OceanSITES

Uwe Send[1], Robert A. Weller[2], Doug Wallace[3], Francisco Chavez[4], Richard Lampitt[5],Tommy Dickey[6], Makio Honda[7], Kostas Nittis[8], Roger Lukas[9], Mike McPhaden[10],Richard Feely[10]

[1] *Scripps Institution of Oceanography, Mail Code 0230, 9500 Gilman Drive, La Jolla, CA 92093 USA, Email: usend@ucsd.edu*
[2] *Woods Hole Oceanographic Institution, MS 29, Woods Hole, MA, 02543, USA, Email: rweller@whoi.edu*
[3] *Leibniz-Institut für Meereswissenschaften/Leibniz Institute of Marine Sciences, IFM-GEOMAR (Research Center for Marine Geosciences), Duesternbrooker Weg 20, 24105 Kiel, Germany, Email: dwallace@ifm-geomar.de*
[4] *MBARI (Monterey Bay Aquarium Research Institute), 7700 Sandholdt Rd, Moss Landing, CA 95039 USA, Email: chfr@mbari.org*
[5] *National Oceanography Centre, Empress Dock, Southampton SO14 3ZH United Kingdom, Email: r.lampitt@noc.soton.ac.uk*
[6] *University of California Santa Barbara, Ocean Physics Laboratory, 6487 Calle Real, Suite A, Goleta, CA 93117 USA, Email: tommy.dickey@opl.ucsb.edu*
[7] *JAMSTEC (Japan Agency for Marine-Earth Science and Technology), MARITEC (Marine Technology Center), 2-15 Natsushima, Yokosuka, Kanagawa, 237-0061, Japan, Email: hondam@jamstec.go.jp*
[8] *Hellenic Centre for Marine Research, Anavyossos Institute of Oceanography 46.7 Km, Athens-Sounio Ave., PO BOX 712, Anavyssos Attica 190 13, Greece, Email: knittis@hcmr.gr*
[9] *University of Hawaii at Manoa, Department of Oceanography, 1000 Pope Road, Honolulu, Hawaii 96822 USA, Email: rlukas@hawaii.edu*
[10] *NOAA/PMEL (National Oceanic and Atmospheric Administration/Pacific Marine Environment Laboratory), 7600 Sand Point Way N.E. Seattle, WA 98115-6349 USA, Email: Michael.J.Mcphaden@noaa.gov, Richard.A.Feely@noaa.gov*

ABSTRACT

The OceanSITES project coordinates and facilitates the implementation of a global open-ocean network of sustained time series sites. It was conceived as a result of the OceanObs99 conference, where need for such a system was recognized and endorsed by the community, to complement the other existing components of the global ocean observing system such as ARGO, satellites, ship hydrography, and underway data such as XBTs. OceanSITES now is an official component of the Global Ocean Observing System (GOOS) and of JCOMM (via the DBCP), and recognized and supported by CLIVAR and POGO. We review the rationale for sustained time series observations and the status of the OceanSITES effort, including data management. We also present recommendations on the forward trajectory for OceanSITES. Specifically, we see value in commitments to increased uniformity, with common sampling strategies and deployment of multidisciplinary sensors. This could be accomplished by having a core or backbone set of the sites equipped with common sensor suites. These sensor suites would provide atmospheric, physical and circulation observations and also expand the scientific focus for this core network to address CO_2 and oxygen dynamics in the upper layer of the ocean and their relation to daily to seasonal phytoplankton primary production, net community production and mixed layer dynamics. A vision and goal for OceanSITES are to collaborate across disciplines, agencies and countries to implement share and mutually enhance sites and platforms to establish this backbone system. Another proposed step forward would be the development of a standard mooring design, essentially an OceanSITES blueprint, that can be replicated anywhere, coupled with training and manuals for mutually agreed procedures based on the expertise of the entire OceanSITES community. A goal will also be to work across borders and program boundaries to exchange disciplinary, technical and sensor expertise.

1. INTRODUCTION

The OceanSITES project coordinates and facilitates the implementation of a global open-ocean network of sustained time series sites. It was conceived as a result of the OceanObs99 conference, where a need for such a system was recognized and endorsed by the community, in order to complement the other existing components of the global ocean observing system such as ARGO, satellites, ship hydrography, and underway data such as XBTs. The unique strengths and contributions of such measurements are:

- high temporal sampling for resolving events and rapid processes
- long sustained measurement of multiple interrelated variables from sea surface to seafloor

- presence in fixed and critical locations that are difficult to maintain with mobile platforms (e.g., straits/passages, boundary currents)
- deployment of large, heavy or power-hungry instrument systems.

In addition, there are other applications such as serving as benchmarks for satellite and float systems, for model validation, as community platforms which can accept a variety of instruments of outside users, and as test beds for new sensor systems. Sustained time series sites play important roles in process studies and ongoing interaction with modellers in climate and ocean research programs such as those funded under WCRP (e.g. the extensions of the TAO array in the eastern Pacific done in support of the CLIVAR EPIC program [1]; the sustained mooring under the Chilean stratus deck also established during EPIC [2]; and the use of sustained surface meteorological and air-sea flux observations to examine numerical weather prediction model performance (see AC-2B-39: Verification of Numerical Weather Prediction Marine Meteorology using Moorings: An OceanSITES Application). OceanSITES now is an official component of the Global Ocean Observing System (GOOS) and of JCOMM (via the DBCP), and is recognized and supported by CLIVAR and POGO.

In recent years the concept of oceanic equivalents to the Mauna Loa CO_2 curve in the atmosphere has developed, leading to the notion of ocean "reference stations". This is a useful approach to take, since the number of sites around the globe will always be sparse and under sampling spatially. The goal of OceanSITES thus is not to provide complete information at global scales but to provide high-quality, well-calibrated continuous data from discrete locations that are either representative of a region/province/regime or critical for specific processes. Such data can then be used to monitor for small trends or changes in long time series, to detect sudden changes and events, to validate e.g. assimilation runs and forecast products, measurements from remote sensing or platforms that cannot be post-calibrated, to provide temporal statistics (aliasing issues), and to develop and improve models. The focus of this Community White Paper is on the status of the OceanSITES effort and on a proposal to go forward. Many other Community White Papers are resources that illustrate the critical roles of sustained time series sites in the ocean observing system (e.g., CWP-2B-03 Observations to Quantify Air-Sea Fluxes and Their Role in Climate Variability and Predictability, CWP-2A-10 The Global Tropical Moored Buoy Array, CWP-2A-11 Observing Systems in the Indian Ocean, CWP-2B-01 Monitoring ocean - atmosphere interactions in western boundary current extensions). Thus, OceanSITES is an umbrella for plans for sustained time series observations for sustained operational and research efforts, including the research done under World Climate Research Programme (WCRP) programs such as CLIVAR.

While most time series being collected (largely with moorings) traditionally were physical or atmospheric, attention is now shifting increasingly to multi-disciplinary "observatories". This is partly a result of enabling technology, but more importantly driven by a recognition that the earth is experiencing major human-induced forcing to its climate system and ecosystems. This is superimposed on forcing arising from natural climate variability. Responses of ecosystems and biogeochemical processes to variable forcing involve complex interactions and feedbacks of physical, chemical and biological processes. Understanding of these responses is central to our ability to predict how the global climate- and eco-system will respond to the human forcing and whether strong feedbacks exist that might reinforce or reduce the effects of this forcing.

All scientists agree that large amounts of data and, especially, long records are required to accurately characterize and understand such complex interactions. It is fair to say that sustained time-series records have been the most powerful observational tool not only for identifying but also for understanding global change and its effects. Figure 1 provides an example from [3], where sampling from a mooring captures the temporal variability in SST and seawater pCO2 that less frequent sampling by Volunteer Observing Ship (VOS) could not capture. Obviously if the goal is to understand links between climate and ecosystems and biogeochemistry, then measurement of physical or biological records alone is not sufficient: the records must be interdisciplinary and capture, simultaneously, key measures of the physical forcing, together with the biological and chemical response.

With care to the issues of calibration, successive deployments at one site can be combined to provide a long-term record capable of observing trends. At the same time, the sustained sites provide the high resolution that can capture the impacts of strong transients, such as the passage of a hurricane accompanied by entrainment of cool, nutrient-rich water into the upper ocean and a subsequent bloom with extreme levels of productivity. The accurate surface meteorological and air-sea flux records from OceanSITES reference stations in locations such as under the marine stratus off northern Chile provide the means to identify errors and biases in gridded surface fields from numerical weather prediction models, remote sensing, and climatologies. Further, these sites provide anchors for the generation of new, improved, hybrid and blended air-sea flux fields (see CWP-2B-03 Observations to Quantify Air-Sea Fluxes and Their Role in Climate Variability and Predictability) and then the improved flux fields provide improved surface forcing to runs of ocean models.

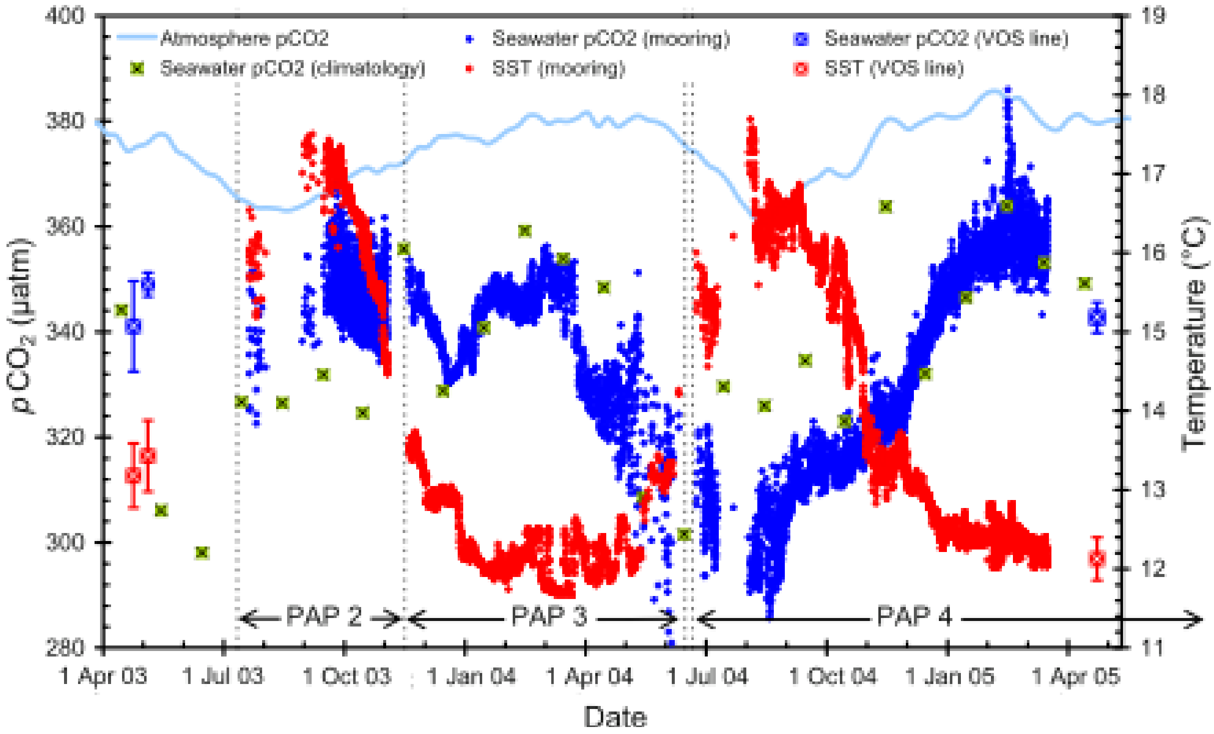

Figure 1. From [3], pCO_2 and temperature in the mixed layer from mooring deployments at the Porcupine Abyssal Plane (PAP) observatory at 49°N, 16.5°W. The advantages of the high temporal sampling by the moored instruments, and the success at constructing a long-term record from successive mooring deployments are evident.

Despite their obvious importance and proven scientific utility, such long-term interdisciplinary records are severely lacking for the ocean. Why are they so rare?

- The time-series are recognized as valuable when they are needed, but on a day-to-day basis, and in the context of a competitive funding environment, often appear routine or mundane. They risk being given lower priority for funding relative to some new, interesting idea or hypothesis…. which often, itself, can only be adequately tested with time-series data.
- The time-series can be very resource intensive (i.e. expensive).
- Closely related to this is the risk of "mission creep". Particularly for biogeochemical time-series, the list of potential measurements is nearly endless and justifying inclusion/exclusion is difficult. Decisions as to what to measure, as well as how to measure, are never trivial. The list of "essential" measurements for time-series can grow to the point that sustainability of the entire enterprise is put at risk.
- The ocean observation community has not always effectively promoted shared, interdisciplinary use of expensive long-term observation platforms and sites. In part because of fear of "mission creep" and risks to sustainability. In other cases, available platforms are limited practically in terms of which additional measurements they can support without damaging the quality or quantity of the existing measurements.

Despite these risks, the need to collect data to promote understanding of how variability in climate and ocean circulation affects biological productivity, food-chain processes, abundances of organisms, and geochemical fluxes to the atmosphere and the deep sea remains strong, and must be addressed, and time series are a key component to such studies.

2. STATUS

OceanSITES seeks to fill a gap that existed for the coordination and data management of the *time series* component of the global ocean observing system, providing a home for the otherwise isolated and independently operated sites around the globe. OceanSITES continuously invites and encourages all operators of sustained open-ocean time series at fixed sites to participate in the project, on the condition that the data will be shared freely and publicly with only the required processing delay, ideally in real-time.

There are a few criteria which serve to keep the project manageable and to avoid duplication of efforts in other programs, such as a requirement for reasonably high temporal resolution (usually at least monthly, for very long time series quarterly), exclusion of repeat hydrography or SOOP sections, and exclusion of national coastal moored networks (which already have a management structure).

In preparation for OceanObs'09, the recently created OceanSITES project office has been in contact with many known operators of sites that may qualify for inclusion in the system, requesting needed information about the sites in the case of interest to participate. The map in Fig. 2 shows the current status based on the feedback received so far, and this is evolving and being updated continuously.

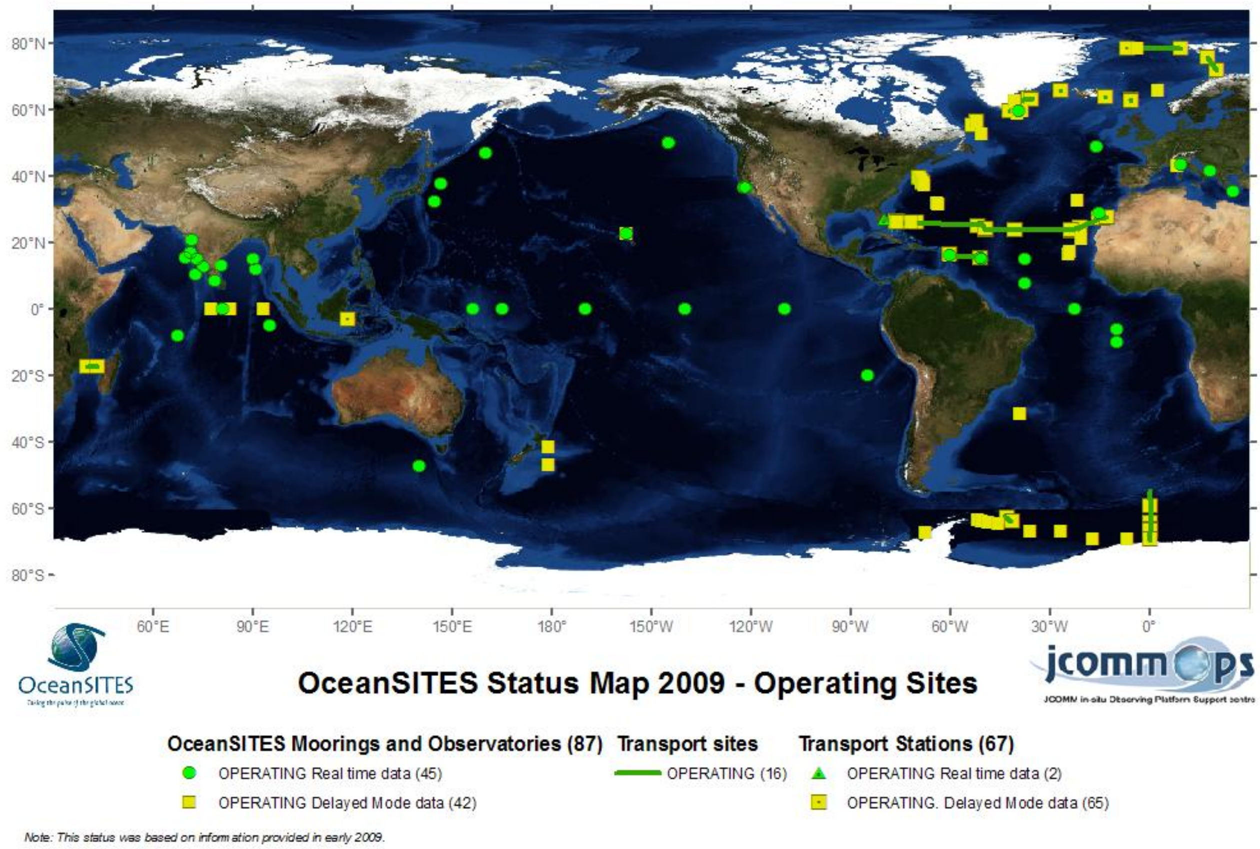

Figure 2: Current status of OceanSITES based on a census of sites/operators that are willing to participate in the project and make their data publicly available to the OceanSITES data system. The tropical arrays TAO/TRITON/PIRATA/RAMA are also part of the global system, but for clarity only the biogeochemical "super" sites are shown here.

While the map may look impressive in terms of the pure number of sites, it is somewhat misleading since many of the present locations measure only a few variables focused on a specific discipline or process (e.g. circulation, air-sea fluxes, convection, benthic environments). As a result, the system is extremely inhomogeneous, making it difficult and often impossible to compare measurements from several sites and analyze data in a network or system sense. Based on inputs from members of the OceanSITES

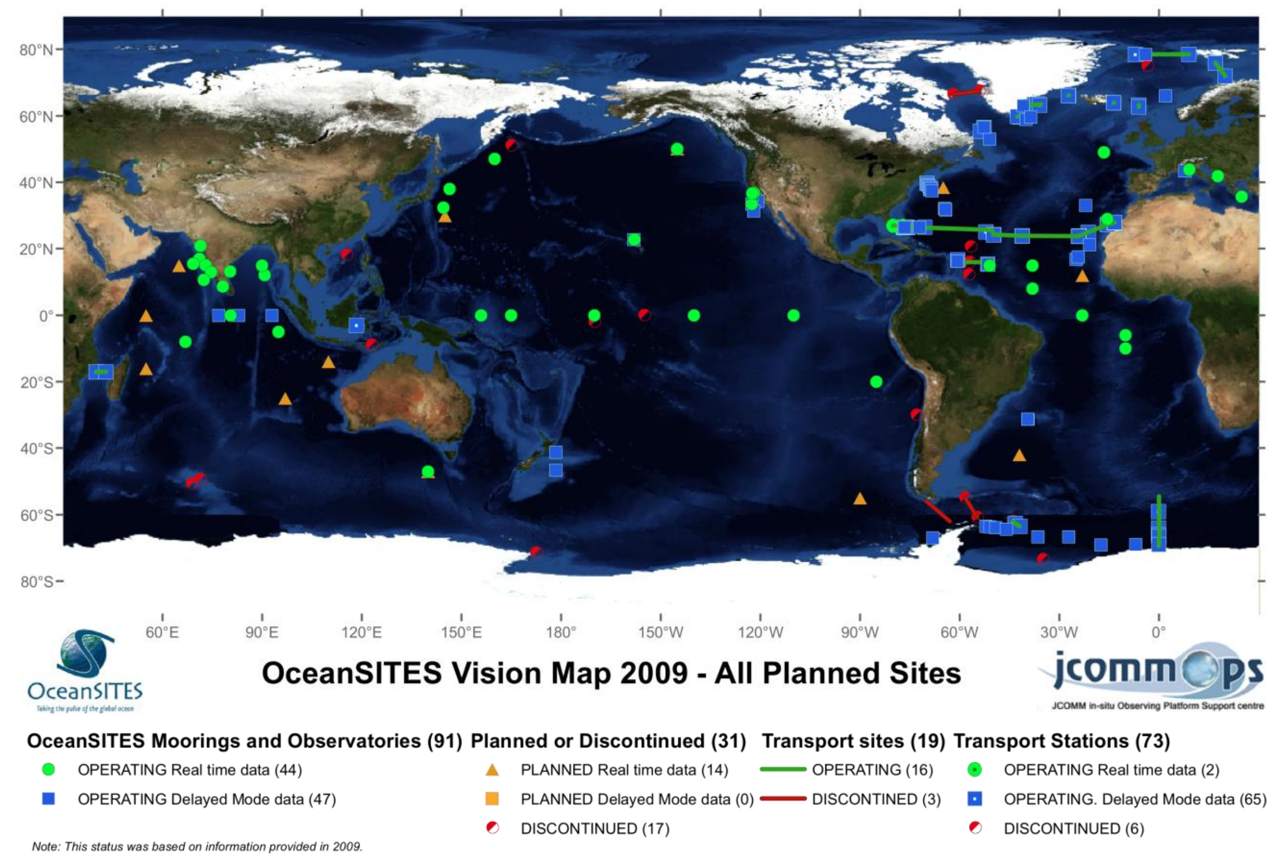

Figure 3: Probable near-term status of OceanSITES based on a census of sites/operators that are willing to participate in the project and make their data publicly available to the OceanSITES data system. The tropical arrays TAO/TRITON/PIRATA/RAMA are also part of the global system, but for clarity only the biogeochemical "super" sites are shown here.

group, Figure 3 shows the probable near-term development of OceanSITES.

3. HOMOGENIZING THE SYSTEM

In order to make the sites more comparable and allow comparisons or joint analyses, as many of them as possible need to be multi-disciplinary, delivering measurements (ideally with equivalent methods) that are of interest to many disciplines. Apart from a few well-known ship occupied sites, the initial system comprised mainly moored time series of physical and/or atmospheric measurements. Since then, biogeochemistry, carbon science and ecosystem studies have become increasingly important in time series observations of the ocean and, in fact, some of the prime examples and successes of sustained ocean time series come from these disciplines. One of the main drivers now for time series is to provide both monitoring and process observations to detect, understand, and predict global biogeochemical changes, probably with a focus on ocean carbon uptake/storage and acidification, but including the role of and impact on ecosystems.

A practical and rapid way forward would be to establish a globally distributed "core" or "backbone" network of selected sites in representative biomes, or biogeochemical provinces, that carry out a minimum suite of identical measurements of atmospheric forcing, physical variables, biogeochemical processes, and ecosystem parameters. The goal is to use moorings with real-time telemetry and existing sensor technology. These would serve as sustained background observations, around which other, more intensive process-oriented studies can be clustered with enhanced spatial footprint or more ship visits for in-situ verification of autonomous measurements. They would also enable a global-scale time-series study of biological production, O_2 and CO_2 dynamics in relation to surface fluxes and mixed-layer dynamics.

4. A BACKBONE MULTIDISCIPLINARY NETWORK

The proposed backbone measurement program is "minimalistic" because a conscious effort has been made to reduce the number of measurements and associated sensors and costs to the minimum necessary to address a key scientific issue. Such an approach is necessary in order not to jeopardize OceanSITES principles such as expansion of geographical coverage, inter-comparability of measurement sites, data-quality and data-availability, and sustainability over the long-term. Additional measurements, or sensors to address other scientific questions, would have to be supported with separate funds and, possibly, additional platforms. They would however have access to, and therefore potentially benefit from, the basic information collected by the backbone program.

Apart from providing atmospheric, physical and circulation observations, the initial scientific focus for this core network is on understanding CO_2 and oxygen dynamics in the upper layer of the ocean and their relation to daily to seasonal phytoplankton primary production, net community production and mixed layer dynamics.

Phytoplankton occupy a central role in oceanic ecosystems, as their nutrient uptake, growth and sinking mediate: (1) the biogeochemical fluxes of carbon and other elements (here oxygen and nitrate as well as carbon) between the surface ocean and the atmosphere and deep ocean, and (2) the conversion of inorganic nutrients and sunlight to the organic compounds that support essentially all life in the seas. Because the atmosphere and oceans are physically coupled, climate exerts strong effects on phytoplankton-mediated biogeochemistry and food webs. How can we measure in a cost-effective manner the time-varying relationships between atmospheric forcing and phytoplankton production and associated changing air-sea gas fluxes in different parts of the global ocean?

We propose instrumentation of a geographically-distributed set of long-term moorings with a core set of meteorological measurements of atmospheric forcing (heat, radiation, wind) and air-sea fluxes, physical oceanographic measurements of mixed layer dynamics and circulation, chemical measurements of pCO_2, oxygen and nitrate and optical measurements of phytoplankton biomass. This would provide the basis for significant advances in our understanding of these relationships as well as an invaluable data set for interpolation, extrapolation and interpretation of observations from other in-situ observing systems (e.g. ARGO-O2, VOS), development of biogeochemical models, and development of algorithms for satellite remote sensing.

4.1 Approach

Within the mixed-layer, the concentrations of both inorganic carbon and dissolved oxygen are altered by net community biological production (with opposing signs). These biologically forced changes are inter-related by a relatively constant photosynthetic quotient (ref Laws, others). The associated variations in oxygen are rapidly re-equilibrated with the atmosphere via air-sea fluxes on timescale days to weeks, whereas the pCO_2 of seawater is relatively insensitive to air-sea exchange (equilibration timescale seasons to years. These differences and relations between O_2 and inorganic carbon can be used, in the context of a time-series data set, which includes detailed physical characterization, to separately determine estimates of net community production and air-sea gas fluxes.

An example of this approach was demonstrated recently by [4] based on long-term time-series of pCO_2, pO_2 and physical data from a mooring in the central Labrador Sea. Figure 4 from this data set shows

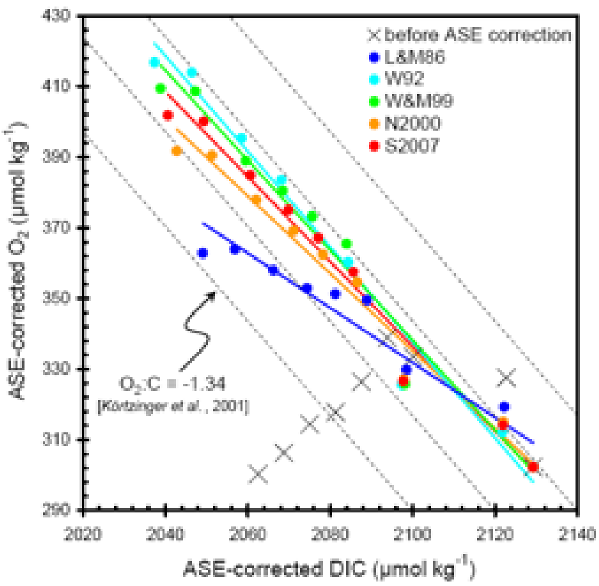

Figure 4. Relation of DIC and oxygen concentration [4]. The colored circles denote concentrations after correction for gas exchange using various wind-speed dependent parameterizations; the crosses denote the dissolved inorganic carbon (DIC, calculated from pCO_2 and estimated alkalinity) uncorrected, measured values.

the relationship between weekly-averages of mixed-layer and oxygen concentrations from a long, moored time-series before and after correction for the effects of gas-exchange. It is clear that only certain gas-exchange parameterizations give O_2/CO_2 variability consistent with known values of the photosynthetic quotient. It is also clear that the magnitude of the gas-exchange correction is as much as 6x larger for $[O_2]$ as it is for

[DIC]. Based on this, the gas-exchange-corrected DIC trend can give useful information on net community production in the mixed-layer.

(Note also that empirical verification of the effective rate of gas exchange between the ocean and the atmosphere for a time-series site is required given continuing controversy over the appropriate parameterization of the wind-speed dependence of gas transfer coefficients as well as concern that such parameterizations' may be location- and time-specific given the potential influence of surface films and/or surface wave conditions.)

A first global-scale attack at the scientific issue outlined above should be within reach in terms of potential resources. We judge that a scientifically useful demonstration of the approach would require a core network of 10-15 ocean sites with an identical, minimal set of high-frequency measurements, in different ocean basins, latitudes and biogeochemical provinces. Figure 5 provides a map with a set of sites put forward for consideration as the set of backbone sites. The sites should cover a range of external forcing and operate long enough to detect climate variability. The minimum measurements proposed are:

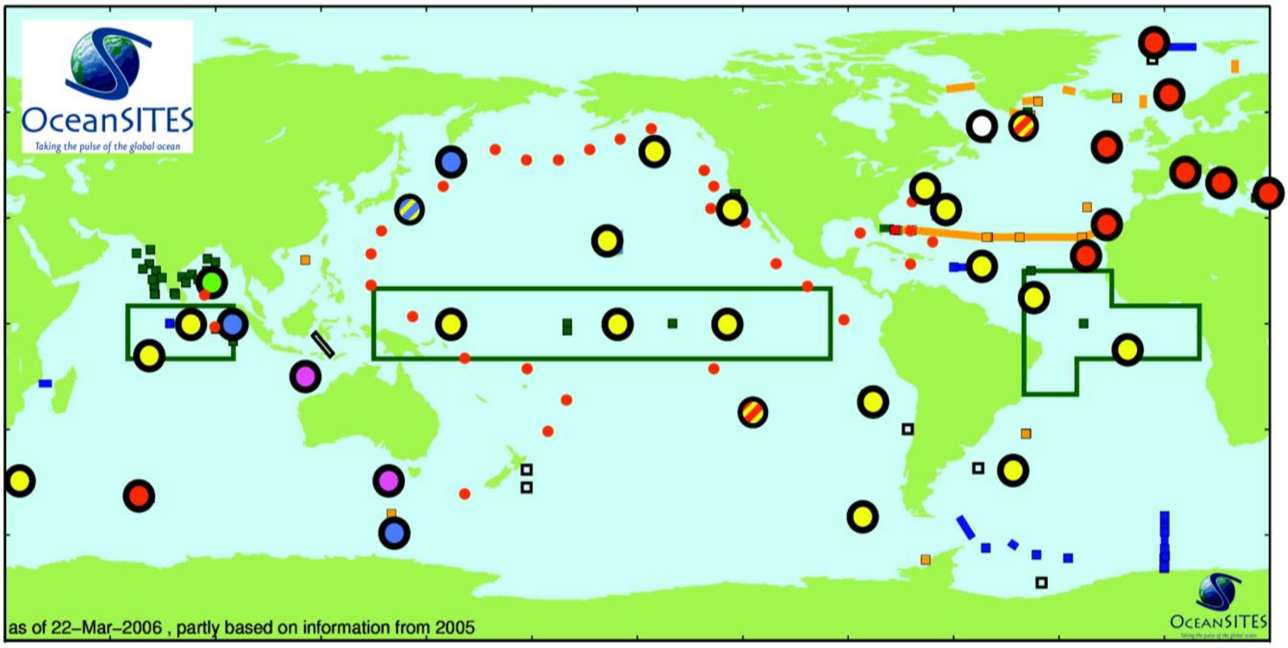

Figure 5: A selection of candidate sites where the backbone multi-disciplinary moorings with identical measurements could be installed. Most of them already have existing or planned sites that would lend themselves to upgrading. Boxes encompass the areas covered by the tropical moored arrays: RAMA in the Indian Ocean, TAO-TRITON in the Pacific, and PIRATA in the Atlantic. Solid lines denote locations where transports are measured. The large circles are the proposed backbone sites, color-coded by potential sources of support (red–European, yellow-US, blue-Japan, green-Indian, purple-Australia.

1. Surface heat/water/momentum flux measurements
2. 15 m currents for mixed-layer circulation studies
3. at least 10 temperature sensors to resolve the detailed mixed-layer structure and dynamics
4. One pCO_2 sensor (near-surface). This is essential to estimate the DIC drawdown associated with net community production. The required estimate of alkalinity must be derived from measurement of surface salinity and empirical alkalinity-salinity relationships. Based on these data, an estimate of the regional and temporal sea-air flux of CO_2 can be derived. The data also provide a long-term estimate of natural pH variability as well as long-term trends associated with ocean acidification.
5. Circa. 5-6 O_2 sensors (covering the mixed-layer and extending into the permanent thermocline). Oxygen data simultaneous with measurements of pCO_2 allow definition of net community production as well as gas exchange with the atmosphere. Oxygen concentrations (Apparent Oxygen Utilization) are correlated with nitrate below the ocean mixed layer.

6. Dissolved nutrients: Nitrate sensors (one within mixed-layer) and one at an additional depth in the permanent nitricline. Surface nitrate measurements are essential for understanding the forcing of net community production measured with the gas sensors and potentially are relevant for any variability in the photosynthetic quotient. Information on sub-surface nitrate is important for understanding supply of nutrients to the euphotic zone, which fuels net production. In-situ nutrient analyzers are expensive and nitrate profiles can potentially by reconstructed more cost-effectively based on higher depth-resolution measurement of T, S and O_2 below the mixed-layer. There are also issues of biofouling for the surface sensor or analyzer.

7. Biomass variability: Net production is correlated with biomass as well as light, temperature, nutrients, etc. In-situ measurements of biomass are problematic due to calibration and measurement issues with fluorescence measurements, variations in the relation between fluorescence and chlorophyll, and variations in the relation between chlorophyll and carbon-biomass. We propose that a minimalist approach to measuring integrated biomass would be to deploy at least two sub-surface spectral radiometers that can be compared with data from a similar sensor deployed on the surface buoy (i.e. an above water reference). The exact number and deployment depths for the instruments will depend on local conditions (e.g. attenuation characteristics of the water column). Some spectral information should be collected (including 490 nm, but also 400 nm and other wavelengths) as this can provide a basic data set for algorithm development and testing.

8. Full water-column characteristics, hydrography and transport: Although the biogeochemical sensors will focus on processes in and near the surface mixed layer and the euphotic zone, they must be combined with a full-depth mooring that is suited to long-term measurements of hydrographic conditions in the deep ocean and large-scale geostrophic shear and water mass transport. Hence the moorings should be equipped with ca. 20 T/S sensors (or profiling CTDs), oxygen sensors, current profilers, and bottom pressure sensors.

4.2 Implementation

In order to implement this, the basic concept should be discussed between OceanSITES and national and international programs. This is already initiated within the SOLAS program but must be expanded to IMBER. The SOLAS-IMBER carbon panel is one group that could take this forward in cooperation with OceanSITES. The International Ocean Carbon Coordination Project is another obvious body to work on implementation.

Basic steps are as follows:

1. Approval of the OceanSITES concept and backbone design in principle by international bodies and scientific groups (e.g. SOLAS, IMBER, IOCCP, IOCCG as well as, potentially, space agencies interested in ocean color, sea surface salinity, and surface circulation calibration).

2. Formation of an OceanSITES task team of physical and biogeochemical oceanographers to plan an initial network of sites. Obviously, sites where components of the network are already established or where useful time-series are also established should be strongly considered in this process. Figure 3 shows candidate sites that would lend themselves to upgrading.

3. Writing of proposals, acquisition of funding. (Generally, at a national level, once national possibilities, interests, and responsibilities have been identified).

The initial investment needed for sensors would be 200-250k$ per site, plus possibly 100k$ to upgrade the existing mooring hardware/configuration. Thus a one-time investment of approximately 5Mio$ could get this going at roughly 15 sites and truly provide a quantum leap for time series reference observations of the ocean. The challenge of course would be to sustain the effort, and provide the disciplinary and sensor expertise, for servicing, maintenance, quality control, and this is something the OceanSITES and partner communities need to take on as a shared responsibility.

5 DATA SYSTEM

Another requirement to make the system a success is easy access to all OceanSITES data in a unified format with agreed QC procedures and best practices, and the development of products and indicators for a variety of users. This has been initiated now within the project but depends on the contributions of all members and operators of OceanSITES.

Global Data Centers (GDACs) for OceanSITES now are Coriolis/IFREMER in France and NDBC/NOAA in the USA, operating as mirror sites. These centers provide virtual or centralized access to all OceanSITES data, maintain the OceanSITES data catalogue, and check the consistency of the files and data delivered. The GDACs receive the data from Data Assembly Centers (DACs), which assure availability of the PI data, implement the agreed OceanSITES format, perform agreed QC procedures, and supply real-time data to the GTS. Future distributed data may physically reside at the DACs. For small site operators, regional DACs will offer their services, but large institutions operating many sites and having required infrastructure may act as their own DAC. Look at http://www.oceansites.org/data/ for links to the GDACs and other data servers.

Metadata are being collected by the GDACs with the help of the DACs and the OceanSITES project office. A Data Management Team consisting of the active and interested participants has been created and is coordinating the efforts of data collection, formatting, delivery, quality control and quality assurance. Details about the format and procedures can be found in the manual and documentation at www.oceansites.org.

6. BENEFITS

Coordinating the many independently operating sites around the globe and bringing them together in an umbrella system has a number of benefits. Probably the single most important aspect is the development of a user community, which will be essential for assuring the long-term maintenance of the observations. Providing the data from a *network* of sites in a unified format with standardized QC procedures, and assuring the ongoing availability of the data, is the pre-requisite for developing working relations with other communities and users. No modeller or remote-sensing developer will take the effort to develop validation procedures or metrics that depend on data, which come and go, or for sites that measure something different at each location. A functioning data system thus is a priority, as is the development of products and indicators, which are useful for researchers, programs, organizations, agencies, policy-makers, and the public.

Joint advocacy also can make a difference, since a global project like OceanSITES has more weight and visibility than a single site operated by one PI. Several researchers already found it helpful for their national funding requests to be a recognized element of the official time series component of the global ocean observing system.

The interaction and regular meetings by the time series operators in the OceanSITES Science Team allows for exchange of expertise and ideas, the development of common approaches and technologies, and mutual support and sharing of efforts.

7. OUTLOOK

A vision and goal for OceanSITES is to collaborate across disciplines, agencies, and countries to implement, share and mutually enhance such sites and platforms. The joint implementation of the backbone system described above would be a huge success. A number of national, regional, and international efforts are showing progress in their areas of focus. Interest in ocean acidification monitoring has lead to increased deployment of carbon dioxide sensors. A number of countries are looking at how to add sustained sampling of the high latitudes. For example, the U.S. National Science Foundation's Ocean Observatory Initiative will add four sustained sites at high latitudes (Irminger Sea, Gulf of Alaska, Argentine Basin, and in the Southeast Pacific off southern Chile; see AC-4A-40: The Ocean Observatories Initiative) and EuroSITES will also address the Irminger Sea (see AC-4A-17: EuroSITES: The Central Irminger Sea (CIS) Observatory); and an element of the Australian Integrated Marine Observing System will be a time series sites south of Tasmania. OceanSITES seeks to coordinate across diverse efforts and disciplines and provide the common sampling, open data exchange, and commitment to multidisciplinary sampling that will make the sum of all the sustained time series sites an even more valuable component of the ocean observing system.

In part, this requires OceanSITES to work toward sustained support of its sites. In support of this OceanSITES will continue to work with international research programs such as WCRP, the Partnership for the Observation of the Global Ocean (POGO), national ocean research and observing programs, and the international ocean observing organizing bodies such as JCOMM-OPS. As part of this, OceanSITES should work toward enabling capability. Thus, another joint step forward would be the development of a standard mooring design, essentially an OceanSITES blueprint, that can be replicated anywhere in the world, coupled with training and manuals for mutually agreed procedures that draw on the expertise of the entire OceanSITES community. A goal must be also to work across borders and program boundaries to supply disciplinary, technical and sensor expertise to each other. Establishment of a project office aligned with JCOMM-OPS has been an important enabling step, and building the foundation of international contributions to support the project office is a critical task now at hand.

The OceanSITES project office (projectoffice@oceansites.org) is continually collecting updated information about sites that want to participate in the network, and making those available via the OceanSITES website in tabular and graphical form (http://www.oceansites.org/network/index.html). A Google Earth interface is being developed that will provide interactive status about each site.

OceanSITES is now positioned to become the global sustained time series reference network for studying processes, events, and changes related to ocean circulation, air-sea interaction, carbon uptake and ocean acidification, ocean biogeochemistry, and ecosystems, at representative or critical sites in the climate and Earth system.

8. REFERENCES

1. Cronin, M.F., Fairall, C.W., & M. McPhaden, M.J. (2006). An assessment of buoy-derived and numerical weather prediction surface heat fluxes in the tropical Pacific. *J. Geophys. Res.*, 111, C06038, doi:10.1029/2005JC003324.

2. Bretherton, C. S., Uttal, T., Fairall, C.W., Yuter, S.E., Weller, R.A., Baumgardner, D., Comstock, K., Wood, R., & Raga, G. B. (2004). The Epic 2001 Stratocumulus Study. *Bull. Amer. Met. Soc.*, **85**(7), doi: 10.1175/BAMS-85-7-967.

3. Körtzinger, A., Send, U., Lampitt, R. S., Hartman, S., Wallace, D. W. R., Karstensen, J., Villagarcia, M. J., Llinás, O. & DeGrandpre, M. D. (2008), The seasonal pCO_2 cycle at 49°N/16.5°W in the northeastern Atlantic Ocean and what it tells us about biological productivity, *J. Geophys. Res.*, **113**, C04020, doi:10.1029/2007JC004347.

4. Körtzinger, A., Send, U., Wallace, D. W. R., Karstensen, J. & DeGrandpre, M. (2008). The seasonal cycle of O_2 and pCO_2 in the central Labrador Sea: Atmospheric, biological and physical implications. *Global Biogeochem. Cycles* **22**, GB1014, doi:10.1029/2007GB003029.