International Repeat Hydrography and Carbon Workshop

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Report of the International Repeat Hydrography and Carbon Workshop

Contents

1. Introduction to the Conference

During the decade of the 1990s the World Ocean Circulation Experiment (WOCE) conducted an extensive survey of hydrographic properties in the global ocean in an effort to develop a global picture of ocean properties that was as synoptic as possible. In collaboration with the WOCE global survey, the Joint Global Ocean Flux Study (JGOFS) ensured that inorganic carbon measurements were made on a majority of the cruises. The WOCE/JGOFS effort lead to numerous scientific advances in understanding the physical and biogeochemical state of the global ocean. However, this work also lead to the realization that the effect of climate variability on the ocean is still poorly understood. An international conference, entitled "The Ocean Observing System for Climate" (or OceanObs'99), set the initial scientific and implementation framework for post-WOCE hydrography. It was recognized that, while hydrography provides a critical and unique platform for ocean observations that will be required for the foreseeable future, understanding of ocean variability on basin and global scales is still emerging and will require the development of new techniques, integration with other observing platforms, and close scientific scrutiny to ensure the highest possible data quality and scientific interpretation. For this reason, it was suggested that the hydrography program would sit more appropriately within the framework of a research program such as the Climate Variability and Predictability (CLIVAR) program rather than the sustained observing systems (e.g., the Global Ocean Observing System, and the Global Climate Observing System). However, it was also recognized that the CLIVAR program at that time did not include some key aspects (such as CO_2 measurements) that are essential to understanding the ocean's role in climate. The OceanObs'99 conference thus highlighted the need for an umbrella structure to more closely link the future global programs and optimise the ocean sampling scheme (Gould et al., *Proceedings of OceanObs'99*).

Recently, both the CLIVAR community and the ocean carbon community have recognized the urgent need for better coordination of planning, implementation, standardization, and data synthesis and interpretation efforts for hydrography. It was also recognized that today's hydrography programs address different issues than were addressed during the WOCE era; issues that require a more integrated approach both in terms of variables measured, sampling strategy, and integration of ship-based sampling with other platforms such as Argo and time series stations.

The International Ocean Carbon Coordination Project (IOCCP) and CLIVAR, with the leadership and support of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), developed this workshop to address these issues and to examine potential ways and means for developing the kind of coordination structure foreseen by OceanObs'99 as the next generation of hydrography. One of the immediate goals of the workshop was to lay the foundations for the development of a robust and comprehensive information system about on-going and planned hydrographic activities, and to actively publicize the need and enthusiasm for a new era of integrated hydrographic research. A longer-term goal is to develop an international hydrography program that has a sustained coordination mechanism for data / information management and data synthesis activities, yet remains driven by science through national, regional, and global research programs.

The workshop brought together 49 participants from 11 countries, with expertise covering carbon, hydrography, tracers, prognostic modelling, data assimilation, and the Argo profiling float program, along with data and information management experts (Annex I).

2. Science Highlights : findings and intriguing issues from repeat hydrography

The workshop began with opening remarks from Masao Fukasawa highlighting the significance of this meeting, which brought together the physical and biogeochemical communities to discuss the status of the repeat hydrography program. This program is an area of mutual benefit and true collaboration between the communities. Richard Feely followed this up with a discussion of the primary goals of the workshop, which included:

1. Review post-WOCE global ship-based hydrography activities;
2. Review the extent to which these observations are accessible;
3. Identify global priorities for ship based hydrography to fulfill the specific science aims of CLIVAR and the ocean carbon and tracer community, and in light of the existence and needs of Argo;
4. Establish a robust mechanism to compile information on future ship-based hydrography plans and to ensure that data from these observations are rapidly made available; and,
5. Take steps to publicize to the wider science community, the continuing importance of carrying out ship-based hydrography.

Feely also reviewed the core objectives of the repeat hydrography program: to provide data for carbon system studies, heat and fresh water storage and flux studies, deep and shallow water mass ventilation studies, model calibration and validation, and for calibration of autonomous sensors. He pointed out that the international program to date has completed roughly one half of the decadal survey and is meeting nearly 100% of the core objectives. Most of the data are being submitted to data centers at much faster rates than in the past and preliminary results indicate substantial changes in many observed properties, suggesting that there will be many exciting discoveries coming from this program. Some of the challenges facing the program are continued support for funding and ship-time needed to complete the first global decadal survey by 2012 as planned, and the need to continue to foster collaborations with national and international partners to coordinate the modeling and synthesis of these results with the growing international data set. Feely also highlighted the links between the repeat hydrography program and other international programs like Argo and promoted the development of a joint team to investigate the feasibility and benefits of adding oxygen sensors to Argo floats. Additional specific recommendations included the testing and implementation of new methods for high-resolution O_2 and CO_2 profiling on repeat hydrography cruises, increasing repeat hydrography cruise coverage in areas where active ventilation is occurring, the development of basin-scale carbon models that accurately reproduce gas exchange, ventilation and biogeochemical processes, and additional support for international data synthesis and exchange efforts.

After these introductory talks, there was a series of plenary talks that summarized some of the physical and biogeochemical lessons learned from the WOCE/JGOFS

global survey, as well as a summary of the intriguing new findings from the current repeat hydrography program. Brian King presented the first science talk and pointed out that perhaps one of the most important lessons learned from WOCE and other associated studies is the idea that the ocean is not a slowly evolving animal with smooth decadal trends that can be detected in a straightforward manner as part of patterns of global change. Examples from cruises in the southern Indian Ocean and North Atlantic that were occupied multiple times over two decades indicated significant changes in circulation and variations in several physical and biogeochemical tracers. These changes were not always of the same character and in some cases not even in the same direction as one might have predicted from secular trends related to anthropogenic forcing. Some of these variations (e.g. circulation changes and variations in bottom water properties) could only be seen with high-resolution repeated hydrographic sections. Furthermore, a proper interpretation of these changes can only be made with full water column boundary-to-boundary sampling made over multiple decades.

Doug Wallace pointed out that the WOCE/JGOFS survey data were successful in answering the first order question of what is the global ocean inventory of anthropogenic CO_2 and how is it distributed, but also raised many other questions about how the ocean uptake of carbon will change in the future. There is still a lot of work that must be done to better understand what controls the distribution of natural and anthropogenic carbon in the ocean. Model development, inverse calculations and transport estimates are helping to improve our understanding of these processes, but periodic reassessments of the carbon and related tracer distributions are critical for improving our understanding of the mechanisms controlling the ocean sink for anthropogenic CO_2. As more data become available, new techniques for examining the different components of the total carbon signal must be investigated and the methods for estimating the anthropogenic carbon increase should be re-evaluated. Wallace also encouraged the repeat hydrography community to start thinking about how recent technological advances might be used to expand the capabilities beyond what was accomplished with WOCE. He promoted establishing closer ties with the Argo community to directly relate the changes observed on the hydrographic sections to the growing temporal data set collected by Argo, particularly if additional parameters such as oxygen could be included on the profiling floats. Shipboard measurements will still continue to be critical, but by making closer connections with other observational approaches (e.g. time series stations) and alternative platforms (e.g. profiling floats or gliders), we can improve our ability to interpret the shipboard data and potentially minimize biases in the temporal resolution of the data.

Terry Joyce's presentation focused on intriguing new findings from the current repeat hydrography program. The US repeat hydrography effort started in the North Atlantic, where substantial changes have been seen in water mass distributions since WOCE. These changes are observed in several tracers and are found throughout the water column. It appears that these changes may be related to variations in the North Atlantic Oscillation (NAO) and the advective timescales for the gyres and deep western boundary currents. Joyce pointed out that many of the historical North Atlantic measurements were made in the 1960s and 1970s when the NAO was generally low. The WOCE North Atlantic work was in the mid 1990s during a period of very high NAO. Without a proper understanding of the impact of large scale climate phenomena on water mass properties it would be impossible to interpret the

changes that might be observed. The North Atlantic work also showed the importance of understanding changes in the Arctic, a region that was not well represented in WOCE. We are still working to understand the changes that have been observed with the repeat hydrography cruises now that the NAO is once again decreasing. The repeat hydrography program has shown us the importance of repeated measurements for properly attributing changes to the correct mechanisms and has illustrated the need for much more research in this area.

Scott Doney also presented results showing significant changes in the biogeochemical measurements coming from the repeat hydrography program. The complicated patterns of these changes clearly show that these properties are being influenced by more than simple secular changes in anthropogenic tracers. Preliminary results indicate that we need a better understanding of natural variability, perhaps related to climate modes like NAO, and improved definitions and techniques for isolating the anthropogenic and natural components of the observed variability. For example, one intriguing finding from the recent cruises is the suggestion that the anthropogenic carbon inventories are increasing in the Pacific at about twice the rate of the Atlantic over the last 10 years. This is in contrast to the long-term anthropogenic CO_2 inventory that shows larger column inventories in the North Atlantic. The answer to this finding may lie in the effects of climate modes like NAO or PDO on the decadal scale circulation.

Masafumi Kamachi discussed the advances being made in physical data assimilation into models and the importance of getting hydrographic section data. The GODAE system accepts data from a wide variety of sources, but the repeat hydrography data fill an important niche in the data assimilation process as these are an important source of high resolution boundary current and deep ocean data. The assimilation models can also be useful for identifying key areas where additional sections would be useful.

Keith Rodgers presented some model analyses for the North Pacific in an attempt to address the extent to which the rate of uptake of anthropogenic CO_2 in the North Pacific is varying with the phase of the Pacific Decadal Oscillation. The primary findings from this study were that there was a strong seasonal component to the North Pacific uptake of anthropogenic CO_2, but that there did not seem to be a strong interannual correlation with the Pacific Decadal Oscillation. This appears to be in conflict with CO_2 flux observations that have indicated a shift in the North Pacific uptake rate, and preliminary repeat hydrography results showing larger recent inventory changes in the Pacific relative to the Atlantic. The models do not seem to reproduce this finding. It should be noted however, that the model results may be sensitive to the fact that the models are not eddy resolving and that mixed layer depths may be biased in the models. There is a strong need for a better evaluation of model biases and a close comparison of decadal trends observed from the repeat hydrography program and the decadal trends inferred from models.

The final presentation of the introductory session, by Gregory Johnson, examined the relationship between the Argo program and the repeat hydrography program. A comparison of the type of information gained from the two approaches shows that they are clearly complimentary. The Argo data can provide the large-scale context for the limited number of repeat hydrography lines. At the same time the repeat

hydrography cruises provide an opportunity for deploying the profilers, provide calibration data for the floats, and can resolve many features like boundary current regions and deep water changes that cannot be properly addressed with Argo profilers. Johnson pointed out that there is an opportunity for the Argo community to establish even closer ties to the repeat hydrography program by including additional sensors on the profilers that will allow the Argo data to be interpreted in a manner more similar to the shipboard data. He showed that oxygen sensors have been successfully deployed on profiling floats and that they allow a greatly expanded interpretation of the data including the possibility of estimating carbon distributions using multiple linear regression techniques. Although there are addition financial resource requirements, limitations on float power, and concerns about sensor stability that still need to be addressed, the benefits of such closer interaction could be substantial for both communities.

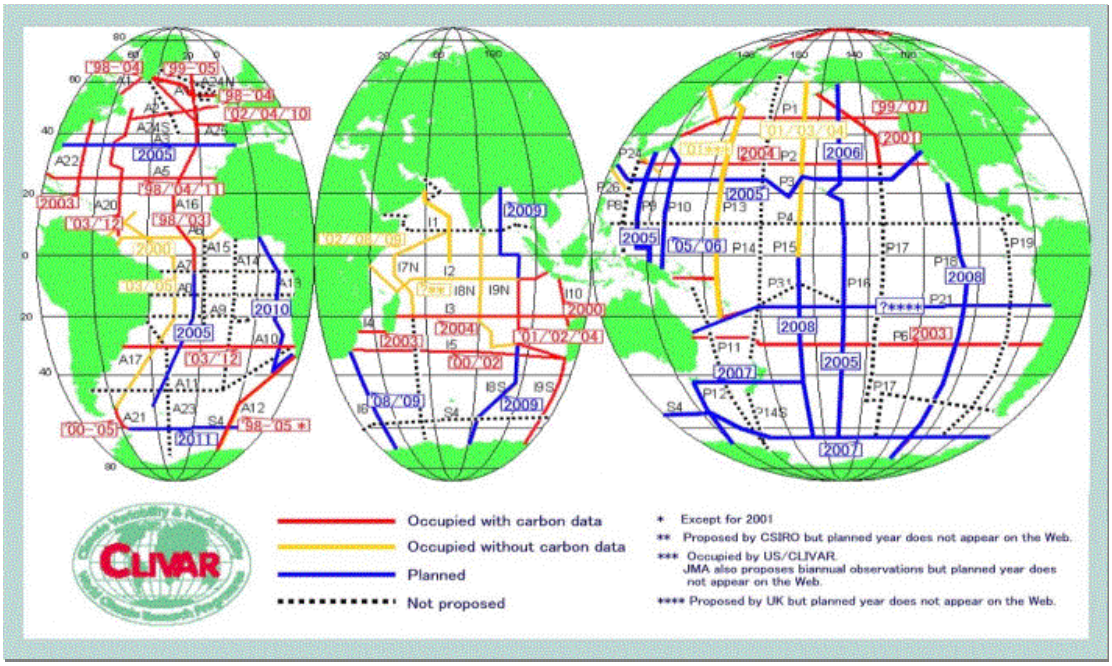
3. Status of post-WOCE Repeat Hydrography

Speakers in the section provided brief overviews of post-WOCE hydrography, focusing mainly on new activities and future plans in each basin. The following information is in no way a comprehensive listing of all post-WOCE hydrographic activities. It was felt that such a compilation was definitely needed, but was far beyond the scope of this workshop to produce.

Global Overview

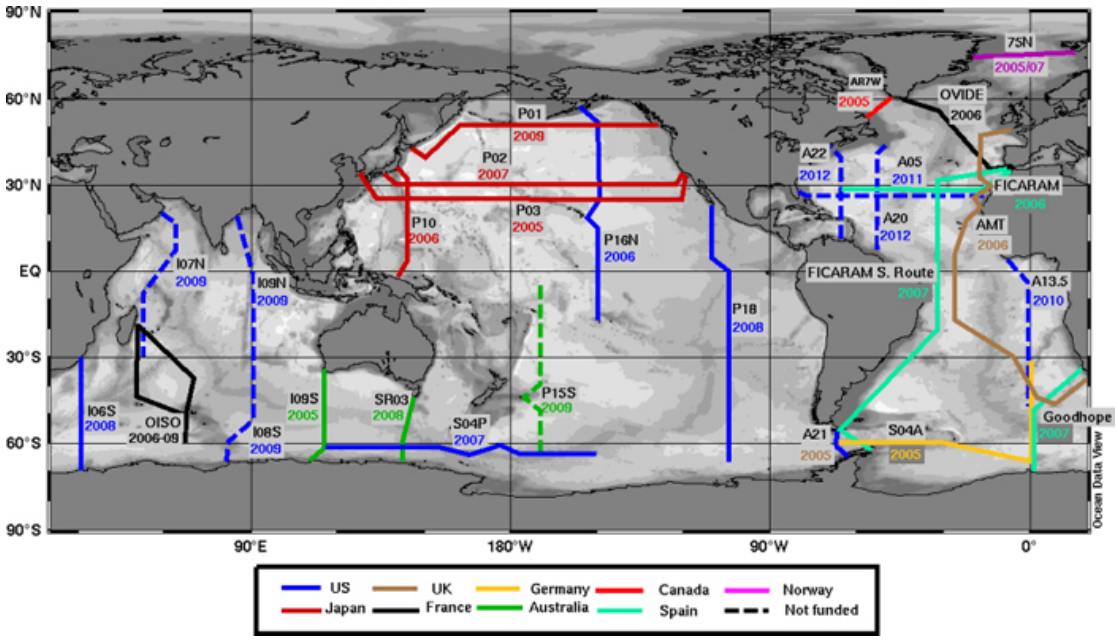
The most comprehensive view of post-WOCE hydrography has been compiled by Masao Fukasawa and colleagues as part of the CLIVAR Global Synthesis and Observations Panel (GSOP) activity. The map below shows the hydrographic sections that have been implemented or planned since the year 2000 (last updated in September 2005). The map indicates which sections were occupied with carbon, without carbon, which lines have been planned but not yet funded, and which WOCE lines have not been scheduled for reoccupation. This compilation does not include information about coastal sections, marginal seas sections, or one-off process studies. Much of this information exists in the Basin Groups (see below), but has not been integrated into a global view.

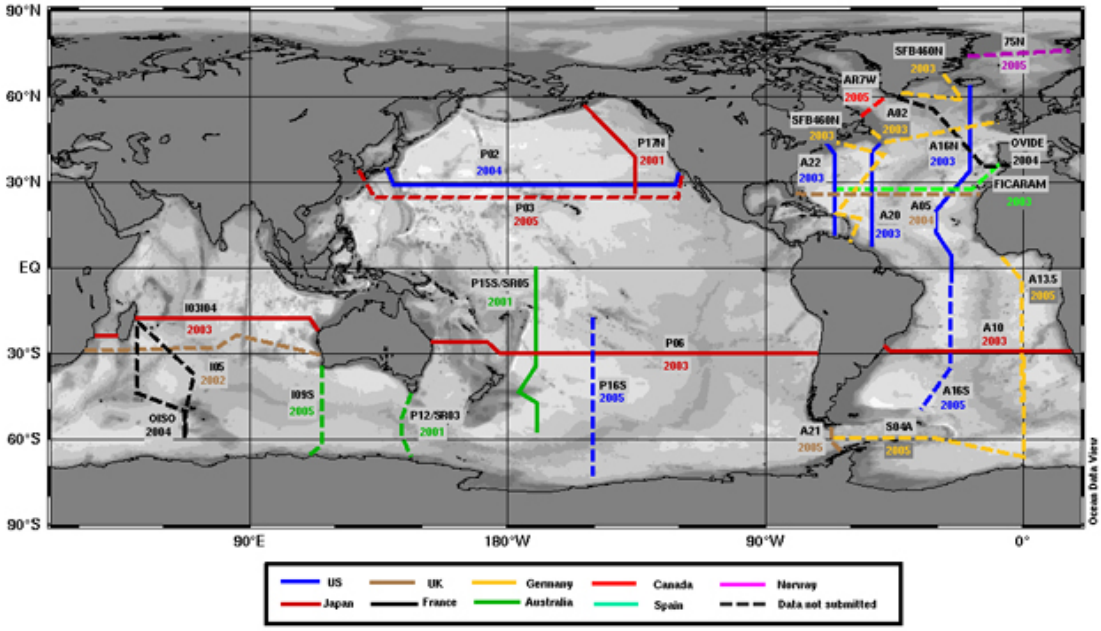
Information and data from these cruises is available at the CLIVAR and carbon hydrographic data office (CCHDO) at : http://whpo.ucsd.edu/index.htm.



CLIVAR Global Repeat Hydrography Map

For carbon, the Carbon Dioxide Information and Analysis Center (CDIAC) Ocean CO_2 program (http://cdiac.esd.ornl.gov/oceans/home.html) and the IOCCP jointly maintain up-to-date compilations of hydrography lines on which carbon parameters have been measured, and include several lines not shown on the CLIVAR map. The IOCCP map (top) shows the cruises that are on-going or planned (2005 and on-ward), and the CDIAC map (bottom) shows all past, post-WOCE cruises. The solid lines indicate cruises for which carbon data are available, while the dashed lines indicate that the cruise has taken place but data are not yet available.





While the CLIVAR CCHDO and CDIAC have a joint data and information management plan, the CLIVAR center has only been dealing with those transbasin sections that are considered part of the repeat global survey, while CDIAC maintains a comprehensive collection of all ocean carbon data. The joint Data and Information Management Plan can be found at: http://cdiac.esd.ornl.gov/oceans/RepeatSections/CDIAC_WHPO_plan.pdf.

A more comprehensive and integrated system is needed, but will require new strategies and new resources to develop. Participants at this workshop emphasized that one of the most important aspects for coordinating and integrating hydrographic activities is a comprehensive and up-to-date information system, making such an activity a top priority for any future hydrography program. (see Section 4 for more discussion).

The following basin reviews highlight plans for future hydrographic activities in each basin that were presented at the workshop. While these should not be considered as comprehensive reviews, the compilation does provide useful information for the development of an eventual hydrography information database.

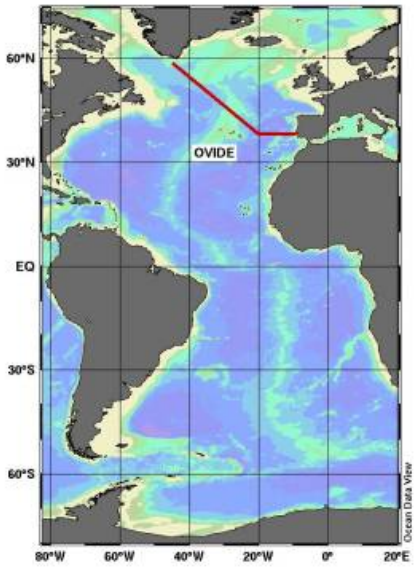
Atlantic Basin

The CLIVAR Atlantic Basin panel maintains a compilation of hydrographic sections, including carbon, at: http://www.clivar.org/organization/atlantic/IMPL/index.htm. This site also links to the IOCCP/CDIAC hydrographic information pages for further details about carbon cruises: http://ioc.unesco.org/ioccp/HydrographyMap.htm, with links to table information for each basin. Unfortunately, as with the global overviews, the two sites are not synchronized and provide information and maps in different formats and are updated on different timescales.

Doug Wallace (Germany, Leibniz-IfM) provided an overview of several Atlantic basin hydrography programs and future plans. He also presented some work in the

Atlantic sector of the Southern Ocean, which we have grouped with the other Southern Ocean cruises for this report.

OVIDE (Observatoire de la Variabilité Interannuelle à Décennale du gyre subpolaire de l'Atlantique Nord et des mers nordiques).



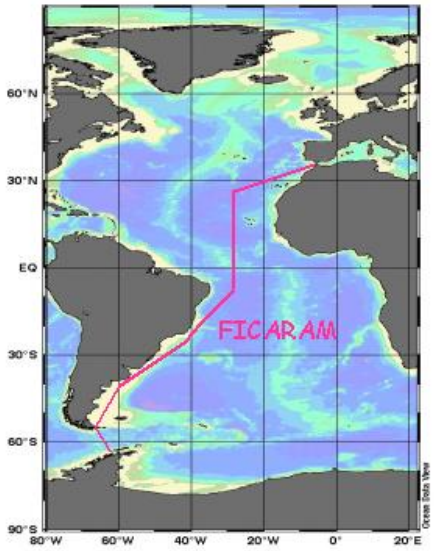
Implementation: Laboratoire de Physique des Océans, France, and the CO_2 group of the Instituto de Investigaciones Marinas, Spain. Implemented in the framework of CLIVAR.

Section Information:

- Occupations in 2002, 2004;
- Plans: 2006 (repeated every 2 years)
- Number of stations: 96
- Variables measured: T, S, O_2, CFCs, nitrate phosphate, silicate, pH, alkalinity, pCO_2.

More information:
http://www.ifremer.fr/lpo/ovide/ovide04/ovide04.htm

FICARAM (Flujos de Intercambio aire mar en una sección meridional en el océano Atlántico)



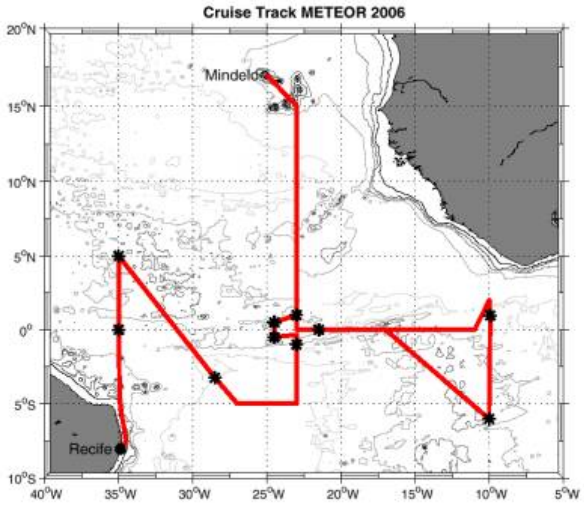
Implementation: CO2 group of the Instituto de Investigaciones Marinas, Spain

Section Information:

- Occupations : 2001 (FICARAM II), 2002 (FICARAM IV), 2003 (FICARAM VI)
- Plans: 2007 (planned each 3 years)
- Number of Stations: 2001 (29), 2002 (19), 2003 (9)
- Variables measured: T, S, O_2, nitrate, phosphate, silicate, pH, alkalinity, pCO_2. Gaps: CFCs, CT (planned to include since 2007)**More information:**

http://www.iim.csic.es/~rbos/grupoCO2_e.htm

Meteor 2006 Equatorial Atlantic

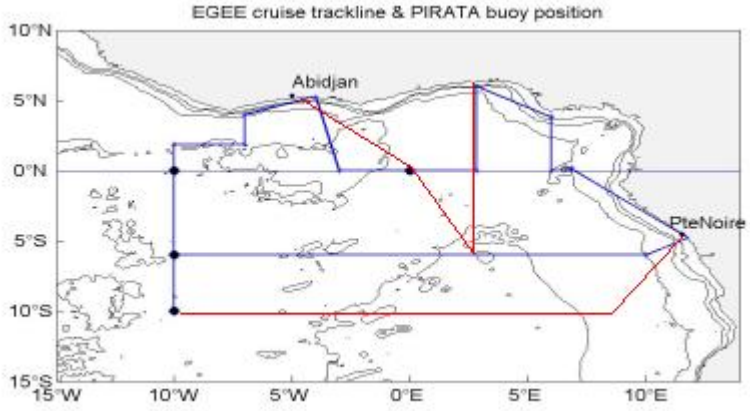


Implementation: IfM-Geomar

Section Information:
Occupations: 2000, 2002, 2004
Plans: 2006

More information:
http://www.ifm-geomar.de/index.php?id=1185&L=1

AMMA / EGEE - Analyse Multi-échelle de la Mousson Africaine / Etude de la Circulation oceanique et de sa Variabilite dans le Golfe de Guinee



Implementation: France, IFREMER

Section Information:
- Occupations: 2/year x 3 years
- Plans: 2006
- Variables Measured: hydrography, nutrients, CO_2, upper 1000m

More information:
http://www.brest.ird.fr/actualites/EGEE-2.htm
http://www.brest.ird.fr/actualites/EGEE-1a.htm
http://www.brest.ird.fr/activites/act_LEGOS_Brest.htm
Chief Scientist: Bernard.Bourles@ifremer.fr and Bernard.Bourles@ird.fr

Pacific Basin

The Pacific Basin overview was presented by Dick Feely (US, NOAA/PMEL). The table (taken from information provided by Masao Fukasawa) outlines the sections that were occupied during WOCE, which were recommended for reoccupation by the OceanObs'99 conference, and the current status of implementation. The bold numbers in the column "occupied year" indicate that carbon measurements were also taken or proposed.

Section	WOCE Ref.	Frequency Recommended	Recommended by OceanObs99	Occupied Year
50N	P1	5-7 years	yes	**1999**; proposed 2007
24N or 30N	P3	5-7 years	yes	**2005**
32S or 43S	P6/P7	5-7 years	yes	**2003**
137E (3N-30N)	P9	Annually / quarterly	yes	Quarterly, not full depth; **proposed 2005**
144E (Eq – 35N)	P10	Annually	yes	**2005**
165E(3S-45/50N)	P13	Annually	yes	2001; **proposed 2007**
170W	P15	5-7 years	yes	North 2003, **2004**; South 2001, **proposed 2008**
150W	P16	5-7 years	yes	North proposed 2006; **South 2005**
110W	P18	5-7 years	yes	**Proposed 2008**
24N or 30N	P2	5-7 years	yes	**2004**
145E (40S-70S)	P12			**2001**
Gulf of Alaska	P17N			**2001**
18S	P21			Proposed year?

Comparisons of repeat hydrography in each basin show that there has been relatively little hydrography in the Pacific:

Basin	Occupied	Occupied more than 2 times	With Carbon
Atlantic	18	11	12
Indian	6	2	5
Pacific	9	1	6
Arctic	1	1	0
Antarctic	3	3	0

However, future plans include 9 lines to be reoccupied before 2008 and details of these plans can be found on the CLIVAR composite map and on the IOCCP site and tables. Along most of the lines occupied in the Pacific after 1999, carbon variables and tracers have been incorporated into the cruises.

There are an extensive number of hydrographic stations in the Pacific being implemented as part of process studies or on-going hydrographic programs that were not part of the WOCE reoccupations. The most complete information about these is provided on the CLIVAR Pacific Basin Panel, although this information is not specific to hydrography and has not been updated for some time. It is unclear from the present compilation how many of these plans were implemented and what the current state of hydrographic activities is for the Pacific.
(http://www.clivar.org/organization/pacific/)

Indian Basin

CLIVAR and the IOC established an Indian Ocean Panel in 2004, and the panel has compiled information on observation activities and plans on the Panel site: (http://www.clivar.org/organization/indian/).

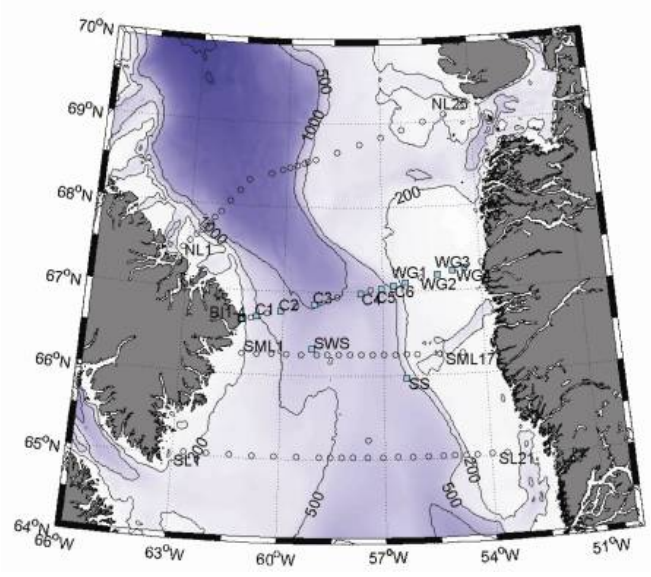
Bernadette Sloyan (Australia, CSIRO CMAR) presented the Indian Ocean hydrography overview. The table below shows the summary of post-WOCE activities. All listed cruises measured carbon variables except for the 2002 UK occupation of I05.

Section	Occupations	Plans	Status / Comments
DOTSS – I10, I02(E), I05(E)	2000 (Aus)	2010, Aus	Request not submitted; Australia committed to repeat hydrography in the eastern Indian Ocean but international coordination is needed. Questions now raised whether the planned reoccupation of DOTSS is best use of resources if US occupy I9N in 2009. Cruise most likely 2009/2010 given Australian planned IPY Southern Ocean cruises in 2008. Australia also need international support for CFC measurements
I09S	1995 (US), 2005 (Aus)	2012, Aus	Request not submitted;
I07N	1996 (US)	2009, US	Proposed
I09N	1995 (US)	2009, US	Proposed
I08S	1994 (US)	2009, US	Proposed
I05	1987 (US), 1995 (US E/W ends), 2000 (Aus, E end), 2002 (UK)	2010, US	Proposed
OISO (Reunion, Crozet, Kerguelen, Amsterdam)	1998 – ongoing	2/year, France	Funded / Implemented on schedule. Large station spacing as no ship time given to CTD/Carbon program.
I06	1993 (France), 1996 (France)	2008, US	Funded.
I03/I04	1993 (US), 2003 (Japan)	None	

Arctic

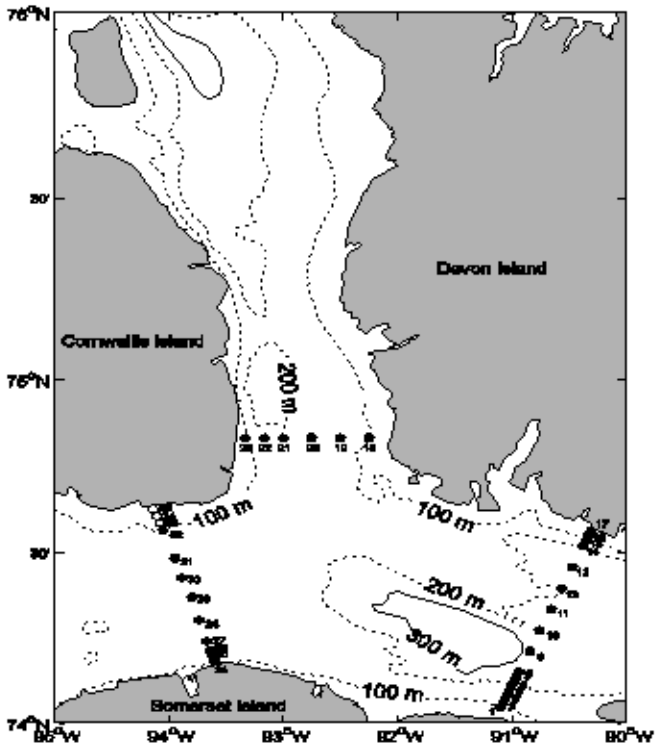
CLIVAR did not establish a separate Arctic Panel, but rather includes information about Arctic observations through the other panels. However, in planning for the International Polar Year (2007/08), a comprehensive compilation of activities and plans is emerging for Arctic Ocean research and observations. Lisa Miller (Canada, ISO) provided an overview of several programs that are underway or planned.

Baffin Bay (US and Canada)



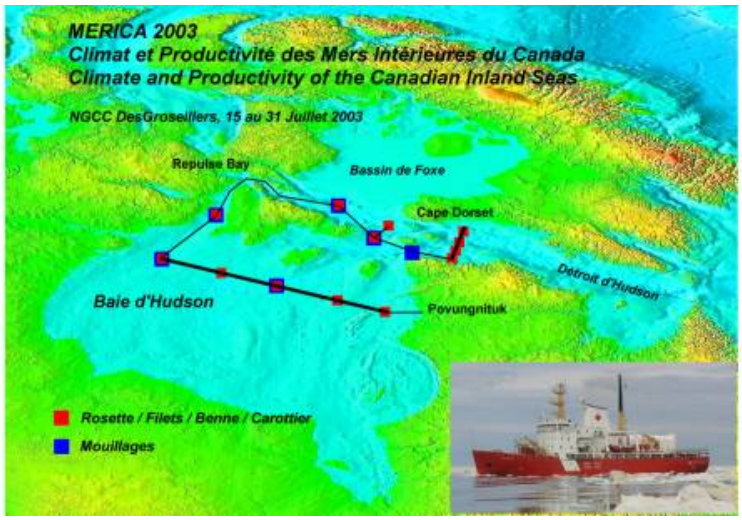
These Davis Strait sections, maintained by Craig Lee (University of Washington) and Brian Petrie (BIO, Canada) started in 2004 and field work has been funded for 2005, 2006, and 2007. During each cruise, the four sections depicted in the map will be occupied. (Hollow marks = hydrographic stations, the light blue marks indicate mooring positions). Extra time will be used to focus on specific circulation features. Sampling includes standard CTD, trace metals (Phil Yeats), total inorganic carbon, total alkalinity, and oxygen isotopes (Kumiko Azetsu-Scott), CFCs (Mark Warner), iodine (John Smith), dissolved oxygen and nutrients (Craig Lee and Brian Petrie). Chemical parameters are mostly constrained to the section following the mooring line (blue dots). This group will propose to continue this work for an additional 3-5 years, extended the current program until 2012. More information on this project can be found at: http://iop.apl.washington.edu.

Barrow Strait (Canada)



Three CTD lines in the Barrow Strait have been repeated since 1998: the "Eastern and Western Barrow Strait Lines" at 91° W and 94° W, and the "Wellington Channel Line" at 74° 50'N, for a total of 35 stations. It is expected that these lines will continue in the future. Contacts: Jim Hamilton, Simon Prinsenberg, Kumiko Azetsu-Scott, Bedford Institute of Oceanography, Canada).

Hudson Bay (Canada)_



The MERICA program is a research and monitoring study of climate and productivity in the Hudson bay that began in 2003. The long-term objective of the program is to establish an integrated Observation / Modelling System for detecting, following and predicting ocean and ecosystem changes in the Hudson Bay Complex. Key oceanographic and living resource data sampled comprise variables such as temperature, salinity, current, nutrients, oxygen, abundance and biodiversity of the planktonic and benthic biota, particle sedimentation, contaminants, paleo-environmental and paleo-climatic proxies. Contact information: Azetu-Scott, BIO; Michel Starr, IML Canada).

Canadian Archipelago

As part of the Joint Western Arctic Climate Study (JWACS) and the Beaufort Gyre Exploration (BGEP) study, scientists from the US, Canada, Japan, and China are carrying out shipboard hydrographic sampling at about 30 sites on each cruise. Temperature, salinity, oxygen, and nutrients, CFCs, carbon tetrachloride, total alkalinity, dissolved inorganic carbon, Tritium-^{3}He and $\delta^{18}O$ will be measured and analyzed at the locations along each section.

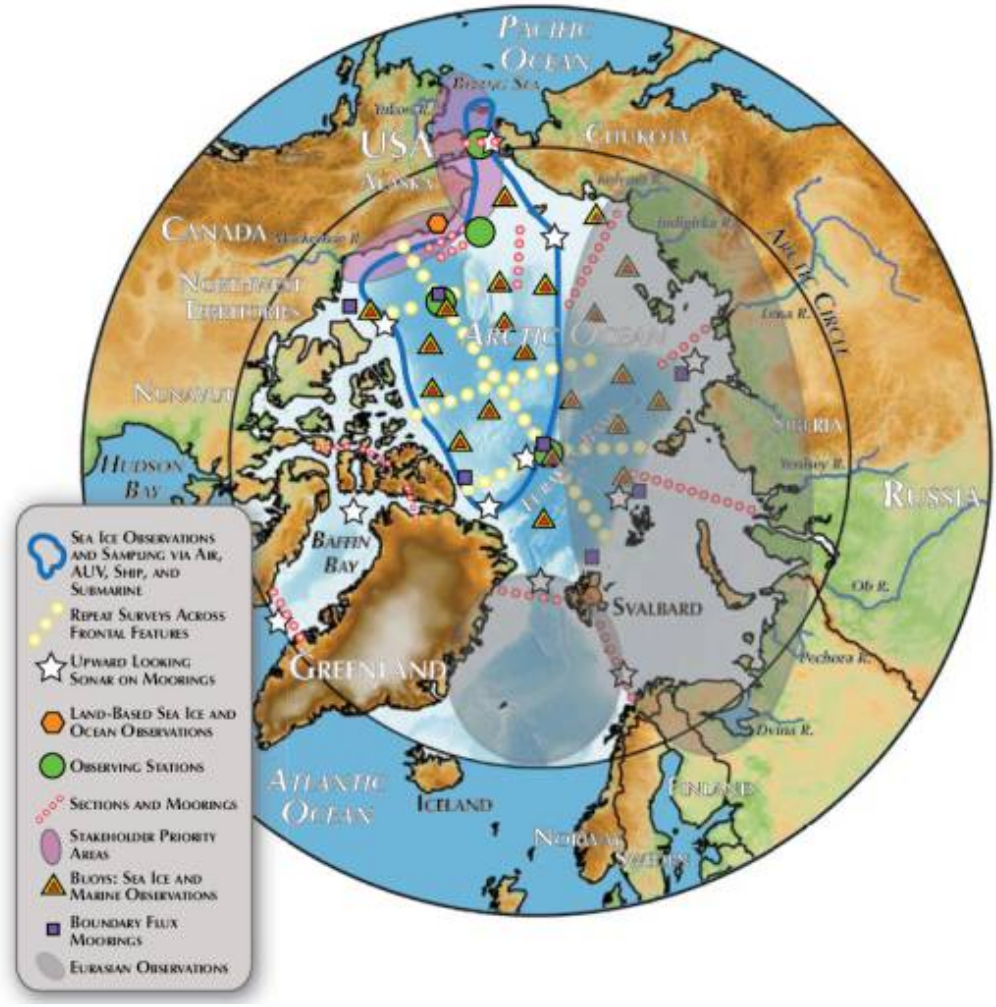
More information: http://www.whoi.edu/beaufortgyre/

Study of Environmental Arctic Change (SEARCH, US) (*information provided by Peter Schlosser)*

SEARCH is a system-scale, cross-disciplinary, long-term Arctic research program that began in 2005 with currently over 40 core projects funded through NSF, NOAA, and NASA. Observation plans for the program are shown in the figure below.

The highest priority for SEARCH is long-term and large-scale observations of environmental change. Observation requirements include those related to physical/chemical ocean, geophysical sea ice, biological/chemical, and stakeholder-relevant variables; sensors and measurements should be co-located to the extent possible. Key regions include: Beaufort Gyre, North Pole, Bering Strait, Canadian Archipelago, and Eurasian Basin slopes and shelves; Alaska near-shore observations

in the Bering, Chukchi and Beaufort Seas (stakeholder priority areas, purple shading); and the Chukchi/Beaufort shelf-slope area. Priority observation activities include: repeat hydrographic/tracer surveys across frontal features (yellow dotted lines) and sea ice and ocean sampling along transects (blue line) via ship, aircraft, AUVs, and submarine; boundary flux sections (red dotted lines, additional boundary flux moorings denoted by purple squares); drifting buoys for marine and sea ice measurements (yellow/red triangles); sea ice and ocean observations via land-based platforms (orange polygons) and upward-looking sonar on moorings (white stars); and long-term observing stations (green dots). Eurasian observations (gray shaded areas will focus on Arctic / Atlantic linkages, with some explicit U.S. collaborations assumed. The locations of all SEARCH sections, buoys, and moorings in this figure are meant only as general suggestions of deployment schemes. SEARCH will contribute to the IPY project to develop an International Arctic Ocean Observing System.



SEARCH Observation Plans

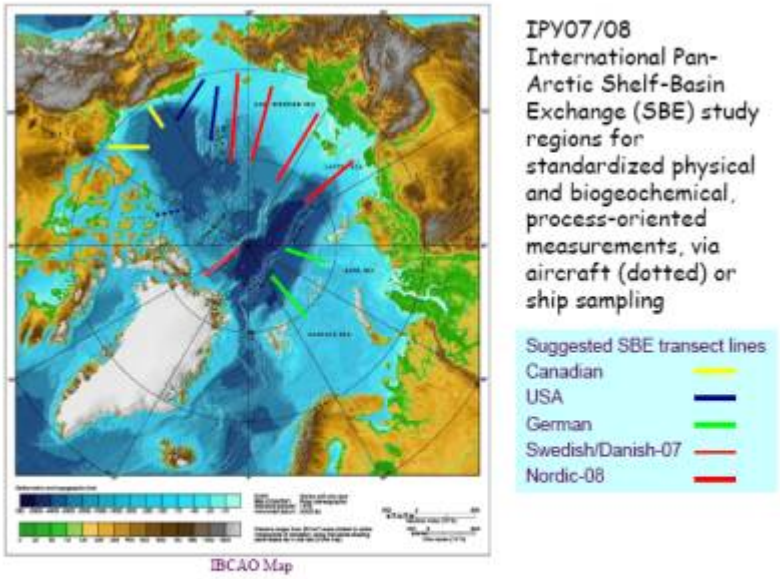
More information:
SEARCH: http://www.arcus.org/SEARCH/index.php
IAOOS: http://www.ipy.org/development/eoi/proposal-details.php?id=14

The IPY proposal site provides the most comprehensive documentation on these activities (http://www.ipy.org/development/eoi/proposal-details.php?id=48).
Proposed projects that will include repeat hydrography are:

- International Arctic Ocean Observing System (iAOOS)
- Bipolar Atlantic Thermohaline Circulation Study
- Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies (DAMOCLES)
- International Study of Arctic Change (ISAC)

International Pan-Arctic Shelf-Basin Exchange (SBE) study

This multi-national project, initially coordinated through the Arctic Ocean Studies Board, focuses on studies at the shelf break to investigate potential changes with ice retreat northward over the shelf break, changing seasonality of shelves and shelf break upwelling, thus CO_2 budgets and shelf-basin fluxes. Measurements will include : Standard suite measurements(temperature, salinity, transmissivity, fluorescence, PAR, currents, nutrients, oxygen, carbon measurements (DIC, DOC, pH), atmospheric measurements from ship, and chlorophyll biomass. It will contribute to the IPY through the International Arctic Ocean Observing System. More information: More Information: http://www.aosb.org/SBE.htm



This is the wish list of sections as it stands today for the SBE program (compiled by Jackie Grebmeier). All the lines are just indicated and will be different when it comes to reality. So they only represent the general area.
The red ones are what we think about for the icebreaker Oden, but we hope to conduct these in a Nordic context.

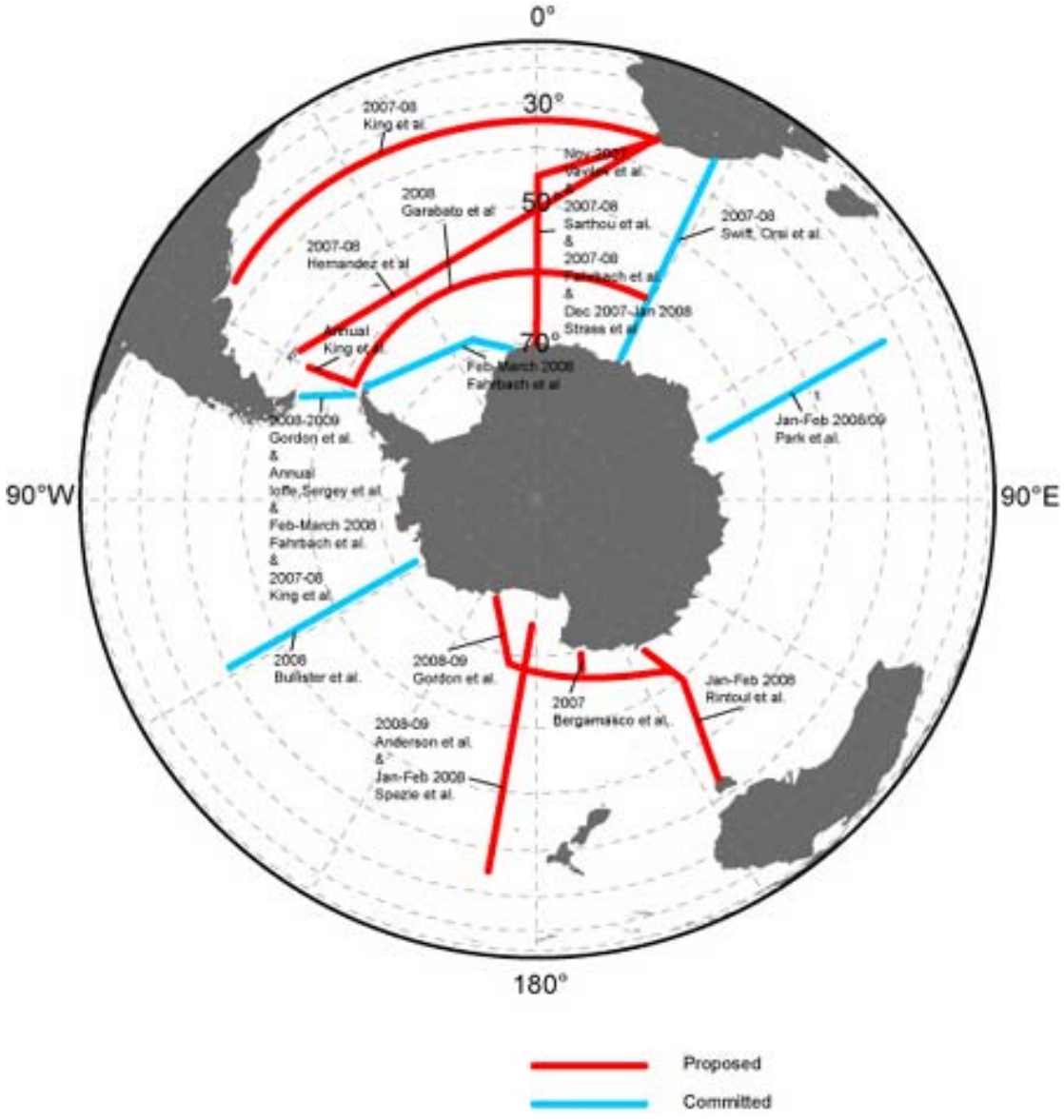
Southern Ocean

Jim Swift (USA, Scripps) presented an overview of Southern Ocean activities. The following table outlines both WOCE reoccupations and some one-off process study activities.

Country	Cruise Name	Years	Frequency	Status
Australia	SR3 (P12)	2001, 2007-2008	7 years	Committed
Australia	I09	2004, 2005	5 years	
Brazil	PATEX / PATEX II	2004, 2005		
Chile	ENOS Cruise	2006-2007	Biannually	Planned
China	Amery Ice Shelf	2006?	Annually?	Ongoing
China	Prydz Bay	2006?	Annually?	Ongoing
France	Goodhope / Bonus	2008		
France	Goodhope	2004		
France	IPY: Cross-Kerguelen Exchange	2008	IPY	Proposed
Germany	ANT XX/2	2003		
Germany	ANT XXII/3	2005		
Germany	CASO, GEOTRACES, XXIV/3	2008		
Germany	CRYONWD – ANT XXIII/7	2006		
Germany	Eisenex-ANTXVIII/2	2000		
Germany	ISPOL (Ice Station Polarstern) – ANT XXII/?	2004-2005		
Germany	S02/A12	1998, 1999, 2000,2002, 2005, 2008	2-3 years	
Germany	S04A	2005		
Germany	SR01	2008		Committed
Germany	SR04	1998, 2005, 2008	2-3 years	
German y / France ?	ANT XXIII/3	2006		
Italy	Balleny Trough	2006 2007		
Italy	IPY: Ross Sea	2008	IPY	
New Zealand	East Auckland Current	1998, 1999, 2000		
New Zealand	STF sections over Chatham Rise	Annually		
New Zealand	Subantarctic	1998, 2000, 2001		
Russia	A21(SR01) (A17)	2003, 2004, 2005		
Spain	FICARAM	2007		
Spain / Russia	SR02	2007		
UK - NOC	A10	2008	One-off	Proposed
UK-NOC	SR01	2002-2004, 2005-2011	Annual	Funded
UK-NOC	SR01 (A21)	1997, 2000, 2001, 2003, 2004, 2005		
UK –UEA	Albatros – JCR40	1999		
USA	A16S	2005		Occupied
USA	A21/S04A	2011		
USA	I06S	2008		
USA	P16S	2005		Occupied
USA	S04A	2010	One-off	Planned
USA	S04P	2007	10 years	

This compilation does not include the French OISO station in the Indian Sector of the Southern Ocean (see Indian Ocean compilation for details).

The CLIVAR Southern Ocean Panel maintains information about plans for the International Polar Year program "Climate of Antarctica and the Southern Ocean (CASO)"; http://www.clivar.org/organization/southern/CASO/index.htm. This map shows the committed a planned lines for that program:

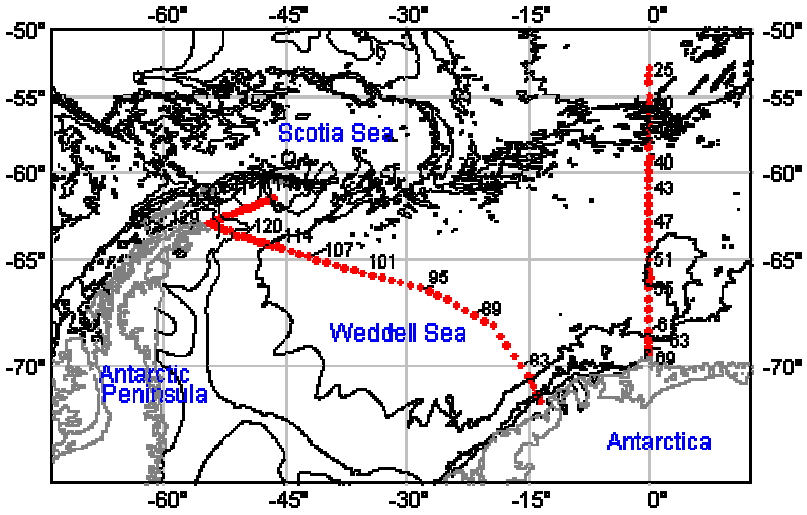


POLARSTERN Cruise ANT XXIII/3

Implementation: Germany: IfM-Kiel and AWI ?

Section Information:

- Occupations: 21 January – 6 April, 2005; Follows parts of A13.5S and A21/S04A
- Plans: See plans for reoccupation of A13.5 and A21/S04A
- Number of Stations: ~150
- Variables Measured: hydrography, nutrients, carbon variables.



Drake Passage

Implementation:
UK, USA, Germany (A21 and S04A)

More information: http://cdiac.ornl.gov/oceans/RepeatSections/clivar_s04a.html

Hydrographic Program Manuals and Guides

The WOCE hydrographic program manual was developed in 1994 and is available on-line at: http://whpo.ucsd.edu/manuals2.htm. Much has changed since that time, and participants strongly urged for this manual to be updated. For ocean carbon variables, a handbook was also developed in 1994 and is available on-line at: http://andrew.ucsd.edu/co2qc/handbook.html. Andrew Dickson (UCSD Scripps) is finalizing preparation for a "Guide of Best Practices for Oceanic CO_2 Measurement and Data Reporting", which should be published by PICES and the IOCCP early next year.

The manuals provide a framework for international cooperation by defining how to make measurements and how to report measurements. There have been many changes in methods and data management practices in the 10 years since WOCE, and we can expect more, and more rapid, changes in the future. We need to ensure a system of regular revision and international agreements on best practices as the technology evolves. Participants agreed that the manuals should be published on-line in individual chapters covering each measurement type. These chapters would then be updated as appropriate and by the appropriate group charged with establishing international agreements. Such a system would keep the manual up-to-date without putting an undue burden on any one group charged with managing the whole manual. CCHDO agreed to be the home site for the on-line manuals.

Participants also noted that there is an urgent need for agreed standards for nutrients. There are currently accuracy problems for both silicate and phosphate. While accuracy for nitrate is good, there are still questions about whether nitrate and nitrite should be measured separately. Improved total nitrogen measurements is also a goal.

IOCCP and CLIVAR representatives informed the meeting that plans for a revision of this manual had been discussed earlier in the year and initial preparations had been made. They agreed to pursue this rapidly as an action item from this workshop.

International Programs

CLIVAR

The CLIVAR/carbon repeat hydrography program is coordinated in close collaboration between CLIVAR's Global Synthesis and Observations Panel (GSOP), which provides the general oversight, and the International CLIVAR Project Office (ICPO), which manages and compiles the information on past, present and future post-WOCE cruises. The ICPO maintains a database with information on cruises, which can be accessed through a password-protected webpage on the CLIVAR website (www.clivar.org/carbon_hydro/). PIs and chief scientists can, and indeed are encouraged to, input new and updated information themselves about their cruises. This database is intended to hold information not only on cruises that follow former WOCE lines, but is also open to include details on any scientific cruises that make physical and/or carbon measurements. Currently, the whole CLIVAR website is being redesigned, aiming for an improved navigability and access to information.

The hydrography datasets acquired on the scientific cruises will have a final repository at the CLIVAR and Carbon Hydrographic Data Office (CCHDO)

(http://cchdo.ucsd.edu). The CCHDO, in close collaboration with ICPO, is working to gather data from the scientific community and from national data centres, where PIs will primarily submit their datasets. The CCHDO also merges and makes freely available quality-controlled data, improves the adherence of data to original WOCE format and content specifications, and assembles and provides relevant documentation. The scientific expertise in interpreting the hydrography datasets resides in the four CLIVAR Ocean Basin Panels (for more information on the CLIVAR Ocean Basin Panels, see http://www.clivar.org/organization/index.htm). In collaboration with GSOP, the Basin Panels aim at international coordination and facilitation of activities to develop the global and regional scientific understanding of oceanographic processes.

Who's who:
ICPO – Director: Howard Cattle, Website manager: Nico Caltabiano
GSOP – Co-chairs: Detlef Stammer and Dean Roemmich
CCHDO – Director: Jim Swift, Data manager: Steve Diggs

Ocean Carbon Community
For carbon, several programs work together to provide technical coordination, data management, and scientific oversight for ocean carbon observations and research. Technical coordination is provided by the IOCCP, which compiles information about ocean carbon observations being carried out in national, regional, and global research programs to create a continuously-updated global view of the ocean carbon observation network. The IOCCP also brings together the community periodically to analyze this information and to ensure that a) the coverage from this combined network is sufficient to meet research needs for basin and global scale issues, b) the data from individual activities are comparable (e.g., through use of standards and reference materials, qc/qa procedures, best practices, etc.), and c) the data management practices of each program are compatible and coordinated. CDIAC Ocean CO_2 program serves as the international data center for ocean carbon, and also hosts the GLODAP data synthesis project, which is compiling data from all existing programs that have measured water column ocean carbon variables into a single format data set and gridded data product. These data will soon be made available through Live-Access Server in partnership with NOAA PMEL. The SOLAS / IMBER Carbon Implementation Group provides scientific guidance at the international level and leads the coordination of data synthesis activities.

These groups, which plan and implement activities jointly, work together to provide both a sustained organization for technical coordination and data and information management (IOCCP and CDIAC), and a science driver that evolves as the science issues and research programs develop (SOLAS / IMBER from ~ 2004 – 2014).

Who's who:
IOCCP - Chair: Chris Sabine, Project Coordinators: Maria Hood, Roger Dargaville
CDIAC Ocean CO_2 – Alex Kozyr
SOLAS/IMBER Carbon Implementation Group – Arne Koertzinger and Truls Johannessen (Co-Chairs); Niki Gruber (ocean interior working group leader)

4. Working Session I: Assessment of Current Program and Proposals for Improvements

Participants at the meeting were asked to evaluate the successes and failures of the post-WOCE hydrographic program thus far and to consider what improvements are needed immediately and longer-term. The participants broke out into two groups, one for physical hydrography and the Argo Program, and the other for carbon and tracers, and then compared assessments in plenary discussions.

1. Is the current design of the hydrographic program appropriate, and is there a need to better coordinate the design and planning of the cruises ?

The < 10 year repeat strategy has been successful in permitting us to see significant changes, but we currently have a problem in maintaining synopticity in the repeat sections. From the number of repeated sections that have already been implemented, we can see significant changes and are beginning to understand what processes are responsible for them. This is also true for carbon inventories. For both physics and carbon, however, interpretation and attribution of changes is still a challenge, either due to sparse sample spacing or inability to distinguish between physical and biogeochemical processes that control the distributions. There are problems with the synopticity of the global survey, with sections being completed many years apart whereas the goal should be to complete the survey within a 2-3 year time period. Accomplishing this requires tight international coordination that doesn't exist at present.

Based on what we learned from the WOCE program, science questions have evolved and a new strategy is needed. While property transport calculations still need to be a core aspect of the hydrography program, we need a new emphasis on detecting and attributing inventory changes and accumulation rates of globally significant water masses. The current sampling strategy is well suited for transport calculations but is less well-suited for quantifying inventory changes. There are a number of hydrographic programs that have been carried out since WOCE that do not form part of the OceanObs'99 strategy, yet provide extremely useful information for interpretation of processes and filling gaps in sparse sampling. In addition, there have been many technological advances since WOCE that offer new possibilities for science, including a broader suite of freons, high-quality DIC and DOC with certified reference materials, and lowered Acoustic Doppler Current Profiler (ADCP). The relevance of time series observations to the goals of this new program cannot be overstated and should be considered an integral part of this program, through integration of time series stations and survey lines as well as a common data management structure. There are also new programs being developed to look at other issues that will also be critical for understanding carbon, such as the proposed GEOTRACES program for trace metal processes and inventories. It is also extremely important to make critical linkages with the Argo program and to pursue the potential to extend Argo to measure O_2 and possibly other biogeochemical parameters.

Having up-to-date and comprehensive information is crucial to plan, implement, and coordinate hydrography. Information is critical, and at present, there is either too much unstructured information about specific programs or not enough information about the global suite of programs that could contribute to hydrography. Resources

are needed to focus efforts at an international office or data center, with more effort to maintain up-to-date information and someone to serve as a pro-active coordinator to chase down information and data. If comprehensive information about programs were available, joint planning and synthesis efforts could be implemented through existing groups and would not require a new international program. A small committee with representatives from existing groups should be established to provide guidance on these immediate coordination issues as well as strategy issues mentioned above, and resources should be found in the project offices and/or data centers to establish the necessary information system.

2. Is there a basic set of requirements for a cruise to count as a repeat hydrography line ?

Repeat hydrography can no longer be considered to be just ship-based surveys. Repeat hydrography is implemented through time series stations, through Argo, and through ship-based hydrographic programs that have not traditionally been included in the global survey strategies, such as sections in marginal seas, coastal regions, or those carried out as part of process studies. Many countries are implementing programs that are extremely useful for interpretation, but many of these programs may not be able to adhere to a set of requirements that is too prescriptive.

We can define a set of goals for a core ship-based hydrography program, recognizing that other cruises and platforms form critical partnerships for meeting science goals of the program. The goal for a post-WOCE international hydrography and carbon program should be to quantify and contribute to the understanding of decadal changes in the inventory and transport of heat, fresh water, carbon dioxide (CO_2), and related parameters in the ocean. The approach involves multidisciplinary shipboard hydrographic survey cruises that are reoccupied, in close collaboration with other platforms and programs, such as time series stations and Argo. While it is recognized that ship-based hydrography alone cannot meet the science goals, it still remains the only means of directly measuring the full suite of ocean water properties at high-vertical resolution. There is a need to define the core set of ship-based hydrographic cruises that will form the hydrography component of this larger observing network.

The core ship-based hydrography program should focus on laying down a baseline for the future, where lines with a variety of sampling resolutions can contribute to the global survey as long as they are repeated. The participants defined two broad categories of lines that contribute to a ship-based repeat hydrography program: 1) high-resolution cruises for transport calculations that follow the traditional WOCE sample spacing of 30 nautical miles with full water column sampling; and 2) repeated lines (not one-off lines) with varying resolution. There are currently many repeat sections being implemented that provide useful information, but are either higher frequency cruises without carbon or lower resolution cruises with carbon. These provide critical information for interpretation and filling gaps in the global network. For carbon, a minimum criteria would be one station at least every 400 km with casts below the mixed layer and repeated regularly.

Defining a core set of measurements is important for developing a cohesive program with agreed goals and priorities, but should not be so prescriptive as to exclude groups from participating as full partners in the global network. Participants felt that it was

important to set goals for recommend core measurements that should be included on cruises, which may provide some countries the leverage they require to get the measurements included. However, it is equally important not to make the list so prescriptive that some groups would not be able to meet the requirements and thus would not consider their cruises as a contribution to the program. Ideally, core program lines should measure temperature, salinity, pressure, nitrate, phosphate, silicate, oxygen, chloroflurocarbon tracers (CFC-11, -12, -113), shipboard and lowered ADCP and at least 2 carbon parameters (e.g., DIC, Alk, pCO_2, pH). All measurements should be made with the highest resolution possible with WOCE-level precision and accuracy. The type of carbon measurements and their quality need to be sufficient to determine DIC and Alkalinity to approach the accuracy goals of the program (2μmol kg^{-1} for DIC; 4 μmol kg^{-1} for ALK). Also recommended are an occasional third carbon parameter for internal consistency purposes, separate measurements of NO_2 and NO_3 (and at least clear reporting of what was measured), organics (POC, DOC), ^{13}C, and underway surface measurements (including pCO_2, pigments, and related biological parameters at the surface).

The frequency of repeat sections should be designed to resolve both natural and anthropogenic changes. Anthropogenic climate change is not the only driving force of interest that should be addressed with ship-based hydrography. Natural variability and regional climate phenomena are often driving changes on shorter timescales than anthropogenic forcing. In the North Atlantic, the dominant period is 10-12 years; for the Pacific, it is about 15 years; for the Indian, we do not actually know very much, but this also argues for a higher frequency repeat. With Argo, we will learn more about the dominant variability in each basin, but we won't learn this for possibly another 10-20 years. This argues for a global repeat frequency for ship-based hydrography of no more than 5-7 years. As mentioned earlier, synopticity issues will be critical and tight coordination at the international level will be required.

There is a need to agree on a consistent definition for this new period of post-WOCE hydrography. Currently at the international level, the program is referred to as "CLIVAR/Carbon Repeat Hydrography", which is both misleading and inappropriate. CLIVAR is a program, and carbon is a parameter that we measure. There is also a need to define this future activity independently of research programs having a finite lifetime. Participants agreed that an appropriate definition would be the "International Repeat Hydrography and Carbon Program". While keeping the word carbon in the title may appear to be redundant, some participants noted the importance of keeping the word carbon explicitly in the definition to signal that this is not simply a mapping activity.

5. Working Session II: Approaches for Data Management, Syntheses and Interpretation

Participants were asked to consider the best approaches for synthesis and interpretation of international data sets, and how to ensure that proper credit is given to data collectors. Meeting science goals of the program requires a clear strategy for data synthesis and interpretation, and participants were asked to evaluate how syntheses could be carried out systematically for a sustained program. This necessarily involves discussions of data and information management.

Data syntheses from a sustained observation activity requires a different approach than has been traditionally carried out through research programs. Participants recognized that any synthesis mechanism that is developed must address new realities of working within the framework of a sustained observation program that has no "sunset clause", but which also will have a requirement to produce scientific products on a timescale that is much shorter than the traditional 10-year approach carried out by global research programs in the past. The repeat hydrography program will need to continually justify its value through publications and data products, and a mechanism for data syntheses must be developed to address these needs.

Data syntheses activities should be driven by the science. Participants recognized the continued importance of keeping the repeat hydrography program focused on addressing science questions, and noted that attempts to carry out data syntheses are only successful when there is a clear science issue to be resolved through standardizing and merging of basin and global scale data sets. Participants at the meeting also emphasized that ship-based repeat hydrography data will increasingly be synthesized with data from other platforms to address specific scientific issues, which requires a bottom-up science approach rather than a top-down data management approach.

Data syntheses are best carried out using an ocean basin approach. This is an approach that has been used successfully in the past by many programs, is a convenient scale to define many scientific issues, and basin groups already exists for most areas. Participants agreed that there should be 4 groups: Atlantic (which would include the Arctic), Pacific, Indian, and Southern Ocean. The products of these basin syntheses would address both specific scientific questions and contribute to an ever-growing global synthesis product.

A 3-step basin synthesis approach was outlined, bringing together interdisciplinary science, the data synthesis activity, and the interpretation and products development. Several participants provided overviews of recent synthesis activities that were conducive to both science and contributing to the development of a continuously growing global synthesis. Participants discussed how to adapt current approaches to deal with issues of larger integration between physics and biogeochemistry, other measurement platforms, observationalists and modelers, etc., and outlined the following potential approach:

1. For each basin, develop a science workshop to bring together observations, models, and ideas around a particular science issue that sets the framework for the data synthesis activity. These issues will evolve over time with the science

and with the state of the observing system, and may include topics such as the value of adding new biogeochemical sensors to profiling floats, looking at what we know about decadal variability, or comparisons between observations and models, etc. This would involve (and may be led by) existing global or regional research programs, where appropriate.

2. From this workshop, develop a list of the collaborative projects to be carried out to address the science issues, and establish a working group that will carry out the necessary data synthesis activities. Technical coordination groups such as the IOCCP, the Ocean Observations Panel for Climate (OOPC), the North Pacific Marine Science Organization (PICES) Carbon and Climate (Pacific), and research program based groups such as CarboOcean (Atlantic), and the CLIVAR Basin Panels could provide support for these activities.

3. Hold a smaller follow-up workshop to present results and outline product development, including scientific journal articles (e.g., papers contribute to a special issue of a journal) as well as publication and release of the data synthesis and merging these data with the global dataset.

Participants stressed that this 3 step procedure should take no more than 2-3 years from first workshop to final product delivery to be able to show continued progress and justification of the continued program. A process like this would provide flexibility for science issues to evolve over time and foster integration among a wide range of communities (physics, biogeochemistry, observationalists, modelers, etc). Moreover, it would also provide a more sustained and continual framework for producing coordinated basin and global scale data products on a regular basis.

There are many data and information management activities operating at the national, regional, and international level, but there is a need to establish a single coordinated service for repeat hydrography. Presentations on data and information services were provided by the following groups: CLIVAR and Carbon Hydrographic Data Office (Swift), Carbon Dioxide Information and Analysis Center (CDIAC) Ocean CO_2 program (Kozyr), the US-National Oceanographic Data Center / World Data Center A (Garcia), the Argo data system (King), PICES CO_2 Related Data Integration for the North Pacific (PICNIC) (Suzuki), World Data Center for Marine Environmental Data (WDC-MARE) (Dittert), EU-CarboOcean (Pfeil), International Ocean Carbon Coordination Project (Hood), CLIVAR International Project Office (Caltabiano). While all agree that a one-stop-shopping system for information and data from hydrography is desirable, there is also a strong need to keep all of the carbon data together with carbon data from other platforms. The carbon community is relatively well-organized, with national and regional data centers working closely with CDIAC to provide global and comprehensive carbon data and information. For hydrography, CCHDO and CDIAC have developed a joint data management plan (http://cdiac.esd.ornl.gov/oceans/RepeatSections/CDIAC_WHPO_plan.pdf), where CDIAC makes all repeat hydrography carbon data available to CCHDO as it becomes available. However, these collaborations need to be reinforced and cruise information on CCHDO needs to be modified to include information in the general description of the cruise to indicate if carbon variables were measured. For information management, the IOCCP and CDIAC have developed a single system maintained by CDIAC to provide up-to-date information, maps, and tables about on-going and

planned ocean carbon activities and data. For physical hydrography variables, the CCHDO and CLIVAR IPO currently have similar information on their respective web-sites, but use different metadata standards. The CLIVAR IPO site is currently undergoing revisions to improve navigation and information access, but still relies on individual PIs to update information. Participants emphasized the need for a more pro-active approach to keeping information up-to-date, stating that a good information system can often replace the need for establish new international oversight and planning committees.

Developing a sustained program requires regular and frequent product development to justify the program's continuing value. This will only be possible through rapid data release. The US repeat hydrography program currently sends a data manager on the ship for every cruise to make the data available as soon as the ship returns home. This has been a tremendous aid to the scientists and has significantly improved the overall quality of the program. In addition, a major portion of the program's value will be the rapid (near-real time) data availability for other research and observing programs like Argo. Suggestions have been made for all future lines to submit temperature and salinity data in real-time via TESAC on the GTS. The CLIVAR GSOP developed a CLIVAR Data Policy (http://www.clivar.org/data/data_policy.htm) that addresses issues of data quality and timely release of data relevant to hydrography. This policy should be re-examined to ensure that it considers issues of data quality and release for carbon and biogeochemistry parameters.

To facilitate rapid release of data, we need to develop a system to appropriately recognize the efforts of data contributors. While the system of having data contributors participate in synthesis activities for co-authorship may resolve many of these issues, there will be cases where data contributors may not be able to participate actively in the synthesis work. And ultimately, the system needs to evolve to the point that data sets are released as soon as possible without waiting for the start-up of another 2-3 year synthesis activity. In the carbon community there has been a persistent phobia that data made public will be used without recognizing the contribution made by the contributor, although participants emphasized that, in practice, there are very few examples of this ever happening. However, participants felt that it is still important to establish community-wide practices to standardize how to appropriately acknowledge data contributors. Nicolas Dittert described a system currently being used by WDC-MARE that involves identifying data sets with DOI identifies (Digital Object Identifiers). The DOI system provides a framework for identification and management of intellectual content across all forms of electronic media (e.g., electronic publications as well as data sets). Once a data set has been given a DOI, it can be referenced in the same manner as a publication in a journal article. Participants also recognized the importance of requesting reviewers of journal articles to insist that data sets are appropriately recognized in publications using this DOI reference system.

6. Summary and Actions

Participants summarized the following immediate coordination needs and actions resulting from discussions at this workshop.

Establish a small advisory group to develop a cohesive and comprehensive international repeat hydrography and carbon program:

- Oversee the writing of technical white papers to highlight successes and needs for a sustained and integrated international repeat hydrography and carbon program;
- Facilitate linkages with critical partners such as Argo and OceanSITES time series network;
- Provide oversight and feedback to data and information management system;
- Provide oversight of basin synthesis activities to encourage multi-disciplinary and multi-platform integration;
- Serve as an international focal point for the development of this program and lobby for its support.

Immediate Actions:

Establish the International Repeat Hydrography and Carbon (IRHC) Advisory Group, to be co-sponsored by IOCCP, CLIVAR-GSOP, and SOLAS/IMBER Joint Carbon Coordination Group (*S.I.C.*). Suggested names put forward at the workshop include scientists working in CLIVAR-GSOP, Argo, SOLAS/IMBER Carbon Implementation Group, CarboOcean, US Ocean Carbon and Climate Change (OCCC) program, IOCCP, and the CLIVAR International Project Office.

Responsible for Action Item: Maria Hood (IOCCP), Nico Caltabiano (CLIVAR-IPO), and a S.I.C. representative (to-be-determined) to provide oversight and technical support.

Timeframe: 1st quarter 2006 to establish group and agree on working arrangements and actions to address coordination needs listed above.

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Establish closer links with Argo:

- Increase the emphasis on deep salinity data in the repeat hydrography program in key areas;
- Encourage and facilitate rapid release of CTD data;
- Investigate the feasibility and mutual interest for O_2 sensors on a subset of Argo floats.

Immediate Actions:

- Establish a "Friends of Oxygen" working group to develop plans and proposals for inclusion of O_2 on Argo Floats;
- Working Group to draft a technical white-paper on Argo-O_2 to present the utility and practicality of adding O_2 sensors to a portion of the Argo array as a pilot project. Issues to be addressed include the number of sensors required, interpretation of the resulting data, and technical issues such as the sensor design, calibration accuracy and stability, power usage, satellite communication requirements, and additional costs;
- Working Group to present an overview of the science of O_2 from profiling floats at the 2nd Argo Science Workshop in Venice, March 13-18 (Koertzinger);

- Working Group to organize a "Friends of Oxygen" mini-workshop in conjunction with the First North Atlantic Basin Synthesis meeting, tentatively planned for June 2006 in Iceland;
- Address other issues of concern for Argo and Repeat Hydrography (e.g., deep salinities, rapid release of CTD data, etc) via the Advisory Group.

Responsible for Action Item: Niki Gruber (S.I.C.) has agreed to lead the working group; Roger Dargaville (IOCCP) will assist with oversight and technical support of Friends of Oxygen working group; Greg Johnson and Nico Caltabiano (CLIVAR-IPO) will assist with linkages to Argo on other issues.

Timeframe: Friends of Oxygen Working Group = Immediate. *Actions already underway December 2005*: Establishment of the writing group has begun and plans for the way forward have been agreed. Contacts have been made with John Gould and Dean Roemmich (Argo), who welcome and support the initiative. Other collaborative issues between Argo and IRHC group will be a priority activity for the Advisory Panel upon its establishment.

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Improve data and information coordination:

- Develop a more coordinated system between CCHDO, CDIAC, and WDC-A for information, data management, and data archival for repeat hydrography, including both physical and chemical variables;
- Update the hydrographic program manuals;
- Establish internationally-agreed standards for nutrients;
- Establish a regular practice of using DOIs for data sets and enforcing their use in journal articles.

Immediate Actions:

- Develop an agreed plan on how to meet DIM needs expressed at this workshop for the developing IRHC program, and define the ways and means of implementing these activities;
- Set up a small working group to establish internationally-agreed standards for nutrients based on existing best-practices;
- Identify lead authors for updating chapters of the manual and work through CCHDO to make these updated methods readily-available on-line;
- Define and develop a way forward to establish the use of DOIs for data sets and publish this information widely to lobby for adoption and application.

Responsible for Action Items: The IRHC Advisory Group, Jim Swift and Steve Diggs (CCHDO), Alex Kozyr (CDIAC), Hernan Garcia (WDC-A), and Nicolas Dittert (WDC-MARE); Maria Hood and Nico Caltabiano for oversight and technical support of the group.

Timeframe: priority activity for the Advisory Panel upon its establishment.

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Establish a mechanism for integrated data syntheses:

- Develop synthesis activities around scientific issues and through science workshops using an integrated approach (physics, chemistry, observations and models) for each basin, facilitated through existing global and regional research programs;
- Follow-up these science workshops with collaborative data synthesis activities carried out by data contributors;
- Finalize the synthesis activity with a small follow-up workshop to present results of the synthesis and to plan publications and merging of the data product with the global data synthesis.

Immediate Actions:

- Encourage and facilitate a science workshop focused on the North Atlantic from which synthesis activities may be planned;
- Ensure that data synthesis activities are compatible with existing global data synthesis activities, formats, etc.

Responsible for Action Item: IRHC Advisory Group to work with existing research programs to facilitate and encourage this activity.

Timeframe: Immediate for North Atlantic. *Actions already underway December 2005:* CarboOcean has initiated a First workshop for the North Atlantic Synthesis in partnership with SOLAS/IMBER Carbon Implementation Group and US Ocean Carbon and Climate Change program. The workshop will tentatively be scheduled for late June 2006, following the early-June release of the Carbon in the North Atlantic (CARINA) data set, which is being merged with the GLODAP global synthesis. CLIVAR will be invited to co-sponsor this event to encourage and facilitate an integrated synthesis. A "Friends of Oxygen" workshop is being planned as a follow-on to this meeting.

ANNEX I
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