elizabeth 042		X (2 meters)	X (6)	X (2)		X
	Cape Elizabeth 065			X (8)	X	X	
	Cape Elizabeth 100			X (12)	X	X	

Notes: * Cordell Bank also has some historical ADCP measurements.

__**Table A.2**__ OCNMS 2009 measurements (provided for comparison with Table A.1). **Additions / increases** and **removals / decreases** in the instrumentation at each site, compared to the historical list of measurements (Table A.1), are highlighted. Many of the changes are due to resource reallocations. Some of the decreases result from instrument malfunction / maintenance issues.

Sanctuary	Mooring Location	ADCP?	S4?	Therm?	CT?	DO?	F?
OCNMS	Makah Bay 015			X (4)			
	Makah Bay 042		----	X (6)	X (2)		X
	Cape Alava 015			X (4)	X	X	
	Cape Alava 042		X (surface meter)	X (6)	X (2)	X	X
	Cape Alava 065			X (8)	X	X	
	Cape Alava 100			---	---	---	
	Teahwhit Head 015			X (4)			
	Teahwhit Head 042		X (surface meter)	X (6)	X (2)		X
	Kalaloch 015			X (4)	X (2)	X	
	Kalaloch 027		X (surface meter)	X (5)	X (2)	X	X
	Cape Elizabeth 015			X (4)	X	X	
	Cape Elizabeth 042		---	X (6)	X (2)	X	X
	Cape Elizabeth 065			X (8)	X	X	
	Cape Elizabeth 100			---	---	---	

Appendix B: Summary of Conversations With Sanctuary Personnel

A summary of various topics discussed with sanctuary personnel:

The idea of a "network": Like the idea of being part of network, but also worried about local monitoring and issues. Not all of the concerns are the same across all sanctuaries (i.e., urban runoff, sea level changes, fishing enforcement, etc.). See the ability to retain local measurements / monitoring as necessary. The moorings are proposed with this in mind - water quality seems to be the one thing that can have larger-scale responses and also be useful for quantifying smaller-scale local conditions.

Reason for Measurements: Related to the above. Why is this being done, why do it in the future? Do we need to, should we? Can we be of more value? In a sense, this is possibly expanding the mission of the sanctuaries.

Data use / Display: A common them among the research coordinators is that the data is obviously important for quantifying / understanding processes, but is not always getting used. In order for measurements / monitoring to be successful (and to justify continued operation), the measurements must be synthesized in some meaningful way. There is a high level of frustration here among personnel, some of it directed at the sanctuary partners. At the same time, sanctuary folks also consistently mentioned that they realized the amount of money being paid to the partners isn't really enough to do even the amount of work that is currently undertaken. One big frustration is obviously that the sanctuaries can have a big part to play in the ocean / environmental efforts and monitoring taking place in the U.S., but that the resource allocation is somewhat lacking.

Instrument Calibration / Maintenance: Needs to be a priority.

Website (Measurement Access): A good resource that lists the measurements (a “phone Book”). However, measurements are difficult to access / overlay with other measurements. There is a general feeling that the site could be much more (and perhaps will be, given time).

Appendix C: Buoy Measurements That Are Accessible Through NDBC

This section lists the processing systems, payload types, and owners of NDBC buoys. The ability to add an instrument to a buoy depends on all 3. It is recommended that the sanctuary system work with NDBC-maintained buoys when requesting instrument additions, if possible. The “payload” tends to refer to the processing system - not all measurements that could be made are necessarily obtained for a buoy with a given payload.

For a full description of payload types, see the NDBC website [**http://www.ndbc.noaa.gov/rsa.shtml**]**.** The possible instrumentation associated with each payload of an NDBC operated buoy, as well as the typical sampling intervals, are listed on the NDBC website, and also provided in the reference material on the CD accompanying this report.

Table C1. NDBC-listed Buoys located near the Olympic Coast National Marine Sanctuary (adapted from http://www.ndbc.noaa.gov).

Buoy Number	Organization	Payload	Real-Time ADCP?	Historical ADCP?	Notes:
46087	NDBC / Coast Guard	ARES 4.4	Yes		
TTIW1	NDBC	DACT			
DESW1	NDBC	DACT			
46041	NDBC	ARES 4.4		2007	
NEAW1	NOS				
LAPW1	NOS				
WPTW1	NOS				
46211	SIO				

Table C2. NDBC-listed Buoys located near the CBNMS, GFNMS, and northern MBNMS (adapted from http://www.ndbc.noaa.gov).

Buoy Number	Organization	Payload	Real-Time ADCP?	Historical ADCP?	Notes:
46013	NDBC	ARES 4.4			
46026	NDBC	AMPS		2007	
46012	NDBC	DACT			
PRYC1	NOS				
46214	SIO				
46237	SIO				

Table C3. NDBC-listed Buoys located near the southern MBNMS (adapted from http://www.ndbc.noaa.gov).

Buoy Number	Organization	Payload	Real-Time ADCP?	Historical ADCP?	Notes:
46042	NDBC	ARES			
46091	MBARI				MBARI has various historical ADCP data
46092	MBARI				
46093	MBARI				
MLSC1	MLML				
ELXC1	NERR				
ELQC1	NERR				
MTYC1	NOS				
46236	SIO				
46239	SIO				
46240	SIO				

Table C4. NDBC-listed Buoys located near the Channel Islands National Marine Sanctuary (adapted from http://www.ndbc.noaa.gov).

Buoy Number	**Organization**	**Payload**	**Real-Time ADCP?**	**Historical ADCP?**	**Notes:**
46023	NDBC / MMS	DACT		1996-2005	Station to be removed
46053	NDBC	ARES 4.4		1994-1997 2007	
46054	NDBC	ARES		1994-2005	
PTGC1	NDBC	MARS			
46069	NDBC	ARES			
46025	NDBC	ARES			
NTBC1	NOS				
SMOC1	NOS				
OHBC1	NOS				
46216	SIO				
46217	SIO				
46218	SIO				
46221	SIO				
46222	SIO				
46238	SIO				

Appendix D. Conversations With Bill Burnett and Richard Crout

A phone conversation regarding the possibility of requesting specific instrumentation on NDBC buoys took place between William Burnett (NDBC, Data Management and Communications Branch Chief) and Chris Halle on December 10, 2009. Highlights from the conversation are listed below:

1. It is possible to request the placement of specific instruments on specific NDBC buoys (for example, ADCPs). Typically, NDBC has worked with the regional associations to identify priorities (point-of-contact in the past has been Richard Bouchard - NOAA?).

2. The formal procedure is typically initiated with a written request from the regional association to NDBC. Bill is willing to work with the NMS staff on this. In other words, NMS could draft a letter, send it to Bill, and he will help ensure that it gets routed correctly. My impression was that it may help if the various regional associations sign off on the letter as well.

3. Some ADCPs were removed recently because of funding. In addition, the regional associations already have a “request list” into NDBC. It is likely that these modifications would take place prior to NMS-requested modifications.

4. The ease with which an ADCP can be placed on a mooring is a function of the processing system and the mooring configuration. A mooring which has previously been configured with an ADCP will need no modification (assuming that the processing system is unchanged).

5. ADCPs (or other instruments, such as CO2 sensors) can be provided from an organization to NDBC for placement on their buoys. In this case, the cost of the instrument, as well as the cost of additional maintenance (such as additional boat trips, if any) are borne by the organization providing the instrument. NDBC and MBARI have used this arrangement.

6. NDBC services each buoy roughly every two years. Depending on the maintenance schedule, an approved modification for a specific buoy can be processed within a timeframe spanning a couple of months to the full two years.

Another phone conversation regarding the possibility of requesting specific instrumentation on NDBC buoys took place between Richard Crout (NDBC, Chief Scientist) and Chris Halle on December 15, 2009. Highlights from the conversation are listed below:

1. NDBC engineers have worked out a process within the past year where users can install their own instruments on NDBC buoys. Typically, a user will pay for the instrument, and NDBC will also charge a small amount for maintenance. Richard will put the NMS folks in touch with the engineers when we decide what we would like.

2. The regional organizations (the OOS's) came up with a prioritized list of modifications to the NDBC buoys about 1.5 years ago. We should contact them to see if our (to-be-defined) plan is in line with these requested modifications.

3. NDBC added an ADCP for Grays Reef under this program, (and also possibly some instrumentation for Monitor NMS ?).

My impression is that if the decision is made to request NDBC to mount ADCPs on buoys near the sanctuaries, NMS should initially specify general regions and ask for their advice in selecting particular buoys within those regions. This then work with the regional associations to determine if their requests overlap with the sanctuary requirements. We should then chat with Richard and ask for guidance on how to proceed. It may be that certain buoys are better equipped to accept new instrumentation. Such a procedure would ensure ease of installation for NDBC, and decrease the turnaround time for the modifications. If the sanctuary needs are in line with the needs of the regional associations, this approach could also significantly reduce costs to the NMS.

Appendix E. Sample of Satellite Measurements Available Through CoastWatch

List not complete, an extensive sample of what is available as of the summer of 2009. For a complete list, visit the CoastWatch website.

Get the list from my Matlab routine. The list just represents a sample of what we are set up to automatically download at BML.

Appendix F. Conversation With Sharon Mesick

A phone conversation regarding the data display and management of NMS observations took place between Sharon Mesick (NCDDC, Ecosystem Program Manager) and Chris Halle on December 9, 2009. Highlights from the conversation are listed below:

1. NCDDC is in the business of making data accessible and interpretable. They would be glad to work with the sanctuaries on adapting the current Web-based design.

2. Defining the exact nature of the displays and/or storage systems up front is crucial. For example, what format is the data in? Does it need to be stored? Is it only for display, or should it be archived?

3. The organization has recently moved to an ArcServer configuration, which allows for user configuration / display.

4. The U.S. West Coast is a geographical focus for NCDDC this year, so our discussion is timely.

5. NCDDC recently created a demonstration product for Flower Garden Banks NMS. Sharon would like to demonstrate it (over the Web) for interested personnel after the first of the year (Jan/Feb 2010). At the

same time, we could initiate a discussion going regarding a future data management / display vision for the West Coast sanctuaries, with folks from the sanctuaries and NCDDC contributing ideas.

Appendix G: Contact List

Contact information for personnel contributing to and/or contacted during this study are listed in the following tables (Tables G1 - G4).

Table G1. National Marine Sanctuary Personnel

Name	**Position**	**email**	**phone number**
Dave Lott	West Coast Regional Operations Coordinator	dave.lott@noaa.gov	831-647-1920, x 103
Jan Roletto	GFNMS Research Coordinator	Jan.Roletto@noaa.gov	(415) 561-6622, x207
Ed Bowlby	OCNMS Research Coordinator	ed.bowlby@noaa.gov	360-457-6622, x17
Mary Sue Brancato	OCNMS Resource Protection Specialist	Mary.Sue.Brancato@noaa.gov	360-457-6622, x20
John Barimo	OCNMS Research Specialist	John.Barimo@noaa.gov	(360) 457-6622, x22
Lisa Etherington	CBNMS	Lisa.Etherington@noaa.gov	(415) 663-1443

Etherington	Research Coordinator		
Steven Katz	CINMS	steve.katz@noaa.gov	805-963-3238, x12
Andrew DeVogelaere	MBNMS	Andrew.DeVogelaere@noaa.gov	831-647-4213

Table G2. Bodega Marine Laboratory Personnel

Name	**Position**	**email**	**phone number**
Chris Halle	Project Scientist	cmhalle@ucdavis.edu	(707) 875-1928
John Largier	Professor	jlargier@ucdavis.edu	(707) 875-1930
Megan Sheridan	Staff Research Associate	mmsheridan@ucdavis.edu	(707) 875-1929

Table G3. Pacific Marine Environmental Laboratory Personnel

Name	**Position**	**email**	**phone number**
Meghan Cronin	PMEL, Ocean Climate Data Stations Lead	Meghan.F.Cronin@noaa.gov	(206) 526-6449

	Scientist		
Chris Sabine	PMEL, Ocean Climate Data Stations Lead Carbon Scientist	chris.sabine@noaa.gov	(206) 526-4809
Steve Emerson	(Professor, UW)	emerson@u.washington.edu	(206) 543-0428

Table G4. NOAA (NCDDC, NDBC) Personnel.

Name	**Position**	**email**	**phone number**
Sharon Mesick	NCDDC, Ecosystem Program Manager	Sharon.Mesick@noaa.gov	228-688-2256
William Burnett	NDBC, Data Management and Communications Branch Chief	bill.burnett@noaa.gov	(228) 688-4766
Richard Crout	NDBC, Chief Scientist	richard.crout@noaa.gov	(228) 688-1021