Intergovernmental Oceanographic Commission

Workshop Report No. 217

Changing Times: An International Ocean Biogeochemistry Time-series Workshop

La Jolla, California
5-7 November, 2008

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Abstract:
Despite repeated acknowledgement by the international community that time series stations are critical for understanding the processes controlling ocean carbon and biogeochemical cycles, maintaining funding support for these platforms and research programs has been difficult. To support and strengthen the ocean carbon and biogeochemical time-series effort, the IOCCP, OceanSITES, POGO, and the U.S. OCB program sponsored a workshop to mobilize the community to participate in the OceanSITES international network and to highlight the critical research that can only be carried out using time-series (both ship-board and autonomous) observations.

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1. INTRODUCTION TO THE WORKSHOP

Time-series studies comprised a major component of the Joint Global Ocean Flux Study and are providing a continuing legacy of biogeochemical observations over time scales suitable to examine climate forcing. The Hawaii Ocean Time-series, Bermuda Atlantic Time-series Study and CArbon Retention In A Colored Ocean time-series, for example, now have nearly twenty years of data including a wide array of biogeochemical observations in different ocean regions. Literally hundreds of publications have come from the time-series sites and a whole generation of scientists has had some connection to these sites.

Despite repeated acknowledgement by the international community that time series stations are critical for understanding the processes controlling ocean carbon and biogeochemical cycles, maintaining funding support for these platforms and research programs has been difficult. Without a coordinated network of scientists using the stations in an organized effort, community involvement in these programs has become dispersed. Without international support, it is possible that many programs will not continue in the future.

In 1999, at the request of and with sponsorship by GOOS, CLIVAR, and POGO, an international group of scientists formed the OceanSITES program to develop a coordinated, interdisciplinary international network of stations, research programs, and scientists to sustain and enhance the use of open-ocean time-series observations. Although the physical oceanographic community is strongly tied into OceanSITES and biogeochemists are represented on the committee, the biogeochemical community still lacks coordination and involvement. To support and strengthen the ocean carbon and biogeochemical time-series effort, the IOCCP, OceanSITES, POGO, and the U.S. OCB program sponsored a workshop to mobilize the community to better coordinate their time series efforts, to highlight the critical research that can only be carried out using time-series (both ship-board and autonomous) observations and, where possible, to participate in this international network.

The workshop brought together 40 participants from 17 countries to review the scientific rationale for sustained time series observations of carbon and biogeochemistry; the value of networking observations; existing global, regional, and national programmes; needs, interests and emerging issues; technology and development issues; and collaboration and networking needs, interests and possibilities.

The workshop consisted of plenary talks on exciting new science coming from time series studies, brief presentations of time series stations from all 17 countries, and break-out groups to compile basin-scale observing system information, to identify the major science drivers and development of priorities for the next 5-10 years, and to identify regional needs and opportunities for networking and coordination.

Chair, Chris Sabine, welcomed the participants to the meeting (see Annex 1) and introduced the sponsors and committee members for the workshop. He thanked the local organizers, Uwe Send, Tony Koslow, and Tomomi Ushii for their assistance and Scripps for its support for the meeting.

Sabine introduced the goals for the meeting and reviewed the provisional agenda (see Annex 2). Specifically, the goals of the workshop were to:

- identify on-going activities and plans using time series observations;
- examine the suite of observational methods and try to develop standard approaches that will allow more direct comparison of results from different sites;
- review emergent science from the existing ocean time-series sites;
- review the balance between ship-based and moored time series sites;

- identify carbon and biogeochemistry research priorities that can best be addressed through time series observational programs;
- analyze gaps in the network for addressing research priorities;
- encourage and facilitate the development of new collaborations using time series networks;
- explore the potential for using basin-scale and globally networked time series stations;
- inform the ocean carbon and biogeochemistry community of the OceanSITES global network and data management system for the array; and,
- facilitate incorporation of ocean time-series data into model ground-truthing, sensitivity and error analyses, and model-data fusion activities.

Sabine noted that products from this meeting include an on-line station inventory of carbon and biogeochemistry time series work, a workshop report, an EOS or Oceanography magazine article, and possibly plans for a coordination and communication network in collaboration with OceanSITES.

2. OVERVIEW OF LONG-TERM TIME SERIES OBSERVATIONS OF CARBON AND BIOGEOCHEMISTRY

2.1 BERMUDA ATLANTIC TIME SERIES (BATS)
Michael Lomas and the BATS Team

The BATS (1988-) and Hydrostation S (1954-) time-series have allowed observation of seasonal to interannual to decadal changes in hydrography and elemental cycles of carbon, nitrogen and phosphorus in the Sargasso Sea. The combined BATS/Hydrostation S CO_2 time-series (from 1983) is the longest continuous record of oceanic uptake of anthropogenic CO_2, changes in ocean acidification and an increase in CO_2 inventories (IPCC 2007; Bates 2007; Bates and Peters 2007). The surface ocean DIC content has increased at an average rate of ~0.7 µmoles kg^{-1} yr^{-1} while *p*H has increased, and carbonate saturation states have decreased (Bates 2007). Air-sea CO_2 fluxes have also increased over the last two decades as windspeed has increased in this sector of the subtropical gyre in response to climate change and climate mode variability (such as North Atlantic Oscillation, NAO; El Niño-Southern Oscillation, ENSO). In addition, in the North Atlantic subtropical gyre, the CO_2 content of the 18^{o}C subtropical mode water (i.e., Eighteen Degree Water, EDW; lying between the seasonal and permanent thermoclines) has increased at a rate (e.g., ~2.2 µmoles kg^{-1} yr^{-1}; Bates et al. 2002) that is double the rate in surface waters. This increase has been related to changes in ocean mixing and NAO variability, and has resulted in enhanced storage of CO_2 in EDW (with an upper limit of ~2.5 Pg C) over the last two decades.

These oscillations in the dominant climate modes in the western subtropical North Atlantic also appear to have an impact on ecosystem parameters measured at BATS. With the change in mean wintertime (DJFM) NAO index from positive to neutral in 1996 average euphotic zone integrated chlorophyll concentrations have doubled to ~35 mg m^{-2}. Coordinated with this increase in chlorophyll concentrations has been in a commensurate increase in euphotic zone integrated primary production and carbon export to 150m. Theses changes are coherent in time and magnitude suggesting an overall increase in the magnitude of the shallow biological carbon pump. This increase, we hypothesize, is supported by more frequent mixing of nutrient-rich source waters into the euphotic zone associated with this change in the NAO that results in storm tracks closer to Bermuda. This increase in autotrophic biomass and productivity has not been uniform over all phytoplankton groups however, as there has been a decrease in the importance of larger mineral-ballasted eukaryotes (ie., diatoms and coccolithophores) and an increase in the importance of smaller cyanobacteria, specifically

Synechococcus. Furthermore, this increase in the shallow biological carbon pump has not translated into increased carbon export through the mesopelagic. Attenuation of POC fluxes has increased associated with increases in heterotrophic metabolism (evaluated by changes in AOU). During this time free-living bacterial productivity has significantly decreased while micro- and macro-zooplankton biomass, and likely metabolism, has significantly increased.

These changes in the inorganic carbon chemistry and biology of the western subtropical North Atlantic, linked to and perhaps driven by climate variability, need to be included in mechanistic ecosystem models of this region. These findings further highlight the critical role that biogeochemical time-series play in generating, and testing, hypotheses about long term changes in the ocean.

2.2 CARBON RETENTION IN A COLORED OCEAN (CARIACO TIME SERIES STATION)

Eduardo Klein

CARIACO is an inter-institutional, international, hypothesis-driven time series located in the Southeastern Caribbean (10.5°N -65.67°W). The Cariaco basin is a depression (~1400m) in the continental shelf off Venezuela with strong seasonal upwelling and permanent anoxia below ~250m. The ship-based station has completed, as of October 2008, 148 monthly core-cruises, 27 sediment and current meter cruises, 28 biogeochemical and microbial process cruises, and 5 regional cruises. Core measurements include standard continuous variables (CTD, fluorescence, beam attenuation, dissolved oxygen) and discrete water column chemical/biological variables (oxygen, C, N, P, Si, Chl and pigments, zooplankton, phytoplankton, bacteria, viruses) throughout the entire water column (surface - 1310m). Carbon assimilation (Primary and bacterial production, minerals) is also assessed, as well as optical measurements (surface irradiance, downwelling irradiance, upwelling radiance, satellite imagery). The station also maintains an array of moored sediment traps at five depths (150, 230, 410, 810, 1200m) used to estimate particle flux measurements, and a moored ADCP (>200m; Physical Oceanography program ended in CARIACO in 2008 because of lack of funding).

The time series has been able to discern the seasonal wind-driven upwelling pattern of the southeastern Caribbean. We have observed a progressive decrease in the upwelling intensity since 2001, which reached a minimum in 2005 and resulted in regional sardine fishery collapse. Since 2006 the upwelling has slowly recovered, but not the fisheries. A secondary upwelling period and annual production peak were identified in June-July of every year. Upwelling delivers high DIC and CO_2 fugacity into the euphotic zone (Source of CO_2). However, the evasion of CO_2 has decreased slightly in the last 12 years due to weaker upwelling and an increase in atmospheric pCO_2. Advection of water into the basin through the sills surrounding it is a major source of oxygen to the oxic-anoxic zone (ventilations). Since 1997 we have also observed a decrease in chemoautotrophic bacterial production but we don't known whether this is related to changes in primary production. Particulate Organic Carbon flux is poorly related to surface productivity, but closely related to ballast materials. The time series has been able to detect transient events (phytoplankton blooms, earthquake-induced turbidity flows, coastal flooding) that have resulted in the rapid delivery of large sediment volumes to the sea floor.

The CARIACO time series can contribute to understanding the connections between observed changes in primary / secondary production / particle fluxes in the southeastern Caribbean and climatic variations in the North Atlantic (and their link to sediment record). The integration of CARIACO measurements with other TS stations (ESTOC/BATS) may facilitate the detection/study/monitoring of variations in NA gyre intensity. In this context, the integrated time series analysis may help to understand the connection between changes in the process of

Subtropical Underwater (SUW) formation in the NA and its emergence (Margins, Tropics), including detecting long-term changes in N* and biogeochemistry of the NA as recorded in the SUW. Finally, CARIACO observations can provide elements to local and regional ecosystem studies and ecosystem-based management, in particular fisheries in the region.

CARIACO implements a policy for open and public sharing of samples, data, and information. We maintain data repositories in Spanish and English and contribute to the OCB Data Management Office.

2.3 EUROPEAN STATION FOR TIME SERIES IN THE OCEAN (ESTOC)

Melchor Gonzalez

The long-term trends and the average seasonal variability of inorganic carbon in the surface and interior ocean were presented for the European Time Series in the Canary Islands (ESTOC), based on a 10-year series (1995-2004). Seasonal de-trended data of salinity-normalized C_T (NC_T) and experimental fCO_2 show upward trends of 0.99 ± 0.77 µmol kg^{-1} yr^{-1} and 1.57 ± 0.28 µatm yr^{-1}, respectively, indicating a direct relationship between the C_T concentration and the increase in atmospheric CO_2 concentration. The ESTOC series of experimental pH_T data confirm the acidification of surface waters in the East Atlantic Ocean with an inter-annual decrease of 0.0017 ± 0.0006 pH units yr^{-1}. Surface changes are also observed in the upper 1500 m at ESTOC with an important $pH_{T,25^o}$ decrease for the upper 1000 m, where a decrease of 0.0006± 0.0001 is observed. Strongly correlated with the increase in carbon dioxide and reduced pH values, a decrease in the calcite and aragonite saturation state that will affect calcification processes and producers in the next decades is also described.

2.4 THE HAWAII OCEAN TIME-SERIES (HOT): TEMPORAL DYNAMICS IN ECOSYSTEM PROCESSES IN THE SUBTROPICAL NORTH PACIFIC OCEAN

Matthew Church and the HOT Team

Since October 1988, the Hawaii Ocean Time-series (HOT) program has measured a suite of biogeochemical and physical oceanographic properties at approximately monthly time scales at Station ALOHA (22.75^{o}N, 158^{o}W) in the subtropical North Pacific Ocean. In addition to the monthly shipboard sampling program remote and autonomous sensing measurements have been integrated into the shipboard sampling program to provide higher frequency observations of ocean dynamics in this region. Together, this integrated observing system continues to provide unique insight temporal variability in ecosystem processes over time scales ranging from diurnal to decadal. Among the most notable findings, HOT has documented multi-decadal changes to the upper ocean carbonate system, including significant increases in upper ocean pCO_2 with coincident declines in seawater pH. In addition, upper ocean nutrient inventories, and plankton biomass and productivity all appear sensitive to climate-driven (*e.g.* ENSO and the Pacific Decadal Oscillation) variations in ocean physics. Moreover, the sustained observations at Station ALOHA are helping to resolve a potentially important role for mesoscale physical processes in episodic restructuring of plankton community composition and altering rates of new production at Station ALOHA.

The value of the time series record at ALOHA continues to increase. We now recognize several prominent scales of variability important to controlling ocean biogeochemistry, including: 1) secular scale processes such as those driven by natural and human-induced climate change); 2) cyclic processes such as those driven by recurring seasonal and interannual processes); and 3) episodic or event scale processes including those controlled by mesoscale variations in ocean physics. A nearly 15 year record of deep sea material fluxes demonstrates clear seasonality, with peak fluxes occurring in the summer when the upper ocean is strongly stratified and inorganic nutrient concentrations are at their seasonal minimum. Pulsed delivery of carbon to the bathypelagic coincides with delivery of particulate silica, suggesting open ocean diatoms serve an important role in the net movement of material from the upper ocean to the sea bed. Nitrogen isotope signatures of the resulting flux material coupled with direct measurements of nitrogen fixing cyanobacteria indicate nitrogen fixation fuels a major fraction of new production during these episodic flux events.

2.5 CALCOFI AND THE CALIFORNIA CURRENT: A 60-YEAR OCEANOGRAPHIC, BIOGEOCHEMICAL AND FISHERIES TIME SERIES

Tony Koslow and Ralf Goericke

The California Cooperative Oceanic Fisheries Investigations (CalCOFI), a partnership of the Scripps Institution of Oceanography, the National Marine Fisheries Service, and the California Department of Fish and Game, has carried out observations of the of the physics, chemistry, plankton and fisheries of the California Current since 1949. Since 1984, cruises have been carried out quarterly, focusing in the area from north of Point Conception to the US-Mexico border. The data have been used to characterize the influence of the El Nino/La Nina cycle, the Pacific Decadal Oscillation, and, most recently, the North Pacific Gyre Oscillation on physical, chemical and biological aspects of the California Current Large Marine Ecosystem. The potential impacts of long-term climate change are also being observed, including a secular warming trend and a trend toward increased stratification. Since 1984 chlorophyll concentration has increased, but not primary productivity or zooplankton. Data since 1984 also indicate a long-term decline in oxygen levels in the southern California Current, although data back to 1949 indicate a long-term cycle in oxygen concentrations, at least in some areas. Long-term trends are seen in other biogeochemical parameters, such as N*, the balance between inorganic nitrogen and phosphorus in the ecosystem. The relative importance of advection of different water masses and in situ processes in driving these long-term trends is still poorly understood.

Key future directions in CalCOFI include sampling of DIC, pCO_2 and alkalinity on select stations; enhanced sampling of micronekton and small pelagics using acoustics and pelagic trawls, leading to the development of end-to-end models of the California Current; sampling at higher temporal scales with gliders and moorings; and improved database management, linking with other west coast time series.

3. THE SCIENTIFIC VALUE OF NETWORKING OBSERVATIONS

3.1 EVOLUTION OF AUTOMATED INTERDISCIPLINARY TIME SERIES MEASUREMENTS

Tommy Dickey

Oceanographic time series measurements have evolved over the past 25 years thanks to new technologies and a renaissance of interdisciplinary oceanographic research (e.g., compare the work of Fridtjof Nansen (see biography by Huntford, 2001) in the late 1800’s and early 1900’s with that appearing in the literature in the 1960’s and 1970’s with that of the 1990’s to present). Inspiration for sampling ocean processes ranging from millimeters and seconds to global and climatic scales came from such visionaries as Henry Stommel (1963, 1989) and Walter Munk (2000). Interdisciplinary time-space ocean process diagrams such as those forwarded by Dickey and collaborators (e.g., Dickey, 1991, 2003; Dickey and Bidigare, 2005) now provide experimentalists, managers, and modelers with blueprints for observational and modeling studies. A plethora of new ocean platforms, sensors, and samplers (e.g., Dickey et al., 2006, 2008a,b; see Bibliography), have been tested and used for scientific and scientific studies. Examples from several mooring experiments (reviews by Dickey and Bidigare, 2005; Dickey et al., 2006; see Bibliography) have demonstrated the need for high temporal resolution, vertically resolved data sets. Over the past two decades, mooring-based data sets have been collected by the UCSB Ocean Physics Laboratory (OPL) and collaborating laboratories in diverse oceanographic regions including the North Atlantic (south of Iceland [MLML], north of Bermuda [Biowatt], off Bermuda near the BATS site [BTM]), the Arabian Sea [JGOFS Arabian Sea], the equatorial Pacific [JGOFS Eqpac], the North Pacific (off Hawaii [H-A, HOT site], off Canada [OWS 'P'], off Japan [Station K2], and the California coast [MOSEAN CHARM]). These collective efforts have been valuable in increasing the understanding of the relations and coupling of physical and biogeochemical phenomena that include: seasonal cycles, ENSO, Kelvin waves, rapid spring and fall blooms, dust events, and mesoscale eddy-, hurricane-, tropical instability wave-induced phytoplankton blooms and in some cases quick particle transport to depth (e.g., see Bibliography).

Several important lessons have been learned during these interdisciplinary, autonomous-sampling research programs. For example, collaborations among researchers using a variety of platforms and models have led to productive time series programs that have advanced both technologies and led to scientific paradigm shifts. Partnerships built among the academic, government, and commercial sectors have accelerated new discoveries and transitions and proliferation of key technologies. Many challenges to automated time series programs remain. In particular, it is especially difficult to continue to impress reviewers and agencies of the importance of long-term, high frequency observations when funding cycles are typically only a few years. Also, biofouling continues to be a limiter for many measurements. The recent identification of the rapid ocean acidification problem (Feely et al., 2004; Doney et al., 2008), the role of hurricanes and typhoons in affecting upper ocean dynamics, thermodynamics, ocean color, primary productivity (e.g., Dickey et al., 1991; Zedler et al., 2002; Dickey et al., 2001; Babin et al., 2004; Black and Dickey, 2008) and CO_2 fluxes (Bates et al., 1998), and dust deposition effects (e.g., Bishop et al., 2002; Sholkovitz et al., 2006) are especially noteworthy. Understanding and modeling interactions among these (and other) exemplary phenomena and longer term (interannual, decadal, and climate scales) phenomena are especially challenging, but ultimately critical. Development and testing of requisite technologies require significant investment of time and funds. Considerable energy needs to be spent in forming effective partnerships and collaborations – sharing of ideas, data, and credit for successes is highly desirable and ultimately beneficial. Finally, we have found that a diversified research approach including technological-, exploratory-, process-, model- and operationally-based modes of oceanographic activities is intellectually stimulating, scientifically productive, and valuable for maintaining long-term funding.

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3.2 THE VALUE OF NETWORKING TIME-SERIES OBSERVATIONS

Richard Lampitt

The science community, policy makers, and society need time series observations to:

- detect changes
- describe & quantify them
- understand & explain them
- predict future trends

In order to provide the necessary description of temporal changes in the oceans and how these variations are generated, we need observing systems that are sustained, synoptic, of adequate resolution and interdisciplinary. There are several types of observing system falling under the categories: Satellite remote sensing, Ships (Research vessels and Voluntary Observing Ships), Drifters and gliders and Eulerian (fixed point) observatories (Shelf seas Open ocean). In order for us to extract maximum benefit, these need to be integrated such that the data can be effectively used by a variety of groups and most particularly by the modelling community.

Autonomous sensors are an important component of our observational capability. At present there is a limited range of state variables that can be recorded autonomously and such as they are, many of the sensors are unreliable, prone to biofouling, difficult to use and do not address rate variables. However this is an area where considerable progress is taking place and there is optimism that in the next five years, the range of sensors will be much greater and we will have enhanced confidence in acquiring long term high quality data from them.

Marine time series have been poorly used by the IPCC in comparison with those from the cryosphere and land and part of this is due to their inevitable high cost due to the hostility of the environment and remoteness of sites. However other reasons are that the data have often been discontinuous due to funding gaps and that the data are not easily accessed. Coherent and well-focused efforts by the marine science community are required in order to address both of these points and although there is evidence of success in some areas such as for the open ocean fixed point observatories (OceanSITES) and for satellite observations, there is still considerable demand for increased cohesion in the community to draw together these disparate sources of data. The expectation and hope is that this will be progressed during OceanObs 2009.

3.3 NET BIOLOGICAL OXYGEN PRODUCTION DETERMINED FROM IN SITU MEASUREMENTS

Steve Emerson

In this talk, Emerson demonstrated the utility of in situ measurements of oxygen and nitrogen gas on moorings and sea gliders to determine net biological oxygen production in the subtropical Pacific at the Hawaii Ocean Time Series (HOT) and in the subarctic Pacific at Stn. P. This work is an outgrowth of previous studies of oxygen and inert gases at ship-based time series stations, and it is our goal to extend these types of measurements to many more sites than is logistically and economically possible by ship-based programs. The net annual O_2 production in the mixed layer at these locations is determined by interpreting hourly measurements of pressure and wind speed in the atmosphere and temperature, salinity and total dissolved gas pressure at a single depth in the mixed layer. Net oxygen production below the mixed layer is determined using and annual cycle of seaglider oxygen measurements. Preliminary results of these studies indicate that the net annual biological oxygen (and organic carbon) production in the subtropical ocean at HOT is at least as great as that determined in the subarctic Pacific at Stn P. This observation contrasts the trends in organic carbon export fluxes predicted from satellite and global ocean circulation models. One possible explanation for this difference is the seasonality of organic matter export observed at these two locations. At HOT there is net biological oxygen production during most of the year while in the subarctic ocean at Stn P net carbon export occurs mainly in the summertime. Seasonal differences in the efficiency of net primary production export appear to play an important role in determining the annual carbon export at these two locations.

3.4 TIME SERIES OF THE OCEAN ECOSYSTEM BY REMOTE SENSING

Trevor Platt

In the context of fixed-station in situ ocean time series, remote sensing offers the following advantages when used as a complementary observing tool:

1. Constructing parallel time series
2. Setting the fixed-station data in a broader oceanographic context.
3. Giving a basis for interpolation of data between in situ sampling dates.
4. Enhancing the interpretation of both time series.

Using a combination of ocean-colour data (SeaWiFS) and sea-surface temperature (AVHRR) data, we can recover a variety of ecosystem indicators (See Table below) that serve as objective metrics of the state of the marine ecosystem for operational application to detect change (Platt and Sathyendranath 2008), and for use as an information base to support ecosystem-based management. As a combined observing strategy, remote sensing and in situ time series give us a very good picture of the changing ocean ecosystem.

Reference: Platt & Sathyendranath (2008) Remote Sensing of Environment 112: 3424-3436

Table: Some ecological indicators for the pelagic ocean, as developed from remotely-sensed spectral radiometry in the visible (ocean colour)

Indicator	Label	Dimensions
Initiation of spring bloom	b_i	[**T**]
Amplitude of spring bloom	b_a	[**ML**$^{-3}$]
Timing of spring maximum	b_t	[**T**]
Duration of spring bloom	b_d	[**T**]
Initial slope of light-saturation curve	α^B	[**L**^{2}]
Assimilation number	P_m^B	[**T**$^{-1}$]
Total production in spring bloom	b_p	[**ML**$^{-2}$]
Annual phytoplankton production	P_Y	[**ML**$^{-2}$]
Generalised phytoplankton loss rate	L	[**ML**$^{-3}$**T**$^{-1}$]
Integrated phytoplankton loss	L_T	[**ML**$^{-3}$]
Particulate organic carbon	C_T	[**ML**$^{-3}$]
Phytoplankton carbon	C_p	[**ML**$^{-3}$]
Carbon-to-chlorophyll ratio	χ	dimensionless
Phytoplankton growth rate	μ	[**T**$^{-1}$]
Spatial variance in biomass field	σ_B^2	[**M**^{2}**L**$^{-6}$]
Spatial variance in production field	σ_P^2	[**M**^{2}**L**$^{-4}$]
Phytoplankton functional types	NA	NA
Phytoplankton size	d	[**L**]
Delineation of biogeochemical provinces	NA	NA

Table: Some ecological indicators for the pelagic ocean, as developed from remotely-sensed spectral radiometry in the visible (ocean colour)

4. GLOBAL, REGIONAL, AND NATIONAL PROGRAM REVIEWS

4.1 OCEANSITES
Uwe Send

OceanSITES is a global network of fixed open-ocean sites that:

- collect time-series of atmospheric, physical, biogeochemical, or ecosystem variables
- are sustained or planned to be sustained
- use mooring or ship-board observations (minimum monthly) or cable or glider observations
- share data freely and in real-time or with minimum delay
- want to cooperate to be part of the network.

The unique contributions and strengths of fixed time series observations were highlighted, but also the difficulty to develop users and demonstrate the value of the network because current sites are very inhomogeneous, data access is either difficult or not available, and QC procedures are not comparable.

Recent developments and initiated activities include:

- adoption of a new version of the OceanSITES NetCDF data format, establishment of two Global Data Assembly Centers (GDACs), agreement on roles of DACs and operators, establishment of two working groups on QC and best practices, etc

- facilitating sharing of platforms, ship time, expertise, etc.
- increasing interactions with other communities
- developing products and indicators from global time-series in the network
- developing a minimum set of core sensors and advocating a core/backbone network of identical minimum time series observatories.

The current definition of a time-series in OceanSITES was presented, which includes criteria such as 'sustained in-situ observations at fixed geographic locations of ocean/climate related quantities at a sampling rate high enough to unambiguously resolve the signals of interest', 'truly Eulerian data, i.e. no ship sections or underway data, no surveys with vessels or gliders around a site', etc., 'coastal time-series are included when they are instrumented to have multidisciplinary impact on the global observing system and if they are not part of a national coastal buoy network', 'real-time data telemetry of operational variables will be pursued, i.e. make effort if technically feasible', 'agreement to make data public in near real-time for real-time data or as soon as processed and post-calibrated for other data'.

A set of discussion issues for the breakout groups was proposed.

4.2 EUROSITES: THE EUROPEAN NETWORK OF FIXED-POINT OPEN OCEAN OBSERVATORIES

Richard Lampitt

EuroSITES forms an integrated European network of nine deep-ocean (>1000m) observatories around Europe. It is coordinated by the National Oceanography Centre, Southampton, UK and involves 13 Partners across Europe and the Cape Verde Islands.

EuroSITES is funded by the EU FP7 (3.5M Euro over 3 years) and integrates and enhances the existing European open-ocean observational capacity to encompass the ocean interior, seafloor and subseafloor. It is designed to produce a more reliable ocean observatory network with common funding streams and data management systems and can be considered as the European implementation of OceanSITES. The network will also enhance the development of more sophisticated sensors to measure more complex properties of the oceans. This will allow a greater understanding of the impact of the changing global Ocean and Earth on mankind and ecosystems at large. This has implications for policy makers, production industries (e.g. fisheries, agriculture) service industries (e.g. insurance) and society at large.

EuroSITES was officially launched on April 1 2008 and further information is available on: http://www.eurosites.info/

4.3 THE CHLOROPHYLL GLOBAL INTEGRATED NETWORK (CHLOROGIN)

Nick Hardman-Mountford

ChloroGIN (the Chlorophyll Globally Integrated Network) is a network of researchers from five continents who are committed to integrating *in situ* time series of chlorophyll measurements with satellite ocean colour-based observations. The network was formed as the outcome of a workshop in Plymouth, UK, on Chlorophyll observations from satellites and *in situ* methods, with support from GOOS, GEO, POGO, IOCCG and Plymouth Marine Laboratory. It builds on an existing Latin American network, Antares, to include representatives from other regions globally. The aim of the project is to promote *in situ* measurement of chlorophyll in combination with satellite derived estimates, to bridge the gap between the two and provide integrated products. Its two main objectives are (a) to deliver products, namely maps of ocean chlorophyll and sea surface temperature, as indicators of the state of the ecosystem needed for ecosystem and fisheries management, and (b) at some sites, to provide a measure of light penetration into the ocean that is needed, along with the other two variables, to calculate plankton primary production. These are three of the core variables recommended for the Global Coastal Network listed in the GOOS Coastal Panel strategic plan. A key factor in developing such an integrated approach globally is capacity building to provide regional expertise. The ChloroGIN workplan consists of two five-year periods, with the first five years aiming to develop infrastructure and regional capacity and the second to move towards fully operational status. Presently, the network consists of three regional centres, in Latin America, Africa and South Asia, linked by good communications to four northern centres (UK, Italy, USA, Canada). There is a global web portal for linking the regional and northern centres at www.chlorogin.org. Additional activities to date include supporting an African training course in ocean colour remote sensing and the development of the DevCoCast project to deliver processed satellite data and value-added products to developing countries. ChloroGIN has recognition as a GOOS pilot project and addresses GEO task EC-06-07.

4.4 NOAA CARBON PROGRAMS

Chris Sabine

Ship-based time-series measurements are impractical for routinely measuring variability over intervals from a week to a month, they cannot be made during storms or high-sea conditions, and they are too expensive for remote locations. Instrumental advances over the past 15 years have led to autonomous moorings capable of sampling properties of chemical, biological, and physical interest with resolutions as good as a minute and duty cycles of a year or more. Although these new technologies are still underutilized, they have been identified as a critical component of the global ocean observing system for climate. In 2004, the moored CO_2 program was initiated by NOAA's Office of Climate Observations (OCO) as part of the ocean carbon observing system. The PMEL built moored pCO_2 systems (MAPCO_2) collect CO_2 and O_2 data from surface seawater and marine boundary air every three hours. A summary file with each of the measurements is transmitted and plots of the data are posted to the web once per day (http://www.pmel.noaa.gov/co2/moorings/). The moored CO_2 network is still in its infancy, but is quickly expanding into a global network of surface ocean and atmospheric CO_2 observations that will make a substantial contribution to the production of seasonal CO_2 flux maps for the global oceans. The long-term goal of this program is to populate the network of OCEAN Sustained Interdisciplinary Time-series Environment observation System (OceanSITES; http://www.oceansites.org/) so that CO_2 fluxes will become a standard part of the global flux mooring network.

4.5 OCEAN OBSERVATORIES INITIATIVE

Uwe Send

The OOI has the goal to provide a transformative interactive ability to conduct multi-disciplinary experiments at remote sites in the ocean. In some sense it is the opposite of the minimum core OceanSITES configuration, by trying to build a maximum capability but at very few locations. There are currently three global locations planned; in the Irminger Sea, at ocean station PAPA, and in the high latitude South Pacific off southern Chile. Each site would have 4 moorings (a surface mooring and an adjacent subsurface profiler mooring, 2 flanking mesoscale mooring) and 3 gliders operating around the sites. An extensive set of multi-disciplinary sensors would be installed on the moorings, profilers, and gliders. Details of the moorings, the sampling, the sensors, and the potential applications were given in the presentation.

4.6 U.S. OCB INTERESTS AND NEEDS
Deborah Bronk

This talk introduced the work of the Ocean Carbon and Biogeochemistry (OCB) and Ocean time-Series Advisory Committee (OTSAC) and focused on the strengths and weaknesses of ship-based time-series and what the community needs to do to move the science forward. Strengths of existing United States sites include: 1) the ability to resolve monthly and inter-annual scale processes, 2) they support interdisciplinary research, 3) they are centers for collaboration, 4) they serve as test beds for instruments and methods, and 5) they are hypothesis generators. Weaknesses of ship-based time-series sites in general are that: 1) there are too few of them and the funding does not exist to expand the number, 2) there is difficulty in coordinating data from all relevant sites or past data sets, 3) there is no long-term storage and archiving of samples, 4) there is a focus on chlorophyll when there is a high need for community composition data, 5) there is a focus on the surface mixed layer despite the increasing recognition of the importance of the mesopelagic and benthos, 6) maintaining continuity of personnel and methods between sites is challenging, and 7) there is a lack of reference materials and certified standards for many measurements. In the bigger picture there are a number of characteristics of ship-based measurements that are holding the science back - they are not able to resolve daily to event-scale processes, there is a lack of spatial context, and there is an inability to respond to event-scale phenomena.

To move the science forward we must integrate the use of moorings, gliders and floats at the sites and throughout the ocean. These platforms have the ability to resolve time scales of minute to days, can provide broad spatial context, and can respond on the event scale. The following action times are suggested: 1) develop platforms and sensors to measure more things, 2) consider developing a sample archive system, 3) establish certified reference materials for all core measurements, 4) establish best practice manual and technical training and exchange programs, and 5) continue to streamline and interface datasets.

4.7 OCEAN ACIDIFICATION TIME SERIES
Richard Feely

Ocean acidification may be one of the most significant and far-reaching consequences of the increase of carbon dioxide in the atmosphere. Some call this the “other CO_2 problem” because, like global warming, it is driven by anthropogenic CO_2 (Doney et al., 2008). It is conceivable that the basic food-web structure of the ocean could change over the next 50 years. It is imperative that we rapidly improve our fundamental understanding of the impacts of ocean acidification on ocean chemistry and ocean biology. Because these changes are unprecedented in the modern era, we cannot predict with confidence how marine ecosystems will respond to this stress in the future. This rapidly emerging scientific issue and possible ecological impacts have raised serious concerns across the scientific and fisheries resource management communities.

An ocean carbon observatory network of approximately 20 sites in U.S. territorial and open-ocean waters of the Atlantic and Pacific would be developed leveraging off existing monitoring sites (OceanSITES). Current observations are insufficient to adequately monitor the ocean acidification because: (a) they are limited in spatial extent, with gross under sampling in the Atlantic and Pacific, which is one of the areas where the impacts of ocean acidification are expected to be most severe; and (b) they measure too few parameters to fully constrain the carbonate system, hindering effective forecasting. Developing an ocean carbon observatory network would fill this gap by ensuring that key parameters (i.e., pH, pCO_2, etc.) for understanding and forecasting the effects of ocean acidification on marine ecosystems. Outputs of monitoring are necessary precursors for forecasting the impact of ocean acidification on living marine resources. This observatory network is a prerequisite for further developing and validating models of ocean acidification.

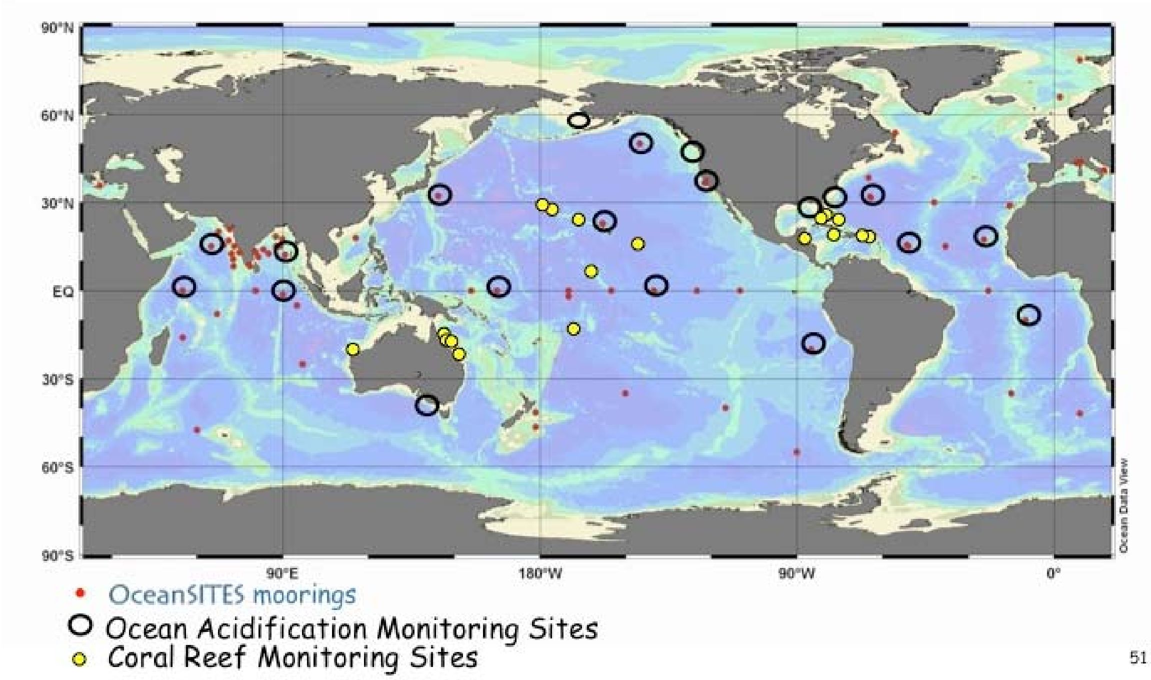

Figure 1. Proposed ocean acidification monitoring sites in open-ocean and coastal regions.

4.8 STATION OVERVIEWS

Information on 38 programs from 17 countries was presented though brief overviews in plenary, station information meta-data sheets, and discussions in the basin break-out groups (see list below and on-line inventory at http://ioc3.unesco.org/ioccp/Time%20series/ChangingTimes.html). The inventory of sustained monitoring programs included 14 moorings, 7 fixed-point ship stations, 11 ship sections, several land-based and coastal stations, and profiling floats. While an inventory by platform is helpful to determine which of these sites might be able to contribute to the OceanSITES project, participants noted that most carbon and biological time series programs are carried out using multiple platforms around either a single point, a repeated section, or an array of sections and points. Some stations will not meet the OceanSITES criteria (focus on Eulerian sites only), but could benefit from closer communication and coordination.

Atlantic Ocean Stations

- Irminger Sea Station - Jon Olafsson
- Iceland Sea Station - Jon Olafsson
- Porcupine Abyssal Plain (PAP) Station – Richard Lampitt
- TENATSO Cape Verde Station – Doug Wallace
- The Östergarnsholm field station (Baltic Sea) – Anna Rutgersson
- CARBON-OPS network (Western European shelf seas stations, Atlantic time series and VOS lines, and Antarctic sections) – Nick Hardman-Mountford
- Barrow Straits Sections – Kumiko Azetsu-Scott
- Atlantic Zone Monitoring Program (Scotian Shelf, Newfoundland Shelf, Gulf of St Laurence) – Kumiko Azetsu-Scott
- Davis Strait sections – Kumiko Azetsu-Scott

- Labrador Sea Section – Kumiko Azetsu-Scott
- Ocean Weather Station M – Ingunn Skjelvan
- European Station for Time Series in the Ocean at the Canary Islands (ESTOC) – Melchor Gonzalez
- DYFAMED – Franck Touratier
- Antares-Ubatuba Station – Milton Kampel
- Carbon Retention in a Colored Ocean (CARIACO Time Series Station) – Eduardo Klein
- Bermuda Atlantic Time-series Study (BATS) and Hydrostation “S” – Mike Lomas
- Bermuda Testbed Mooring – Tommy Dickey
- Gulf of Maine CO_2 mooring – Doug Vandemark
- Piscatuqua River, New Hampshire pCO_2 station – Doug Vandemark
- Gulf of Maine / Wilkinson Basin transect – Doug Vandemark

Pacific Ocean Stations

- K2 and S1 mooring and ship stations – Tsuneo Ono
- P9 underway and hydro sections – Tsuneo Ono
- line section – Tsuneo Ono
- Hawaii Ocean Time-series – Matthew Church
- Line P – Lisa Miller
- Station P – Meghan Cronin
- Kuroshio Extension Observatory (KEO) – Meghan Cronin
- Equatorial Pacific underway and mooring stations – Richard Feely
- Monterey Bay – Francisco Chavez …. still missing station information sheet
- COPAS Chilean TS – Oscar Pizarro…. still missing station information sheet
- Ensenada TS – Martin Hernandez
- CalCOFI – Tony Koslow…. still missing station information sheet

Indian Ocean Stations

- GOA time series station – VVSS Sarma
- Bay of Bengal coastal station - VVSS Sarma
- Bay of Bengal open ocean station (BOBFLUX) - VVSS Sarma
- VEBGES Godavari Estuary station - VVSS Sarma

Southern Ocean Stations

- Southern Ocean Time Series station – Tom Trull
- King Sejong Station / King George Island – Young Chul Kang

Multi-Basin Programs

- Apex/ISUS profiling floats (HOT, BATS, Station Papa, and Southern Ocean) – Ken Johnson
- $MAPCO_2$ surface moored CO_2 systems – Chris Sabine

5. TECHNOLOGY AND DEVELOPMENT ISSUES

5.1 TECHNOLOGY OVERVIEW
Ken Johnson

Time series observations based on periodic shipboard visits to fixed positions or by moorings deployed with autonomous sensors have been our major source for data and insights into changing biogeochemical processes in the ocean. However, the logistical constraints involved in providing ship time, personnel and equipment to support these types of time series will greatly limit most opportunities for their expansion. Surface sensors may be added to moorings deployed for other purposes, but these do not generally provide an opportunity to observe processes deeper in the water column. Satellite sensors can provide very significant information on processes at the ocean surface, but little information on the vertical structure of biogeochemical processes. Given the concern that much of the ocean is undersampled, we must look to new technologies that can be scaled to large numbers for global observations of changing biogeochemistry in the ocean.

It is now possible to deploy a suite of biogeochemical sensors on autonomous and Lagrangian platforms, such as profiling floats and gliders. It has been shown that these sensors can be deployed for multiple years and return high quality data with little or no drift. For example, oxygen sensors have been deployed on profiling floats for periods as long as three years with no detectable drift (Kortzinger et al., 2004; Riser and Johnson, 2008). These sensors have been utilized to study a variety of physical and biological processes in the ocean. Spatial variability and rates of ecosystem productivity have been assessed with oxygen sensors on gliders (Nicholson et al., 2008; Niewiadomska et al., 2008). Carbon export in the subsurface can be assessed from observations of oxygen consumption rates in the meso-pelagic zone using profiling floats (Martz et al., 2008). There are now more than 150 profling floats equipped with oxygen sensors and a proposal has been made to equip the Argo profiling float array with oxygen sensors (Gruber et al., 2007).

Bio-optical sensors have been deployed on profiling floats with a number of innovative results (Bishop et al., 2002, 2004). The technology has now developed to the point that these sensors have operated for three years with no detectable drift. These data show mesoscale events that lead to carbon export to depth (Boss et al., 2008a, b). The spatial variability in bio-optical properties, including the seasonal development of a subsurface chlorophyll maximum, have been monitored for four years with sensors on gliders deployed off the Pacific Northwest coast of the USA (Perry et al., 2008).

Nitrate sensors have been demonstrated to operate for one year with little drift on profiling floats (Johnson et al., 2008) and they have the potential to operate for periods as long as five years. In addition, efforts to develop high stability pH sensors for autonomous, profiling platforms have also begun. Particulate inorganic carbon sensors are being developed with an intent to deploy them on profiling floats (Guay and Bishop, 2002).

The consistency, precision, temporal and vertical coverage in time series observations that are being obtained with autonomous, Lagrangian platforms simply cannot be matched in shipboard or mooring based observing programs. Further, the capability of these platforms to be deployed in large numbers is demonstrated by the global Argo array, which consists of >3000 profiling floats. While the number of variables observable from autonomous platforms is small, these variables can be proxies for major components of the carbon cycle. An integrated observing system that combines in situ sensors deployed on long endurance platforms with satellite sensors and data-assimilating, biogeochemical-ecological models would provide previously unachievable constraints on the carbon cycle and its sensitivity to a changing climate. It would transform ocean biogeochemistry.

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Bishop, J.K.B., T.J. Wood, R.E. Davis, and J.T. Sherman. 2004. Robotic observations of enhanced carbon biomass and export at 55S. Science 304: 417-420.

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Boss, E., D. Swift, L. Taylor, P. Brickley, R. Zaneveld, S. Riser, M.J. Perry and P. G. Strutton. 2008b. Observations of pigment and particle distributions in the Western North Atlantic from an autonomous float and ocean color satellite. Limnology and Oceanography: 53, 2112-2122.

Gruber, N., S. C. Doney, S. R. Emerson, D. Gilbert, T. Kobayashi, A. Körtzinger, G. C. Johnson, K. S. Johnson, S. C. Riser, and O. Ulloa. 2006. The Argo-Oxygen program: A white paper to promote the addition of oxygen sensors to the international Argo float program. http://www-argo.ucsd.edu/o2_white_paper_web.pdf.

Guay, C. K. H. and J. K. B. Bishop. 2002. A rapid birefringence method for measuring suspended $CaCO_3$ concentrations in seawater. Deep-Sea Research I: 49, 197-210.

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5.2 WHAT ARE SATELLITE MEASUREMENTS OF OCEAN COLOR RADIOMETRY TELLING US ABOUT CHANGE IN THE OCEAN?

Jim Yoder

Four recent manuscripts (Gregg, W. et al. 2005, *Geophys. Res. Lett.*, 32, L03606, doi: 10.1029/2004GL021808; Antoine et al. 2005, *J. Geophys. Res.*, 110, C06009, doi: 10.1029/2004JC002620; Behrenfeld et al. 2006, *Nature* 444 doe:10.1038/nature0517; Polovina, J.J. et al. 2008, GRL 35: doi:10.1029/2007GL031745) indicate that phytoplankton chlorophyll/carbon concentrations in large regions of the ocean are decreasing, possibly owing to climate change effects on ocean stratification. However, 3 of the 4 manuscripts are based on time series that began in fall, 1997, with the launch of SeaWiFS. Thus, these time series were intiated during the beginning of one of the largest ENSO events of the century. Other studies (Yoder, J.A. and M.A. Kennelly. 2003. *Global Biogeochemical Cycles*, 17, 1112- ; Yoder, J.A. and M.A. Kennelly. 2006. *Oceanography*, 19: 159- ; Wilson and Adamec, *JGR* 106. 2001) showed that both the *El Nino* and *La Nina* phase of that ENSO event had significant impacts on satellite chlorophyll concentrations in many regions of the global ocean affecting global satellite ocean color radiometry (OCR) anomalies for several years, including high chlorophyll anomalies in the *La Nina* phase which began in 1998. The result is that satellite time series that began in 1997/98 appear to be significantly aliased by the ENSO and that the apparent decrease in satellite chlorophyll in the gyres and other locations may be an adjustment back to normal conditions rather than a long-term trend related to climate change. This conclusion is supported by preliminary analyses of global model output (from a model forced by reanalysis fields, i.e. the physical forcing has a degree of realism) which indicate that the type of changes observed, for example, in an 8-year SeaWiFS record beginning in 1997 are not atypical of changes in model chlorophyll during other 8-year intervals dating back to 1958. Thus, recent papers have not made a conclusive case for changes (trends) in phytoplankton chlorophyll or other OCR products related to climate change, although ocean climate signals (e.g. ENSO, NAO) do have interannual effects evident in the imagery. Longer records will be required to sort out interannual and other cyclical effects from changes related to a changing climate and changing ocean.

The SeaWiFS and MODIS-Aqua project teams, along with ESA's MERIS project team and affiliated program (GlobColour), have led the international community in satellite data analyses of a sufficiently high quality to meet requirements for "climate variables", i.e. measurements that can be used to detect and monitor changes in ocean variables related to climate change. In the U.S., neither NASA nor NOAA has an approved OCR mission that can sustain this time series. ESA plans to continue the time series started by MERIS, and other countries are also planning to launch OCR missions. However, many believe that the expertise developed by the SeaWiFS and MODIS projects will also be important in the future to sustain satellite OCR time series of climate quality data, beyond the lifetime of SeaWiFS and MODIS. The IOCCG is working with the Committee on Earth Observation Satellites (CEOS) to encourage a new level of international cooperation, so that valuable climate quality satellite OCR time series will be collected and distributed in the future to support the Global Climate Observing System (GCOS) and to serve other essential needs.

6. COLLABORATION AND NETWORKING NEEDS, INTERESTS AND POSSIBILITIES

Participants divided up into two groups: Atlantic and Pacific/Indian/Southern Ocean. Group members were asked to discuss which carbon and biogeochemistry stations might meet the OceanSITES criteria (e.g., Eulerian, open data policy), which sites do not fit well within the OceanSITES structure, and to consider what coordination needs the community has in general that should be addressed outside the framework of OceanSITES. Specifically, the charge to each group was to:

- Complete list of who is doing what where
- Major science driver(s) requiring a coordinated time series network
- Major time series development priorities for the next 5-10 years
- Networking and coordinating needs (platforms, data sharing, standards, etc.)

The group reports are given in Annexes 5 (Atlantic) and 6 (Pacific / Indian / Southern). The groups met in plenary after the break-out sessions to compare networking needs and interests. The following section outlines the common views discussed and decisions of the group.

<u>We need to integrate, not just coordinate.</u> There is a need to develop one or several major science issues to be addressed with time series observations. Participants felt that program managers receive a mixed message when we argue the importance of time series stations for global oceanography but then only list individual issues to be addressed at one site through a particular program. Both individual time series and a network of time series would be strengthened by focusing on integrating issues, such as the ability of the ocean to take up carbon or understanding the drivers and coherence of large-scale changes in ocean ecosystems. It was recognized that the strength of time series measurements over other approaches is the ability to resolve seasonal cycles or other rapid events such as mesoscale eddies or dust events, and any overarching questions should keep this unique capability in mind. The basin groups listed several large-scale issues that require time series observations for consideration. Participants stressed that we need to integrate, not just coordinate, both in terms of large-scale science issues to be addressed as well as better data integration and synthesis.

<u>OceanSITES can provide a useful coordination mechanism for some carbon and biogeochemistry time series stations, but not all.</u> After reviewing the list of carbon and biogeochemistry time series sites, the criteria for OceanSITES stations (see Section 4.8, above), and discussing coordination needs, some participants suggested that OceanSITES should relax its definition of time series to include all platforms regularly measuring ocean interior changes (minimum seasonal). In order to make OceanSITES manageable and to fill a

real gap in the international coordination activities, the OceanSITES science team decided from the beginning to limit the scope of the coordination to open-ocean fixed (Eulerian) time series, using moorings, ship-occupied stations, and other assets in fixed locations. However, further expansion of the scope at this point in the project's development may jeopardize the initial goals of developing a global open-ocean network of interoperable multi-disciplinary stations with real-time data delivery, and in particular the development of an effective data management system. The OceanSITES team is following the model of the Argo programme in order to first develop a sustained operational system, which may at some later time be expanded to include more variables and more types of stations. Uwe Send proposed some practical compromises that would allow the majority of stations to participate in the OceanSITES network:

1. OceanSITES might accommodate quarterly ship stations (as opposed to monthly) if this sampling frequency is adequate to reveal trends that contribute to the science objectives.
2. For repeat sections, grids, or other types of time series surveys, 1 or 2 stations that are most representative of the global regime or ecosystem provinces could be identified as an OceanSITES station. For example, from the regular ship surveys around Iceland , data were presented by Jon Olafsson from 2 of the stations that were most representative of the Iceland gyre and Irminger Sea as a whole. These stations could represent the Irminger and Iceland sea regimes in the OceanSITES network. A similar approach could be taken with Line P, CalCOFI, and others.
3. OceanSITES stations should be open-ocean stations, but may also be stations in marginal seas or shelf regions if the signals at those stations reveal information about basin and global trends.
4. All OceanSITES data should be public, but delayed mode delivery of data is acceptable where technical reasons require delays of months for preparation (sampling, processing). It was noted that this is the case with the CARIACO station.
5. All OceanSITES stations have to be willing to cooperate and coordinate their station's work with the OceanSITES Data Assembly Center using agreed formats. For biogeochemistry, many of these formats are still under development and this community can play a leading role in defining them.

It was suggested that we open a dialogue between the biogeochemical time series community and OceanSITES based on these modified criteria to determine which of the sites would form the backbone of the global network, as well as some idea of the minimum common sensors that should be proposed for all the stations.

<u>There is still a need for better coordination among all carbon and biogeochemistry time series programs.</u> Participants agreed that those stations that can meet the OceanSITES criteria would benefit from closer coordination in this global network, including having an integrated scientific project and themes to link individual sites as well as a standardized data format and assembly mechanism that is badly needed for biogeochemical observations. However, the participants felt that by only coordinating the Eulerian sites, some of the carbon and biogeochemistry observations would be left out, especially coastal areas where biology and ecosystem work is of most importance, and that the advantages and synergies that could result from having a more inclusive network would be lost. Participants outlined 2 major coordination needs:

1. Information about sustained carbon and biogeochemistry time series activities (station information, contact information, email and web-based communication tools), and
2. To ensure that data from different stations are compatible and comparable (agreements on data formats, standardized methods, certified reference materials, and data archival).

It was noted that the issue of data formats should be closely coordinated with OceanSITES regardless of whether or not an individual station is part of that network. There are several groups (SCOR, US BCO-DMO) working on data archiving for biogeochemistry process studies which may provide some guidance on this issue.

Chris Sabine emphasized that, while the IOCCP could provide a coordination and communication service to the community, this is not the same as working through a project with an internationally recognized science strategy. Having a site on an IOCCP inventory map would not provide the same leverage with national funding agencies as being an integral part of the OceanSITES network. An IOCCP inventory would include stations that are meant to be sustained (e.g., not process studies or one-off projects) and would only consider sites where the data will be made public within a reasonable time period.

OceanObs09 may present an opportunity to develop a unifying science theme for integrated biogeochemical time series observations. While the coordination actions discussed above will be useful for networking existing activities, participants noted that a technical coordination mechanism alone will not be sufficient to improve the funding situation for time series stations. It was suggested that perhaps SOLAS and IMBER or several larger national programs could consider hosting a large time series science meeting to develop a theme for carbon and biogeochemistry time series measurements, and that a first step might be to develop a white paper for OceanObs09 that would propose a structure for a coordinated program to address a unifying theme. Using such a strategy, individual PIs could write proposals to funding agencies to implement their part of the project. Participants agreed that the white paper should identify the unique niche of time series observations in order to distinguish it from the many other white papers that will seek to address large integrated ocean and climate issues, and that the paper should identify a core set of measurements required on each station to meet the science objectives, not simply list a collection of everyone's favorite sensors. In addition, participants were invited to contribute to a planned OceanSITES white paper to assure proper representation of the biogeochemical, carbon and acidification communities.

7. THE WAY FORWARD

Based on the station information provided, a list of sites that may be suitable as OceanSITES stations will be developed and a dialogue initiated between the OceanSITES leaders and the PIs of those sites to determine if / how those stations should be integrated into the program. This interaction should be initiated via the OceanSITES project office (Hester Viola at projectoffice@oceansites.org)

The IOCCP will develop an on-line map and table inventory of all time series stations and activities, as well as an information page with links to presentations from this meeting.

The IOCCP will initiate a discussion with other national and global research programs and coordination projects to determine what data format / standards / archiving initiatives may already exist for biogeochemistry data.

Several participants agreed to work together to draft a white paper for OceanObs09 to outline a scientific theme that would be addressed by carbon and biogeochemistry time series stations. The IOCCP can provide coordination assistance as necessary.

ANNEX I

LIST OF PARTICIPANTS

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ANNEX II

AGENDA

DAY 1 – November 5	
0900 – 0930	**OPENING:** Welcome and intro of organizing committee and sponsors (Sabine) Logistical information (Koslow) Goals for Meeting and overview of workshop organization (Sabine)
0930 –1030	**SESSION 1: Scientific rationale for sustained Time Series observations of carbon and biogeochemistry** *(20 min talks)* • BATS science overview – Mike Lomas • CARIACO science overview– Eduardo Klein • ESTOC science overview– Melchor Gonzalez
1030 - 1050	Break
1050 – 1130	• HOT science overview – Matt Church • CalCOFI science overview – Tony Koslow
1130 – 1200	**SESSION 2: The scientific value of networking observations** *(30 minute talks)* • Evolution of Time Series: From JGOFS to Present (Tommy Dickey)
1200 – 1330	Lunch (provided)
1330 - 1500	• The value of networking TS observations (Richard Lampitt) • The value of networking TS platforms (Steve Emerson) • Satellite TS and links to in situ observations (Trevor Platt)
1500 – 1520	Break
1520 - 1635	**SESSION 3: Global and Regional Programs** *(10 minute talks plus 5 minute Q/A)* • OceanSITES – Uwe Send • EuroSITES – Richard Lampitt • ChloroGIN Program – Nick Hardman-Mountford • NOAA Carbon Programs – Chris Sabine • OOI – Uwe Send
1635 - 1735	**SESSION 4: Needs, Interests, and Emerging Issues** *(20 minute talks plus 10 minute Q/A)* • US OCB Interests and Needs – Debbie Bronk • Ocean Acidification – Dick Feely
1735 - 1900	Close of day 1 and reception, room T-29.

DAY 2 – November	

6	
0900 – 1030	**SESSION 1. Overviews of Time Series Stations** – *(5 minute talks)* 1. Iceland / Irminger - Jon Olafsson (Iceland) 2. Labrador Sea-Kumiko Azetsu-Scott (Canada) 3. DYFAMED/MOOSE-Franck Touratier (France) 4. Carbon-OPS-Nick Hardman-Mountford (UK) 5. OWS Mike- Ingunn Skjelvan (Norway) 6. Baltic Sea-A. Rutgersson Owenius (Sweden) 7. PIRATA- Milton Kampel (Brazil) 8. Gulf of Maine-D. Vandermark (USA) 9. Line P-Lisa Miller (Canada) 10. A lines-T. Ono (Japan) 11. EQPAC-Richard Feely(USA) 12. Monterey Bay-F. Chavez (USA) 13. Chile Time Series / COPAS - Oscar Pizarro (Chile) 14. Ensenada Time Series – Martin Hernandez-Ayon (Mexico)
1030 - 1050	Break
1100 – 1130	Overviews, continued. 15. GOA time series-Sarma(India) 16. NIWA sites-Kim Currie (New Zealand) 17. PULSE-Tom Trull (Australia) 18. King George Island-Y.C. Kang (Korea)
1130-1230	**SESSION 2: Open Discussion – What are our collaboration and networking needs, interests, and possibilities?** Session Chair and Reporter: Francisco Chavez and Craig Carlson.
1230-1330	Lunch (provided)
1330-1500	**SESSION 3: Breakout Groups for Basin Compilations** • Complete list of who is doing what where (should be based on station information sheets filled out before the workshop) • Major science drivers (basin and global) • Major observation system development priorities for the next 5-10 years • Which of these require regional or global coordination? • Networking and coordination needs (platforms, data sharing, standards, etc.) Session Chairs and Reporters: Atlantic Panel: Nick Hardman-Mountford and Kumiko Azetsu-Scott Pacific/Indian/Southern Panel: Kim Currie and Lisa Miller
1500 - 1520	Break
1520 - 1620	Breakout Groups continued (drafting report…)
1620 - 1730	**SESSION 4: Group Reports to Plenary** • Group reports and open discussion

DAY 3 – November 7	
0900 – 1000	**SESSION 1: Technology and Development Issues** • Technology Overview - Ken Johnson • Future TS opportunities through Remote Sensing – Jim Yoder
1000 - 1030	**SESSION 2: Summary Review of Needs and Interests for Global Cooperation** • Review and Discussions - Chris Sabine, Maria Hood (reporter)
1030 - 1100	Break
1100 – 1230	**SESSION 3: Where do we go from here?** • OceanSITES framework for coordination and possible responses to the needs and interests from carbon and bgc community – Send / Lampitt • Open Discussion on how to integrate coordination activities into the framework of OceanSITES
1230 - 1330	Close of Meeting / Lunch (on your own)
1330 – 1500	**Steering Committee Session** – final drafting, action item assignments, practical programmatic considerations.

ANNEX III

ATLANTIC GROUP REPORT

This group was chaired by Nick Hardman-Mountford, and Kumiko Azetsu-Scott served as reporter. The group began by reviewing the list of stations presented at this workshop and discussing other possible time series programs to include in an inventory. The list was provided to the workshop chair for follow-up.

Major science drivers (basin and global)
A top level question that a network of time series sites would enable us to address is: How are ecosystems changing at the basin scale? Associated questions include:

- What are the driving and controlling processes?
- Can we detect the propagation of signals?
- What are the ecosystem feedbacks on the physico-chemical environment?
- Can we detect large scale climate influences (e.g. NAO) on ecosystem processes at the basin scale

Additional questions that would require the network to address include:

- Integration of temporal and spatial scales, to capture the broader impact of event scale processes (e.g. hurricanes, dust deposition)
- Temporal trends in biogeochemical budgets
- Biogeochemical changes in the MOC
- Detection of lag responses in signals of change around the basin

Other issues such as improved resolution of mesoscale processes can also be enhanced. However, synthesis with models and satellite data are more important here, and can play a significant role for all questions. It is important to engage with modelers in designing time series sites.

An area for societal benefit may be an 'Early warning system' with multiple sites making the significance of changes easier to establish.

Major observation system development priorities for the next 5-10 years

- Autonomous sensor development is a high priority (nutrients, pCO2, pH, flowcytometry, species sensor, gene sensor, low cost bio-profiler, primary production, XBT type sensors for biology/chemistry – local and spatial characterization, zooplankton counter)
- Risks to the continuation of oceanographic satellite missions, especially ocean colour, while outside the coordination of this group, would have serious impacts on the activities here.
- Sustainability of expertise within personnel, including training and capacity building, is also a top priority.
- Further development of time series locations should focus on extending regional coverage to fill poorly represented areas (e.g. fill the void in the S. Atlantic) and to enhance existing time series sites.

Which of these require regional or global coordination?
Regional or global coordination could help with all of these, particular areas of focus could be:

- Determine a core set of measurements (as a guide rather than requirement)
- Development of collaborations and dissemination systems

- (Near) Real time is recognized as increasingly important for biogeochemical variables, both for maintenance of autonomous measurements (e.g. diagnostics) and for integration with models (e.g. validation, data assimilation)
- Developing a framework for automated QA/QC systems that evolve in collaboration with PI expertise (e.g. through having both near-real time and delayed mode QC)

Networking and coordination needs (platforms, data sharing, standards, etc.)

- Basin scale integration
- Capacity building
- Ensuring appropriate biogeochemical standards and Certified Reference Materials are available and sustained (including sustained expertise, not reliant on one person in one place.)
- Promotion of the use of DOIs for data sets will help achieve rapid data release in areas where funders do not necessarily require it
- Open-standards and common formats for data are an important consideration

ANNEX IV

PACIFIC / INDIAN / SOUTHERN OCEAN GROUP REPORT

This panel was chaired by Kim Currie and Lisa Miller served as reporter. A list of time series programs that were not included in the inventory developed by the workshop was developed and the list of stations provided to the workshop chair for follow-up.

Major science drivers requiring coordinated network

- Quantifying the spatial coherence vs. differences in temporal changes in the ocean
- Ability of the oceans to take up carbon
- Understanding and predicting ocean acidification
- Hypothesis testing against different sites w/different forcings
- Separating natural oscillations from anthropogenic variations
- What components of the system are in steady state over the annual cycle? On what time frame can we close off a cycle – annual, interannual, decadal...?
- Overarching theme: The Changing Ocean
- Time scales: daily-seasonal; interannual-decadal; millennial & longer
- Ability to understand mechanisms
- Support of modelling & prediction: input/validation data, as well as mechanistics
- Long- vs. short-term warming

Major observation system development priorities

- Sensor development
    - Publicly-funded oceanographic engineering facilities with manufacturing capabilities are needed.
    - Biological as well as biogeochemical, optical & acoustic sensors should be developed.
    - At least 2 sensors for the carbonate system (not pCO2 & pH: we need to have either DIC or At) need to be deployed together.
        - MBARI has an instrument w/precision of 15 micromol/kg (not yet good enough).
        - A carbonate ion sensor is in development (R. Byrne).
- Reference materials are needed for all measurements
    - Including ways to assure continuity (many existing reference materials are produced by labs funded by short-term programs)
- Need for temporal resolution in more locations w/different forcing
    - Central, subtropical South Pacific
    - Indian Ocean (monsoon forcing): equatorial region
    - High latitude Southern Ocean
- Floats:
    - A practical way to get time series in the Southern Ocean.
    - *Sensors* are even more limited (no pCO2, yet).
- Moorings:
    - Also need to expand types of *sensors* available
    - Mechanical/logistics: e.g. submersible winches, water sampler
- Zooplankton observations are critical; rates are best, but stocks also help; ADCP backscatter
- As much as possible we should be augmenting existing resources/sites: *e.g.* fisheries lines
- Noble gases are useful to separate processes.
- If we can measure something, we figure out ways to use it.

Networking and coordination needs

- Would be useful to establish a platinum standard for a time-series site
  - Emphasis that these standards are not necessary to be part of the network, but they provide an ideal to which we aspire, hopefully facilitating funding applications.
  - Suggestion that the JGOFS core parameter document be used as a starting point
    - Different lists are needed for different platforms
    - We need to both add new things and take out things that aren't appropriate or useful
  - Setting standards for methods and calibrations
    - Reference materials (see above)
    - For methods, draw upon existing documents:
      - Guide to best practices for carbon system
      - JGOFs
      - WOCE
- Getting data together is of primary value in international coordination.
  - There is general dissatisfaction with national and international data submission pathways.
  - We need to have a central clearing house for information on all time series sites.
  - Is a central data holding really necessary, or are well-designed web-sites & collections of links adequate?
  - Compatible formats are useful.
- Role of IOCCP:
  - Funding for workshops.
  - Central clearing house of what's out there
    - Maps & metadata, links
  - No resources for data management
- OceanSITES:
  - Data management
    - Do we want an actual data holding or just links to locations (e.g. CDIAC)?
    - Can some mechanism be developed to force data transfers between databases (*e.g.* CDIAC to NODC)
  - Advocacy:
    - Demonstrates users (provides statistics on data usage).
    - Facilitates/encourages funding from national sources.
  - Linked to NOAA monitoring centre for global observing system.
  - Coordinate integrated time series network
- Future workshops
  - There was significant interest in additional, possibly smaller meetings to focus on specific science needs and what kind of time series measurements would be useful in meeting them.
  - Workshops should also be held on specific methods that are not yet standardized.
- A linkage with SCOR working group 125 on global zooplankton time series should be pursued.

IOC Workshop Reports

The Scientific Workshops of the Intergovernmental Oceanographic Commission are sometimes jointly sponsored with other intergovernmental or non-governmental bodies. In most cases, IOC assures responsibility for printing, and copies may be requested from:

Intergovernmental Oceanographic Commission – UNESCO
1, rue Miollis, 75732 Paris Cedex 15, France

No.	Title	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand, 24-29 September 1973 UNDP (CCOP),	E (out of stock)
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (UNESCO Technical Paper in Marine Sciences, No. 20).	E (out of stock) S (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean; Monte Carlo, 9-14 September 1974.	E,F E (out of stock)
4	Report of the Workshop on the Phenomenon known as 'El Niño'; Guayaquil, Ecuador, 4-12 December 1974.	E (out of stock) S (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/ EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F,S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-13 April 1976	E (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience; Mauritius 9-13 August 1976.	E, F, S, R
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring; Monaco, 14-18 June 1976	E, F E (out of stock) R
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E, S (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976	E (out of stock), S
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects; Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, U.S.A., 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of tock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978	E
21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R
24	WESTPAC Workshop on Coastal Transport of Pollutants; Tokyo, Japan, 27-31 March 1980.	E (out of stock)
25	Workshop on the Inter-calibration of Sampling Procedures of the IOC/ WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters; Bermuda, 11-26 January 1980.	E (Superseded by IOC Technical Series No.22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September- 5 October 1979.	E, S
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji, 24-29 September 1985.	E
40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, Submitted Papers; Sidney, B.C., Canada, 29 July-1 August 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, Submitted Papers; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brasil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988.	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness,	E

No.	Title	Languages
	Observation and Instrumentation. Submitted Papers; Novosibirsk, USSR, 4-5 August 1989.	
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC ad hoc Expert Consultation on Sardine/ Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A. 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria, 30 September – 4 October 1991	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, côte d'Ivoire, 26-28 juin 1991.	E
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September-3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Submitted Papers; Paris, France, 9-12 May 1995.	E
109	First IOC-UNEP CEPPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
110	IOC-ICSU-CEC regional Workshop for Member States of the Mediterranean - GODAR-IV (Global Oceanographic Data Archeology and Rescue Project) Foundation for International Studies, University of Malta, Valletta, Malta, 25-28 April 1995.	E
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM, Bali, Indonesia, 22-26 November 1994.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	Atelier régional IOC-CERESCOR sur la gestion intégrée des zones littorales (ICAM), Conakry, Guinée, 18–22 décembre 1995	F
122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October–1 November 1995.	E, S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K.,4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	E

No.	Title	Languages
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden. Jeddah, Saudi Arabia, 8 October 1995.	E
127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E
133	Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997.	E
134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997.	E
135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	E
136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	E
137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	E
138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S
139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA;Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997	S
140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E
141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997.	E
142	Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995.	E
143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7–11 February 1998.	E
144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998.	E
145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997.	E
146	Taller Internacional sobre Formacíon de Capacidades para el Manejo de las Costas y los Océanos en le Gran Caribe, La Habana, – Cuba, 7–10 de Julio de 1998 / International Workshop on Management Capacity-Building for Coasts and Oceans in the Wider Caribbean, Havana, Cuba, 7–10 July 1998	S/E
147	IOC-SOA International Training Workshop on the Intregration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997.	E
148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998.	E
149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E
150	First IOCARIBE-ANCA Workshop Havana, Cuba, 29 June-1 July 1998.	E
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Áreas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998.	S
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine Environment Qingdao, China, 24-26 June 1998	E
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998.	E
155	Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E
156	IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999	E
157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998	E
158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999	E
159	Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium) – Proceedings, Pushkin, Russian Federation, 18-22 May 1998	E
160	Under preparation	
161	Under preparation	
162	Workshop report on the Transports and Linkages of the Intra-americas Sea (IAS), Cozumel, Mexico, 1-5 November 1997	E
163	Under preparation	
164	IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project), Cape Town, South Africa, 29 November – 11 December 1999	E
165	An African Conference on Sustainable Integrated Management; Proceedings of the Workshops. An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18 –25 July 1998	E, F
166	IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27 –30 September 1999	E
167	IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000	E
168	Geological Processes on European Continental Margins; International Conference and Eight Post-cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000	E
169	International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIWP '99, Langkawi, Malaysia, 1-4 November 1999	***under preparation***
170	IOCARIBE-GODAR-I Cartagenas, Colombia, February 2000	***under preparation***
171	Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks, Toulouse, France, 10-11 May 1999	E
172	(*Under preparation*)	
173	The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999	E, F
174	IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16-17 August 2000	E
175	Geological Processes on Deep-water European Margins, Moscow-Mozhenka, 28 Jan.-2 Feb. 2001	E
176	MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15-17 May 2000	E
177	*(Under preparation)*	
178	*(Under preparation)*	
179	*(Under preparation)*	
180	Abstracts of Presentations at Workshops during the 7th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23-27 April 2001	E
181	*(Under preparation)*	
182	*(Under preparation)*	
183	Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-cruise Meeting of the Training-through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002	E
184	*(Under preparation)*	
185	*(Under preparation)*	
186	*(Under preparation)*	
186	*(Under preparation)*	
187	Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2–6 February 2003	E
188	Proceedings of 'The Ocean Colour Data' Symposium, Brussels, Belgium, 25-27 November 2002	E
189	Workshop for the Formulation of a Draft Project on Integrated Coastal Management (ICM) in Latin America and the Caribbean (LAC), Cartagena, Colombia, 23–25 October 2003 Taller de Formulación de un Anteproyecto de Manejo Costero Integrado (MCI) en América Latina y el Caribe (ALC), Cartagena, Colombia, 23–25 de Octubre de 2003	E F ***(electronic copy only)***
190	First ODINCARSA Planning Workshop for Caribbean Islands, Christchurch, Barbados, 15–18 December 2003	E ***(electronic copy only)***
191	North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes — International Conference and Twelfth Post-cruise Meeting of the Training-through-research Programme, Copenhagen, Denmark, 29–31 January 2004	E
192	Regional Workshop on Coral Reefs Monitoring and Management in the ROPME Sea Area, Iran I.R., 14–17 December 2003	E ***(under preparation)***
193	Workshop on New Technical Developments in Sea and Land Level Observing Systems, Paris, France, 14–16 October 2003	E ***(electronic copy only)***
194	IOC/ROPME Planning Meeting for the Ocean Data and Information Network for the Central Indian Ocean Region	***(under preparation)***
195	Workshop on Indicators of Stress in the Marine Benthos, Torregrande-Oristano, Italy, 8–9 October 2004	E
196	International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework, Paris, France, 3–8 March 2005	E
197	Geosphere-Biosphere Coupling Processes: The TTR Interdisciplinary Approach Towards Studies of the European and North African Margins; International Conference and Post-cruise Meeting of the Training-Through-Research Programme, Morocco, 2-5 February 2005	E
198	Second International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean, Grand Baie, Mauritius, 14–16 April 2005	E
199	International Conference for the Establishment of a Tsunami and Coastal Hazards Warning System for the Caribbean and Adjacent Regions, Mexico, 1–3 June 2005	E
200	Lagoons and Coastal Wetlands in the Global Change Context: Impacts and Management Issues — Proceedings of the International Conference, Venice, 26–28 April 2004 (*ICAM Dossier N° 3)*	E
201	Geological processes on deep-water European margins - International Conference and 15th Anniversary Post-cruise Meeting of the Training-Through-Research Programme, Moscow/Zvenigorod, Russian Federation, 29 January–4 February 2006	E
202	Proceedings of 'Ocean Biodiversity Informatics': an international conference on marine biodiversity data management Hamburg, Germany, 29 November–1 December 2004	E
203	IOC-Flanders Planning Workshop for the formulation of a regional Pilot Project on Integrated Coastal Area Management in Latin America, Cartagena de Indias, Colombia, 16–18 January 2007	*E* ***(electronic copy only)***
204	Geo-marine Research along European Continental Margins, International Conference and Post-cruise Meeting of the Training-through-research Programme, Bremen, Germany, 29 January–1 February 2007	E
205	IODE/ICAM Workshop on the development of the Caribbean marine atlas (CMA), United Nations House, Bridgetown, Barbados, 8–10 October 2007	E ***(electronic copy only)***
206	IODE/JCOMM Forum on Oceanographic Data Management and Exchange Standards, Ostend, Belgium, 21–25 January 2008	*(Under preparation)*
207	SCOR/IODE Workshop on Data Publishing, Ostend, Belgium, 17–18 June 2008	*(Under preparation)*
208	JCOMM Technical Workshop on Wave Measurements from Buoys, New York, USA, 2–3 October 2008 (IOC-WMO publication)	*(Under preparation)*

No.	Title	Languages
209	Collaboration between IOC and OBIS towards the Long-term Management Archival and Accessibility of Ocean Biogeographic Data, Ostend, Belgium, 24–26 November 2008	*(Under preparation)*
210	Ocean Carbon Observations from Ships of Opportunity and Repeat Hydrographic Sections (IOCCP Reports, 1), Paris, France, 13–15 January 2003	E ***(electronic copy only)***
211	Ocean Surface pCO_2 Data Integration and Database Development (IOCCP Reports, 2), Tsukuba, Japan, 14–17 January 2004	E ***(electronic copy only)***
212	International Ocean Carbon Stakeholders' Meeting, Paris, France, 6–7 December 2004	E ***(electronic copy only)***
213	International Repeat Hydrography and Carbon Workshop (IOCCP Reports, 4), Shonan Village, Japan, 14–16 November 2005	E ***(electronic copy only)***
214	Initial Atlantic Ocean Carbon Synthesis Meeting (IOCCP Reports, 5), Laugavatn, Iceland, 28–30 June 2006	E ***(electronic copy only)***
215	Surface Ocean Variability and Vulnerability Workshop (IOCCP Reports, 7), Paris, France, 11–14 April 2007	E ***(electronic copy only)***
216	Surface Ocean CO2 Atlas Project (SOCAT) 2nd Technical Meeting Report (IOCCP Reports, 9), Paris, France, 16–17 June 2008	E ***(electronic copy only)***
217	Changing Times: An International Ocean Biogeochemical Time-Series Workshop (IOCCP Reports, 11), La Jolla, California, USA, 5–7 November 2008	E ***(electronic copy only)***