WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)

JOINT WMO/IOC TECHNICAL COMMISSION FOR OCEANOGRAPHY AND MARINE METEOROLOGY (JCOMM)
SHIP OBSERVATIONS TEAM (SOT)

SEVENTH SESSION

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ITEM: 5.2

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REPORT BY THE ASSOCIATED PROGRAMMES

(Submitted by the Associated Programmes)

Summary and purpose of the document

This document includes reports from associated programmes or projects. Feedback will be requested from the SOT on areas of common interest and potential common actions.

ACTION PROPOSED

The Team will review the information contained in this report, and comment and make decisions or recommendations as appropriate. See part A for the details of recommended actions.

Appendices:
- A. Shipboard Automated Meteorological and Oceanographic System (SAMOS) Initiative
- B. OceanoScientific Programme
- C. World Ocean Council
- D. Group for High Resolution SST (GHRSST)
- E. FerryBox
- F. Global Ocean Ship-Based Hydrographic Investigations Programme (GO-SHIP)
- G. International Ocean Carbon Coordination Project (IOCCP)

APPENDIX A

SHIPBOARD AUTOMATED METEOROLOGICAL AND OCEANOGRAPHIC SYSTEM (SAMOS) INITIATIVE

Submitted by Mr. Shawn R. Smith
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Proposed actions and recommendations

a. SOT is invited to review and comment on the activities of the SAMOS initiative.
b. SOT and SOOP members are asked to recommend a set of standard quality control procedures for underway thermosalinograph (and additional flow through sensor) data.
c. SAMOS recommends that the U.S. VOS coordinator contact NOAA and U.S. university research vessels not presently transmitting via GTS to recruit them as VOS (or VOSClim as appropriate).

1. OBJECTIVES

The shipboard automated meteorological and oceanographic system (SAMOS) initiative aims to improve the quality of meteorological and near-surface oceanographic observations collected in situ on research vessels (R/Vs). Scientific objectives of SAMOS include (1) creating quality estimates of the heat, moisture, momentum, and radiation fluxes at the air-sea interface, (2) improving the understanding of the biases and uncertainties in global air-sea fluxes, (3) benchmarking new satellite and model products, and (4) providing high-quality observations to support modeling activities (e.g., reanalysis), process studies, and global climate programs.

To achieve the science objectives, the SAMOS initiative seeks to (1) improve access to quality assured SAMOS data for scientific and operational users by providing free and open access to data and metadata, (2) expand availability of SAMOS observations collected in remote ocean regions (e.g., Southern Ocean), (3) improve the accuracy and calibration of SAMOS measurements, (4) provide standards for data and metadata collected on SAMOS equipped vessels, (5) ensure routine archival of SAMOS data at world data centers, (6) develop documentation and training materials for use by data collectors and the user community, (7) support comparison studies between in situ platforms (e.g., R/Vs, VOS, buoys), and (8) develop partnerships in the international marine community.

2. DATA COLLECTED BY SAMOS INITIATIVE

The SAMOS initiative focuses on meteorological and near-surface oceanographic data collected by the scientific instrument system (a SAMOS) permanently installed on individual R/Vs. A SAMOS is a computerized data logging system that continuously records navigational (ship's position, course, speed, and heading), meteorological (winds, air temperature, pressure, moisture, rainfall, and radiation), and near-surface oceanographic (sea temperature, salinity, conductivity, florescence) parameters (basically a specialized type of automatic weather system). The SAMOS initiative receives measurements recorded at 1-min intervals and derived from higher frequency samples (on the order of 1 Hz). These data must be differentiated from the typical voluntary observing ship (VOS) reports that occur at 1-, 3-, or 6-hourly intervals. VOS reports are generated by automated (e.g., French BATOS) or manually read instruments provided by the responsible countries' national meteorological service (NMS). Instruments used on R/Vs to make VOS reports are generally, but not always, separate from the instruments comprising a SAMOS (typically climate-quality instruments installed by the vessel operator).

The SAMOS data center at the Florida State University (FSU) has recruited 31 U.S.-operated and 3 international R/Vs (up from 26 and 2, respectively, at SOT-VI). Limited recruitment of additional U.S. university-operated vessels is underway through the Rolling Deck to Repository (http://www.rvdata.us) project. SAMOS data are transmitted near 0000 UTC via daily email attachments containing all 1-min data records for the previous day. Once received at FSU, the observations (1) are automatically formatted and combined with available vessel metadata (sensor types, locations, units, etc.) stored in a ship profile database, (2) undergo automated quality evaluation, and (3) are distributed via web (http://samos.coaps.fsu.edu), ftp, and THREDDS servers within 5 minutes of receipt. Vessel operators and at-sea marine technicians are notified via email when an analyst at FSU notes problems (through automated error logs or subsequent visual data inspection). Additional visual quality control is applied to create research-quality, delayed-mode data only for NOAA-operated vessels. All data received and processed by SAMOS are archived at the U.S. National Oceanographic Data Center.

3. ACTIVITIES RELEVANT TO SOT

The SAMOS initiative continues routine acquisition and quality control of data from R/Vs operating throughout the world's oceans, including areas well outside normal shipping lanes. All data are provided in "real-time" free of any restrictions or holds via web services. At present, these data are not distributed via the GTS. Although, a draft plan of action was developed between the SAMOS, SOT, and VOSP chairs and the U.S. VOS program manager to place SAMOS data on the GTS, regrettably, little action was possible since the SOT-VI because of continued funding reductions. The SAMOS chair will present at SOT-VII an analysis of data received at the U.S. National Climatic Data Center via the GTS for vessels recruited to SAMOS and recommends that the U.S. VOS coordinator contact and recruit the vessels not presently contributing via VOS.

Collecting and updating instrumental metadata for research vessels continues to be a problem. Although initial discussion occurred between the SAMOS chair and the U.S. VOS coordinator, no action has been taken regarding leveraging the port meteorological officer (PMO) network in the U.S. to help with metadata collection during visits to R/Vs participating in SAMOS. SAMOS personnel continue to visit recruited R/Vs to collect instrumental metadata and digital photos as resources allow. NOAA continues to be proactive with metadata collection, developing a database to capture instrumental metadata for all NOAA R/Vs and training personnel to routinely update these metadata. A continuing problem on R/Vs is that the crew may record their VOS observation using either the ship's NMS-provided instruments or the SAMOS, and the source instrumentation of the observation is not routinely transmitted with VOS reports.
The SAMOS data center continues to contribute to educational initiatives targeting marine technicians working on R/Vs. In partnership with NOAA's Earth System Research Laboratory, the SAMOS data center created a professional development short-course for in-service marine technicians that focuses on best practices and techniques for collection of marine meteorological observations on R/Vs to support ocean, atmosphere, and climate research. The short-course has been presented to marine technicians on three occasions since 2011 and course materials for each session are available at http://samos.coaps.fsu.edu/html/mtshortcourse.php.

In support of the JCOMM ETMC, the SAMOS data center continues to develop a catalog of digital R/V observations that may not be readily available in delayed-mode climate archives. The most recent version of the catalog is available in Annex H of the "ICOADS Marine Data Rescue" document available at http://icoads.noaa.gov/reclaim/pdf/marine-data-rescue.pdf. The SAMOS data center is also working to provide a subset of SAMOS observations collected since 2005 for inclusion in release 2.6 of the ICOADS. In addition to supporting ETMC, the SAMOS chair is an acting member of the SOT Task Team on Instrument Standards and the Cross-cutting Task Team on the Marine Climate Data System.

4. ACTIVITIES RELEVANT TO SOOP

In 2009, the SAMOS data center began routine collection and evaluation of water temperature, conductivity, and salinity data from all recruited vessels equipped with a thermosalinograph (or salinometer). Automated range checks from the GOSUD quality control guide have been implemented and visual quality control is completed for all NOAA vessels. Recent application of these quality controlled water data to validate ocean models has resulted in an increased demand by the research community for quality processed underway ocean observations (i.e., pCO_2, turbidity, fluorescence, dissolved oxygen, chlorophyll, and dissolved oxygen). Providing these values through the SAMOS program would require development and implementation of standardized automated quality control procedures. The SAMOS chair recommends that appropriate members of SOT and SOOP identify and define appropriate quality control procedures for underway flow-water system observations. As resources allow, the SAMOS data center would then implement these procedures as part of our routine quality control system.

7. ACKNOWLEDGEMENTS

SAMOS activities at FSU are supported by the Climate Observation Division at NOAA via the Northern Gulf of Mexico Cooperative Institute. Additional funding is provided by the Division of Ocean Science, Ocean Instrumentation and Technical Services branch of the U.S. National Science Foundation.

APPENDIX B

Scientific data acquisition by sailing ships: The *OceanoScientific® Programme*

Reported submitted by Yvan Griboval, SalingOne

The *OceanoScientific® Programme* provides the international scientific community free of charge with scientific data collected at the ocean - atmosphere interface in sea areas subject to little or no scientific exploration.

In November 2006 began a collaboration with the French institutes IFREMER, Météo-France, INSU/CNRS and GEOMAR (Ger.) and later on also with the University of Maine and the Laboratory of Oceanography of Villefranche-sur-Mer. In 2009, the *OceanoScientific® Programme* was presented to the SOT at its fifth session and ever since has been seeking its recommendations. The Programme has also been presented to the World Ocean Council and to FerryBox. Major technical and organizational advancements were presented at SOT-6.

After having received the patronage of the French Research Ministry and of the French Ministry for Ecology and sustainable Development, the *OceanoScientific® Programme* has been recognized by the French Global Economic Competitiveness Cluster Pôle Mer Bretagne in 2012.

The tool of the *OceanoScientific® Programme* is the *OceanoScientific® System* (OSC System), which will be industrialized as from summer 2014. This is a "Plug & Play" equipment for the automatic acquisition and transmission by satellite of at least twelve scientific parameters - formatted according to the standards of UN agencies - related to climate change, collected at the ocean - atmosphere interface. The initializing parameters were wind speed, wind direction, air relative humidity, air temperature, sea level pressure, SST, SSS, and pCO2. Further parameters have been integrated: photoactive radiation, fluorescence, pH and turbidity. Other sensors can still be integrated Plug & Play into the OSC System.

Since 2009, several test and development campaigns have been organized for the various prototypes of the OSC System, named *OceanoScientific® Campaigns*. These have been carried out in the Atlantic in 2009, then in the North Sea, and in the Arctic last summer. The latest prototype of the OSC System is installed from 21 January to 28 April in the Antarctica, on the three-masted barque EUROPA, a superb Dutch tall sailing ship measuring 56 meters and built in 1911, for a testing Campaign from Cape Horn to the Cape of Good Hope, that is to say in data sparse areas.

These test campaigns have enabled major evolutions for the OSC System. Long-term tests have been carried out in the southern ocean on a large vessel implying long cables installations, in high waves on a vessel rolling differently compared to a yacht. The navigation in the Baffin Sea made possible the detection of problems due to sediments, so that filter issues were tracked down. Since then, a long-term test of a new type of pump has been carried out. Furthermore, the innovative pCO2 sensor used in the OSC System has been approved on a Research Vessel (Polarstern). Software issues have also been tackled as further parameters have been implemented into BATOS for real time transmission and a new software project has been launched.

These Campaigns are currently financed thanks to the funds of major European programs:
FEDER Basse-Normandie and ERA-NET MARTEC II Programme.

In addition to create and industrialize the OSC System to be used on all the types of vessels over fifteen meters long, whether it be fleets of ocean-going sailing yachts or ferries getting their passengers around the Arctic and the Antarctica, the aim of the *OceanoScientific® Programme* is now to carry out, as from next summer, expeditions on 16-meter sailing ships especially designed for scientific use, the NAVOSE® - that is to say in French: **N**avire **A** **V**oile d'**O**bservation **S**cientifique de l'**E**nvironnement (Sailing Vessel of Scientific Observation of the Environment).

Recommendations of the SOT will play an important role in the planning of upcoming campaigns, to be able to respond as much as possible to the needs of the community. These expeditions will probably previously be approved by the international scientific community, especially through Météo-France and IFREMER.

The aim is to collect scientific data at the ocean - atmosphere interface and to release autonomous scientific equipment in sea areas subject to little or no exploration, specifically in areas where traditional scientific vessels do not navigate and where there are few or no reliable means to study natural phenomenon at the sea surface. Due to the change from a racing to a scientific vessel, it will now indeed be possible to store floats and buoys on board and to deploy these instruments at sea. As from 2013, scientific expeditions will be carried out every year around the Antarctica, from Cape Town with return in this same harbour of South Africa. The first expedition, with only one sailing ship, is scheduled from next October to March 2014. Then, if the funds collected enable it, the aim will be to make two identical 16-meter sailing ships sail on this same route, during each summer of the southern hemisphere. The ultimate aim is to constitute a fleet of three identical sailing ships, especially prepared for that.

APPENDIX C

WORLD OCEAN COUNCIL (WOC)

A SHORT SUMMARY ON WOC DEVELOPMENTS AND PLANS IN RELATION TO SOT AND POSSIBLE RECOMMENDATIONS

(Report submitted by Paul Holthus, CEO, World Ocean Council)

The World Ocean Council (WOC) is the international, cross-sectoral business leadership alliance on “Corporate Ocean Responsibility”. The WOC brings together a range of ocean industries, e.g. shipping, oil/gas, fisheries, aquaculture, renewable energy, tourism, insurance, etc. to collaborate in working towards a shared goal of healthy and productive seas and their sustainable use and stewardship by a responsible ocean business community.

The WOC is steadily growing and currently has more than 60 leadership companies from around the world and from a broad range of ocean industries. Cross-sectoral industry working groups are addressing priority shared issues: e.g. marine spatial planning, invasive species, water pollution, ocean noise, marine debris, the Arctic, the ocean governance and policy, ocean observations and science.

In regards to private sector ocean, weather and climate observations, the WOC is uniquely positioned to develop and coordinate expanded, improved and better coordinated observations by the wide range of industry vessels (merchant ships, cruise vessels, fishing vessels) and platforms (oil/gas, aquaculture, renewable energy).Leadership companies from oil/gas, shipping, marine technology, and other sectors are strongly encouraging WOC to explore this potential.

The WOC has initiated development of the “Smart Ocean/Smart Industries” (SO/SI) program and working group, co-chaired by Maersk, Marinexplore and a major oil company (tbd).

Since the last SOT meeting, the WOC has followed through on efforts to catalyze an international, multi-sectoral system for engaging ocean industries in coordinated contribution to data collecting, sharing and use. As agreed at the last SOT, the WOC has acted as an advocate for JCOMM and its sampling programmes to ocean industries.

In partnership with IOC, the WOC convened the first SO/SI workshop at the IOC in Paris on 12-13 December 2011. This brought together representatives from shipping, oil and gas, marine technology and other sectors to meet with scientists, government agencies, and inter-governmental organizations, including JCOMM. The report is available on the web[1].

To foster and coordinate progress towards the goal of scaling up voluntary observations by industry, the workshop proposed creating a SO/SI Steering Committee consisting of both the industry leaders interested in advancing observations from ships and platforms and key scientific, government and intergovernmental organizations engaged in observation efforts. The WOC is moving forward in consultation with JCOMM, IOC and the GOOS Committee Co-chairs to create the SO/SI Steering Committee.

The WOC SO/SI seeks to create the institutional basis, continuity and supporting secretariat for advancing a coordinated, global approach to observations. This will learn from/build on ships of opportunity programs and create a program to engage a range of industries in ocean observations at a whole new scale, i.e. major fleets of vessels and offshore platforms participating in long term, integrated data collection.

The SO/SI seeks to expand voluntary observations to more than commercial shipping, to other kinds of vessels as well as a range of types of platforms and infrastructure, and beyond water

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1 http://www.oceancouncil.org/site/smart_ocean.php

column characteristics to a wide range of ocean and climate parameters. The WOC SO/SI seeks to provide a comprehensive framework for voluntary observations by industry that can grow over the years in several ways:

Scope of Observations: Ocean and climate observations;
- Ocean parameters: Surface, water column, seabed, biodiversity, noise, pH;

Scope of Industry infrastructure: Vessels and platforms (and, potentially, pipelines/cables);
- Vessels: Merchant shipping (container, tanker, passenger), ferries, fishing, private yachts);
- Platforms: Oil/gas, offshore wind, aquaculture.

The scope of the WOC SO/SI framework creates considerable opportunities for synergies and economies of scale through a cost effective, efficient coordinating platform for scaling up, optimizing and building on existing programs as well as fostering new ones. There are also a growing number of marine technology firms that are joining the WOC, and many more that are interested in the SO/SI, which bodes well for collaborative efforts to develop cost-effective.

<u>Draft SOT-7 recommendations and action are proposed below:</u>

(i) The Team invited its members to consider nominating themselves to GOOS as prospective members of the WOC joint industry/science SO/SI Steering Committee in order to ensure that there is adequate participation from governments and international agencies in this committee (***action; SOT members; ASAP***);

(ii) The Team requested the Task Team on VOS Recruitment and Programme Promotion (TT-VOSRPP) to work with the WOC to develop a list of key companies involved in voluntary observations (***action; TT-VOSRPP; Jul. 2013***);

(iii) The Team invited the WOC to work with the SOT to help recruit ships for participating in the VOS, SOOP, or ASAP, and to liaise with the Chair of the TT-VOSRPP in this regard (***action; WOC; ongoing***);

(iv) The Team invited the WOC to assist the Task Team on Instrument Standards (TT-IS) in order to facilitate the design of ships, other vessels and other offshore facilities (e.g. aquaculture, wind farms) that would make the installation of marine meteorological and oceanographic instrumentation easier (***action; WOC; SOT-8***);

(v) The Team invited the WOC to assist the Task Team on Satellite Telecommunications Systems (TT-Satcom) to explore how to best achieve cost effectiveness and cost efficiencies for voluntary observation and data telecommunication costs (***action; WOC; SOT-8***).

APPENDIX D

GROUP FOR HIGH RESOLUTION SST (GHRSST)

(Report submitted by Gary Corlett)

.1 INTRODUCTION

The Group for High Resolution Sea Surface Temperature (GHRSST) is the international expert group for the provision and application of the highest quality Sea Surface Temperature (SST) data to global user and research communities. GHRSST offers a suite of global high-resolution SST products, operationally, in near-real-time, on a daily basis. To maintain the high quality of the various SST products it is essential that the Group has access to in situ ocean surface data provided by a range of accurate instruments located on diverse platforms, over a wide range of climate conditions. Drifting and moored buoys provide a wealth of surface data, but lack repeated calibration (at least for drifters) and provision of the important metadata required for accurate validation of the GHRSST products. These latter requirements can only be provided by instruments on research vessels and ships of opportunity. This submission to the Seventh Session of the JCOMM Ship Observations Team (SOT-7) summarises activities relating to ship measurements of SST that GHRSST has been involved with since SOT-6.

The GHRSST Science Team has appointed Dr Helen Beggs, from the Australian Bureau of Meteorology, to be its point of contact with the SOT.

2. GHRSST

The Group for High Resolution Sea Surface Temperature (GHRSST) started in 2002 as one of the pilot projects of the Global Ocean Data Assimilation Experiment (GODAE), and is now the main expert group of users and providers of satellite SST data (Donlon et al., 2007). A new generation of high-resolution (< 10 km) global SST products and services, which have a demonstrated positive impact on ocean and atmospheric forecasting systems, are now provided by GHRSST in near-real-time on a day-to-day basis. Looking forward, GHRSST will continue to improve the quality and provision of high-resolution global SST data. Further information on GHRSST can be found at https://www.ghrsst.org .

2.1 Current uses of ship data within GHRSST

The current use of ship-borne SST data within GHRSST is to some extent limited and falls mainly into two categories. First, radiometric temperature measurements from SI traceable infrared radiometers mounted on ships of opportunity are used as a primary reference data set for infrared sensors that provide a retrieval of the skin SST, such as AATSR, the MODerate-resolution Imaging Spectroradiometer (MODIS), and the Visible Infrared Imager Radiometer Suite (VIIRS). Second, more conventional ship-based kinetic temperature measurements from engine room intakes or hull-mounted sensors obtained via the Global Telecommunications System (GTS) are used in many of the Level 4 analysis products and for validation of depth SST products.

3. ACTIVITIES SINCE SOT-6

Since SOT-6, GHRSST activities relating to ship measurements of SST have been focused in two areas:

1. Recommendations for non-radiometric SST measurements
2. Standardization of ship-borne radiometric SST measurements

Progress in each area is now reviewed.

3.1 Recommendations for non-radiometric SST measurements

The list of recommendations for data transmission resolution given in Table 1 were discussed at the 12th GHRSST Science Team, held in Edinburgh in June 2011, and were provided by Pierre Blouch from Météo France.

Element	Ship Observations	Ship-AWS
Time	1 minute	1 second
Ship's mean SOG	1 m/s	0.1 m/s
Ship's True Heading	5º	1º
Latitude/Longitude	0.01º	0.001º
Pressure	0.1 hPa	0.1 hPa
Wind Direction	1º	1º
Wind Speed	0.5 m/s	0.1 m/s
Air Temperature	0.1ºC	0.1ºC
Relative Humidity	1%	1%
SST	**0.01ºC**	**0.01ºC**
Departure of summer load line from sea level	1 m	
Total Cloud Cover	10%	
Global solar radiation	1000 J.m-2	
Long wave radiation	1000 J.m-2	

Table 1: Proposed data transmission resolution provided by Pierre Blouch

The SOT requested advice on future data transmission resolution for ship measurements and the GHRSST Science Team endorses a reporting resolution of 0.01K for SST. In addition the GHRSST Science Team requests consideration is given to providing non-radiometric SSTs to an accuracy of 0.05K whenever possible and in lieu of engine intake sensors (prone to artificial warming of the measured seawater), GHRSST recommends that SOT encourages commercial vessel owners to install calibrated hull-temperature sensors mounted on the inside of a ship's hull as documented in Beggs et al. (2012).

Helen Beggs presented the GHRSST recommendations from providing XBT data given in Table 2to the 1st XBT Workshop in Melbourne, 7-8 July 2011:

- Near real-time access to QC'd XBT SSTs (with any spikes removed)

XBT Element	Resolution	Accuracy
Time	5 minutes	5 minutes
Latitude/Longitude	0.005°	0.005°
Depth (in top 10 m)	0.1 m	0.5 m
SST	0.01 °C	0.05°C

Table 3: GHRSST recommendations for XBT data

3.2 Standardization of ship-borne radiometric SST measurements

The provision of reference IR radiometric SSTs has advanced since the last SOT meeting through the establishment of the international network for ship-borne IR radiometry. This network has recently been established to provide standardized protocols and procedures for taking IR radiometric measurements at sea and has been meeting through a series of workshops hosted by the International Space Science Institute (ISSI), in Bern, Switzerland.

Part of the ISSI activity has been to draft a best practice guide covering radiometer design, calibration, mounting on ships, uncertainty derivation, intercomparison, as well as an agreed CF compliant NetCDF data format. An initial draft of the guide will be available via the project website at http://www.issibern.ch/teams/satradio/ following the final workshop on 8-12 April 2013.

In addition to reference quality measurements of skin SST, with quantified uncertainties per measurement, the group is developing additional capability for existing radiometers that could potentially provide marine air temperature at an equivalent level of accuracy to SST. This capability would lead to an accurate measurement of air-sea temperature difference using a single sensor with SI-traceable calibration.

4. GENERAL ENGAGEMENT WITH THE IN SITU COMMUNITY

To maintain the high quality of the satellite SST products provided by GHRSST it is essential that the group has access to in situ ocean surface data provided by a range of accurate instruments located on diverse platforms, over a wide range of climate conditions. To attain this goal, GHRSST will continue and enhance its engagement with the SOT.

The following specific recommendations from GHRSST in relation to in situ observations were included in the GHRSST Recommendations to the JCOMM OCG in 2011, some of which will be of interest to the SOT:

1. Adding the provision of radiometric skin SST data to the JCOMM OCG portfolio of VOS measurements. Ships that participate in such a measurement programme should also, ideally, maintain a radiosonde capability.
2. Ensure that ships and other platforms currently providing high quality in situ data where possible expand their provision of high quality meteorological metadata. Wind speed, history of wind speed, air temperature and local humidity are the most important. Measurements of near-surface temperature profiles should also be encouraged.
3. Enhance the capability of Argo floats, drifting buoys and moorings to measure temperature profiles in the top 2 m of the ocean.
4. Where possible a regular accurate calibration of in situ data instrumentation is carried out, preferably against a standard that is traceable to an SI reference.
5. Establishing a JCOMM SOT working group to collaborate with GHRSST to better define requirements for measurements of SST and ancillary variables from ships, and to identify new opportunities that may assist with a more uniform coverage of the global oceans (See action review in Section 0).
6. Planning to obtain ship of opportunity participation in future SST measurement inter-comparison experiments.
7. Encourage JCOMM data providers to use the GHRSST data set to assess the accuracy and performance of their SST measurement instruments.

5. STATUS OF OPEN ACTION ITEMS

There is one open action on GHRSST from SOT-6:

- Action: SOT-6, 39. Ian Barton and the SOT Chair (Graeme Ball) to identify people for the proposed ad hoc working group and decide on the opportunity to establish a pilot project. I. Barton (or GHRSST) & G. Ball to report at SOT-7.

  Status: On 1 March 2013 Graeme Ball and Helen Beggs (GHRSST-SOT contact) met to discuss Action SOT-6 39. Due to the high cost of an SST radiometer, it was agreed that SOT, through the Port Meteorological Officers, would support GHRSST in installing radiometers on ships by assisting with vessel recruitment and coordination. In subsequent communication on 16 March 2013, Graeme Ball indicated that there was no point in establishing a pilot project since SOT could not aid in the purchase of the radiometers, however the proposal to form an ad hoc working group to better define requirements for measurements of SST and ancillary variables from ships, and to identify new opportunities that may assist with a more uniform coverage of the global oceans, could be discussed within the SOT Instrument Standards Group (Chair, Henry Kleta) at SOT-7.

GHRSST supports the formation of an ad hoc working group and proposes Helen Beggs (Bureau of Meteorology, Australia), Werenfrid Wimmer (University of Southampton, UK) and Viva Banzon (NOAA NCDC, USA) as members.

There are two activities from the OCG meeting that the SOT should be aware of:

- The OCG recommended that satellite-ship SST biases be explored in greater detail where metadata is available, for feedback to SOT (by GHRSST, for the next SOT meeting).
  Initial comparisons were reported at SOT-VI and attention is drawn to two other activities to investigate the quality of ship-based measurements of SST using satellites. First, is an EU FP7 project led by the Met Office Hadley Centre, which is about to release its first results (journal paper in review). Second, sea surface temperature measurement biases will be characterized during the satellite era within the NERC-funded project "Historical Ocean Surface Temperature: Adjustment, Characterization and Evaluation" (HOSTACE). Multi-sensor satellite observations will be matched with ship observations and augmented metadata (measurement models, insights from ship tracking, etc.), and relative biases will be examined for predictable systematic dependencies, some of which may also inform the pre-satellite era. The SSTs from the Along Track Scanning Radiometer Reprocessing for Climate (ARC) project will constitute a reference SST across different measurements. Models for ship observation uncertainties will also be developed. The latter project will start in May 2013.

- The OCG requested GHRSST to provide specifications for siting of radiometers on commercial vessels (see also item 5.2.6 in JCOMM MR-84, SOT-VI), and also requested GHRSST provide advice on best practice for ship-based SST measurement to SOT.

  Status: Guidance on the siting of radiometers on commercial vessels is provided in the best practices document "Guidance for the use of IR radiometers in the field for derivation of skin sea surface temperature", available from http://www.issibern.ch/teams/satradio/ in mid-April 2013. Guidance on best practices for non–radiometric ship-based SST measurements is provided in (Beggs et al., 2012).

6. SUMMARY

GHRSST is continuing to provide a suite of operational global high-resolution SST products in near-real-time on a daily basis. GHRSST is also expanding its provision of longer-term SST records covering the satellite era from 1981 onwards. A key part of GHRSST activities is the desire to improve the type, quality and quantity of ship SST and its associated meteorological and oceanographic data made available to the GHRSST program for data validation and quality control. GHRSST welcomes the establishment of a joint GHRSST/SOT working group to better define requirements for measurements of SST and ancillary variables from ships.

7. REFERENCES

Beggs H., R. Verein, G. Paltoglou, H. Kippo and M. Underwood (2012) Enhancing ship of opportunity sea surface temperature observations in the Australian region. Journal of Operational Oceanography(ISSN: 1755-8778), 5, 59-73.http://www.ingentaconnect.com/content/imarest/joo/2012/00000005/00000001/art00006

Donlon, C. and the GHRSST-PP Science Team (2007) The Global Ocean Data Assimilation Project (GODAE) High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP), *Bull. Am. Met. Society,* 88, 1197-1213.

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APPENDIX E

FERRYBOX

Report submitted by W. Petersen*, F. Schroeder*, D. Hydes**

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Overview of the existing observing system

The FerryBox concept has been developed as a partnership between scientists and the companies operating ferries in waters around the world [Hydes et al. 2009]. The strengths of the Ferry-Box program are many: no ship operation costs, no energy restrictions, regular maintenance possible, transects sampled repeatedly and bio-fouling can be better controlled. The potential for data coverage by ferries is large. 800 operate in European seas. Currently in Europe, some 15 ships are involved in this type of work (www.ferrybox.org) and systems have also been in operation for some time in Japan [Harashima et al. 2000] in the USA [Ensign et al. 2006, Paerl et al. 2005] and Australia. A map of the routes currently carrying FerryBoxes on the North West European shelf is shown in Fig 1.

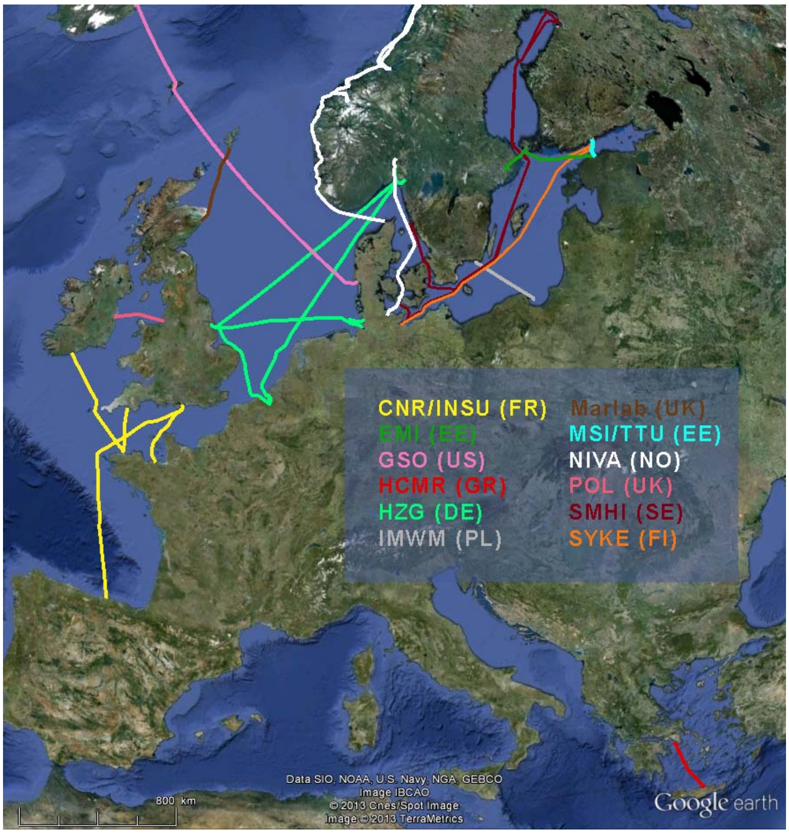

Figure1: FerryBox routes Europe (2013)

The EU FP5 project "FerryBox" (2002-2005) demonstrated the utility of the concept [Petersen et al. 2007]. The FerryBox project used four "core" sensors for temperature, salinity, chlorophyll-fluorescence and turbidity by all partners. Individual groups tested a wider range of sensors and deployed towed instruments such as the Continuous Plankton Recorder (CPR). Conductivity sensors for surface water salinity provided scientifically interesting data on water transport when collected as part of a consistent time series [Kelly-Gerreyn et al. 2006], demonstrating the importance of salinity for coastal monitoring programmes. Where only surface waters were sampled (as was the majority case in the FerryBox project) it was shown that FerryBoxes are highly complementary to other data from fixed buoys, research vessels and modelling [Petersen et al., 2008, Petersen et al., 2011]. In addition profiling instruments such as ADCPs (Acoustic Doppler Current Profiler) can enable observations through the water column [Flagg, et al, 2006, Buijsman & Ridderinkhof, 2007] alongside more traditional XBTs (expendable bathy thermographs) for profiling the water column for temperature [Fuda et al., 2000]. Biological information can be gained acoustically and with towed instruments such as with the CPR (Continuous Plankton Recorder). An overview of all European FerryBoxe activities is given in the Annex I.

Many of the systems have been developed to support the requirements for both scientific and marine management data. For example, FerryBoxes are used by both the Finnish Environment Institute in the AlgaLine system [2] and the Norwegian Institute of Water Research (NIVA), in their NorHAB system (www.ferrybox.no) to improve surveillance of the harmful and nuisance blooms of algae that plague the Baltic and the North Sea.

Globally a major advance has been the monitoring of air-sea fluxes of carbon dioxide (CO2) [Schuster et al. 2007]. This has been coordinated by through the International Ocean Carbon Coordination Project. It is important that this work is continued and expanded in shelf seas, whose contribution to the carbon budget is particularly difficult to predict from existing models. Coastal carbon issues are important in the international (UN) agenda because it is felt that management and policy decisions are more easily made at the local and regional level. The FerryBox/VOS approach outlined here is probably the only way to provide the needed monitoring coverage of both carbon import and export in shelf seas and acidification in the coastal zone in a cost effective manner.

Currently FerryBoxes are being integrated into some European marine management systems such as the European Marine Ecosystem Observatory (EMECO) (www.emecogroup.org/) or regional observatories (e.g. Coastal Observatory Irish Sea (http://coastobs.pol.ac.uk/) or COSYNA Coastal Observation System for Northern and Arctic Seas (www.cosyna.de)).

Looking to the future a SCOR (Scientific Committee on Oceanic Research) working group called 'OceanScope' started work in 2009 to look at the enhancement of the partnership between the ocean observing community and the shipping industry[3]. These activities have been continued by a meeting organized by WOC (World Ocean Council) in Paris to establish a platform/portal that facilitates ocean observing community collaboration with shipping and other ocean industries in the collecting of ocean and atmospheric information[4].

Nowadays FerryBox and other underway data are integrated in the *in-situ* TAC of the EU project MyOcean (http://www.myocean.eu.org/). At least data of T and S are stored as NetCDF files on a central server. The provision of data from outside of the MyOcean consortium is on a voluntary basis. In future all FerryBox data within Europe shall be provided by the EMODnet data portal for physical parameters (www.emodnet-physics.eu).

2 www.itameriportaali.fi/en/tietoa/algaline_seuranta/en_GB/algaline_seuranta/
3 http://www.scor-int.org/Working_Groups/wg133.htm
4 http://www.oceancouncil.org/site/pdfs/Smart%20Ocean%20-%20Smart%20Industries%20Workshop%20Report%20FINAL.pdf

Conclusions:

The evolution of FerryBox systems reached a status of maturity that could be proven during many yeas of operation at different sites. There are worldwide increasing activities operating FerryBoxes and other systems on ships of opportunities. However, most of them are temporary activities and are on a volunteer basis. There is no sustained funding in order to get reliable and comparable data over longer time periods.

FerryBox systems are ideal platforms for biogeochemical sensors/instruments (easier maintenance, no energy restrictions etc.) in order to overcome the still existing lack of sufficient spatial coverage and a particular lack of robust biogeochemical measurements.
The monitoring of algal bloom by agencies has very low spatial and temporal coverage and in northern Europe optical remote sensing is often restricted by clouds. Data are needed for management (prognosis) of fisheries and tourism: Amount of plankton controls the fish yield, occurrence of harmful algae blooms influences fish, oyster and mussel yield and occurrence of algal degradation products influences tourism (e.g. foam on beaches). FerryBox system can close this gap due to the high spatial and temporal resolution of the data along the transect.

In addition the development of more reliable autonomous sensors for chemical and biological parameters for ecological monitoring including green house gases has to be intensified. The budget of climate-relevant gases in shelf seas and estuaries and its contribution to global climate development is still not quite clear. There exist only isolated field campaigns with measurements of pCO2/carbonate, CH4, N2O and halogenated hydrocarbons. FerryBoxes give the opportunity to get continuous measurements in these areas.

The consolidation of FerryBox systems into operational Marine Core Services (MCS) is feasible and should be considered quickly. This will push forward the MCS not only in the way of getting more data but to get much more reliable data and a new dimension of chemical/biological information. In addition, there will be a high potential for evolution: The implementation of new sensors that are already working in the lab, e.g., new optical and genetic sensors for automated algae identification. In 2011 started the EU project JERICO (Joint European Research Infrastructure network for Coastal Observatories, www.jerico-fp7.eu) to develop and facilitate the development of coastal observatories. Among other platforms the FerryBox systems play here an important role. However, besides all existing activities the main issue is still the long-term funding. A mechanism has to be found for a sustainable funding of such “routine measurements” in order to guarantee the operation over longer time periods.

Short summary:

- FB systems reached a state of maturity
- FBs are cost-effective monitoring tools for surface waters with high resolution in space and time
- New sensor developments can be easily implemented allowing the extension to more biogeochemical related parameters
- FBs can play a role in the implementation of the EU Marine Strategy Framework Directive (MSFD)
- Within Europe all FB data (at least T and S) are centrally stored and are available in near-real time (MyOcean and EMODnet)
- Sustainable funding is still an issue: most activities are temporary activities mainly on the basis of research money.

Possible contributions/support of JCOMM-SOT:

- encouraging shipping and other companies to support FerryBox activities as an active contribution to protect the marine environment
- promote concepts preparing new build merchant vessels to be already ready for installation of FB systems (e.g. SCOR and WOC initiative)
- foster the collaboration between XBT/XCTD and FerryBox activities on the same vessels enabling combination of high resolution surface measurement combined with depth profiles
- encourage the collaboration between carbon ocean research groups and FerryBox activities
- promote sustainable funding for long-term observations

References:

- Buijsman, M.C. & Ridderinkhof, H. (2007). Long-term ferry-ADCP observations of tidal currents in the Marsdiep inlet. J. Sea Res. 57, 237-256
- Ensign, S.H. & Paerl. H.W. (2006). Developing an unattended estuarine nutrient monitoring program using ferries as data-collecting platforms. Limnol. Oceanog. Methods 4,70-76
- Flagg, C. N., Dunn, M., Wang, D-P., Rossby, H. T. & Benway R. L. (2006), A study of the currents of the outer shelf and upper slope from a decade of shipboard ADCP observations in the Middle Atlantic Bight, J. Geophys. Res., 111, C06003, doi:10.1029/2005JC003116.
- Fuda, J., Millot, C., Taupierletage, I., Send, U. & Bocognano, J. (2000). XBT monitoring of a meridian section across the western Mediterranean, Sea Deep Sea Res. (1) 47, 2191-2218.
- Griffiths G. & Diaz J. (1996). Comparison of acoustic backscatter measurements from a ship-mounted Acoustic Doppler Current Profiler and an EK500 scientific echosounder. ICES Journal of Marine Science, 53, 487-491.
- Hydes D. & Co-Authors (2009). The Way Forward in Developing and Integrating Ferrybox Technologies. OceanObs'09, Venice (white paper): https://abstracts.congrex.com/scripts/jmevent/abstracts/FCXNL-09A02a-1766265-1-hydes%20et%20al%20%201766265%20Ferrybox%20OceanObs09.pdf
- Harashima, A. & Kunugi, M. (2000). Comprehensive Report on Marine Environmental Monitoring and Related Studies Using Ferry Boats. CGER-Report, National institute for Environmental Studies, Environmental Agency of Japan, CGER-M007-2000, ISSN 1341-4356.
- Kelly-Gerreyn, B.A. et al. (2006). Low salinity intrusions in the western English Channel. Continental Shelf Research, 26, 1241-1257.
- Paerl, H.W., Valdes, L.M. Adolf, J.E, Peierls, B.M. & Harding Jr. L.W. (2005). Anthropogenic and climatic influences on the eutrophication of large estuarine ecosystems. Limnol. Oceanogr. 51, 448-462
- Petersen W. & Co-Authors, (2007). FerryBox: From Online Oceanographic Observations to Environmental Information. Petersen, W., Colijn, F., Hydes, D., Schroeder, F., Editors. EuroGOOS Publication No. 25. EuroGOOS Office, SHMI, 601 76 Norkoepping, Sweden ISBN 978-91097828-4-4.
- Petersen, W., Wehde, H., Krasemann, H., Colijn, F. & Schroeder, F. (2008). FerryBox and MERIS Assessment of coastal and shelf sea ecosystems by combining in situ and remotely sensed data. Estuarine, Coastal and Shelf Science 77, 296-307.
- Petersen, W., Schroeder, F., Bockelmann, F.-D. (2011) FerryBox – Application of continuous water quality observations along transects in the North Sea, J. Ocean Dynamics, submitted
- Schuster, U., & Watson. A.J. (2007). A variable and decreasing sink for atmospheric CO2 in the North Atlantic, J. Geophys. Res., 112, C11006, doi:10.1029/2006JC003941.

Annex I of Appendix E

Overview of European FerryBox Activities (from www.ferrybox.org)

Institution	Destination harbours	Name of platform	Observed parameters	Shipping Company & website		public awareness website	Start of operation	End of operation
BCCR, UiB	**Amsterdam - Bergen**	M/S Trans Carrier	pCO2, T, S, Trb, Chl-a, pH	Sea Cargo	http://www.sea-cargo.no	http://www.bjerknes.uib.no/	2005	2009
EMI	**Tallinn – Mariehamn – Stockholm**	Victoria I	T, S, Trb, Chl-a	Tallink	http://www.tallinksilja.com/en	www.sea.ee		
HCMR	**Piraeus-Heraklion**	Olympic Champion	T, S, Trb, Chl-a, DO, pH	Anek Lines		www.poseidon.hcmr.gr	2002-2003	today
HZG	**Cuxhaven - Harwich**	Duchess of Scandinavia	T, S, DO, Chl-a, pH, Trb, nutrients	DFDS A/S	http://www.dfdsseaways.de	www.cosyna.de	2002	2005
HZG	**Cuxhaven - Immingham**	TorDania	T, S, DO, Chl-a, pH, Trb, nutrients	DFDS TorLine	http://www.dfdstorline.com	www.cosyna.de	2006	2012
HZG	**Moss-Halden-Zeebrugge-Immingham**	LysBris	T, S, DO, Chl-a, pH, Trb, nutrients	DFDS Lys Line	http://www.lysline.com	www.cosyna.de	2012	today
HZG	**Moss-Halden-Cuxhaven-Chatham-Bilbao-Immingham**	LysBris	T, S, DO, Chl-a, pH, Trb, nutrients	DFDS Lys Line	http://www.lysline.com	www.cosyna.de	2007	2012
HZG	**Cuxhaven- Helgoland**	MS FunnyGirl	T, S, DO, Chl-a, pH, Trb	Reederei Cassen Eils	http://www.Helgolandreisen.de	www.cosyna.de	2009	today
Ifremer	**Portsmouth-Santander-Plymouth-Roscoff-Cork**	Pont-Aven	T, S, DO, chl-a, Trb, CDOM	Brittany Ferries	http://www.brittany-ferries.co.uk	http://abims.sb-roscoff.fr/hf/fbox.html?execution=e1s3	2011	today
IMGW	**Gdynia – Karlskrona**	Stena Balitica	T, S, Trb, Chl-a, DO	Stena Line	http://www.stenaline.se		2008	2009
IMR	**Bergen-Kirkenes**	MS Vesterålen	T,S, Chl-a fluorescence	Hurtigruten Group	http://www.hurtigruten.com/		2006	today
IMR	**Norwegian West Coast (Bergen)**	KV TOR	T,S, Oxygen	Coast Watch Norway	http://mil.no/Pages/default.aspx#2		2011	today
Marlab	**Lerwick - Aberdeen**	MV Hascosay	T, S, Trb, Chl-a	North Link Ferries	http://www.northlinkferries.co.uk	http://www.scotland.gov.uk/Topics/marine/science/Research/Researchers/AEProgramme/oceanographic		
MIO (CNRS/INSU)	**Genova -Libyan harbours**	Jolly Indaco	T, S	Linea Messina	http://www.messinaline.it	http://www.ciesm.org/marine/programs/partnerships.htm	may 2010	may 2010
MIO (HYMEX/CNRS/INSU)	**Marseilles-Algiers**	Niolon	T, S	Marfret	http://www.marfret.fr	http://www.hymex.org		
MSI/TTU	**Tallinn - Helsinki**	MS Baltic Princess	T, S, Chl-a, turb, phycocyan nutrients (wkl sampl)	AS Tallink Grupp	http://www.tallinksilja.com/	www.msi.ttu.ee	1998	today
NIVA	**Histhals, Stavanger, Bergen**	MS Bergenfjord	T, S, Trb, Chl-a, nutrients (weekly samples)	Fjord Line	http://fjordline.com	www.ferrybox.no	2008	today
NIVA	**36 locations from Bergen to Kirkenes**	MS Trollfjord	T, S, Trb, Chl-a, nutrients (weekly samples), irradiance, radiance, wind	Hurtigruten Group	http://www.hurtigruten.com/	www.ferrybox.no	2006	today
NIVA	**Oslo, Kiel**	MS Color Fantasy	T, S, Trb, Chl-a, CDOM, cyanobacteria, nutrients (weekly samples), irradiance, radiance	Color Line	http://www.colorline.com	www.ferrybox.no	2008	today
NIVA	**Tromsø, Bjørnøya, Longyearbyen, Ny Alesund**	MS Nordbjorn	T, S, Trb, Chl-a, nutrients (weekly samples), irradiance, radiance	Nb Norbjorn as	http://www.norbjorn.no	www.ferrybox.no	2008	today
NIVA/MARLAB	**Histhals, Torshavn, Seydisfjord**	MS Norrøna	T, S	Smyril Line	http://www.smyrilline.com	www.ferrybox.no	2008	today
NOCS	**Portsmouth-Bilbao**	Pride of Bilbao	auto:T, S, Chl-a, Trb, O2, pCO2; (monthly samples nutrients, pigments, plankton, coccoliths)	P&O Ferries	http://www.poferries.com	www.noc.soton.ac.uk/ops/ferrybox_index.php	2002	2010
NOCL	**Birkenhead- Dublin**	Lagan Viking	T, S, Chl-a, Trb	DFDS Seaways	http://www.dfdsseaways.co.uk		2006	today
SMHI & SYKE	**Gothenburg-Kemi-Oulu-Lübeck-Gothenburg**	TransPaper	T, S, Trb, Chl-a,, Phycocyan, CDOM, DO, PAR, airPress, airTemp (phytoplankton, salinity, chl a, CDOM).	TransAtlantic AB	http://www.rabt.se/en	http://www.smhi.se/klimatdata/2.1326	2009	today
SYKE	**Helsinki - Stockholm**	Silja Serenade	T, S, Chl-a, Turb, Phycocyan, nutrients, phytoplankton	TallinkSilja	http://www.tallinksilja.com	http://www.itameriportaali.fi/en/itamerinyt/levatiedotus/en_GB/levatiedotus/	1998	today
SYKE	**Helsinki-Travemunde, Helsinki-Gdynia**	Finnmaid	T, S, Chl-a, nutrients, Phycocyan, CDOM, TURB, nutrients, phytoplankton	Finnlines OY	http://www.finnlines.fi	http://www.itameriportaali.fi/en/itamerinyt/levatiedotus/en_GB/levatiedotus/	Finnpartner 1998 - 2006, Finnmaid 2007-	today
Univ. Rhode Island	**Esbjerg - Torshavn - Brimnes**	Norrøna	T, S, Trb, Chl-a	Smyril Line	http://www.smyril-line.com	http://po.msrc.sunysb.edu/Norrona/		

APPENDIX F

GLOBAL OCEAN SHIP-BASED HYDROGRAPHIC INVESTIGATIONS PROGRAMME (GO-SHIP)

Activities undertaken in 2012 and 2013

(Report submitted by Bernadette Sloyan, CSIRO, Australia)

1. Sections Completed

In 2011 and 2012 sections completed included:

Ocean Basin	*Section Identifier*	*Country*
South Atlantic	A10	US
Southern Ocean	S04P	US
Southern Ocean	SR03	Australia
Pacific Ocean	P13	Japan
Southern Ocean	A12	Germany
North Atlantic	AR07W	Canada
North Atlantic	A01E/AR7E	Netherlands
North Atlantic	A02	Germany
North Atlantic	75N	Norway
Southern Ocean	I09S	Australia
North Atlantic	A22	US
North Atlantic	A20	US
Southern Ocean	S04I	Japan
Southern Ocean	P14S	Japan
Barrow-Svalbard		Sweden

Figure 1 provides a map of sections with dates of most recently completed and future planned occupations. CTD and bottle data are sent to CCHDO, and carbon data to IOCCP. We are currently reviewing the data status at CCHDO and IOCCP to ensure that all data are at the data centres.

We have now completed a global reoccupation of the GO-SHIP hydrographic sections. The global re-occupation was completed in a 10 year time-frame beginning in the Atlantic in 2003 and finishing in 2013 with the completion of the high latitude Southern Ocean Indian section (S04I and P14S).

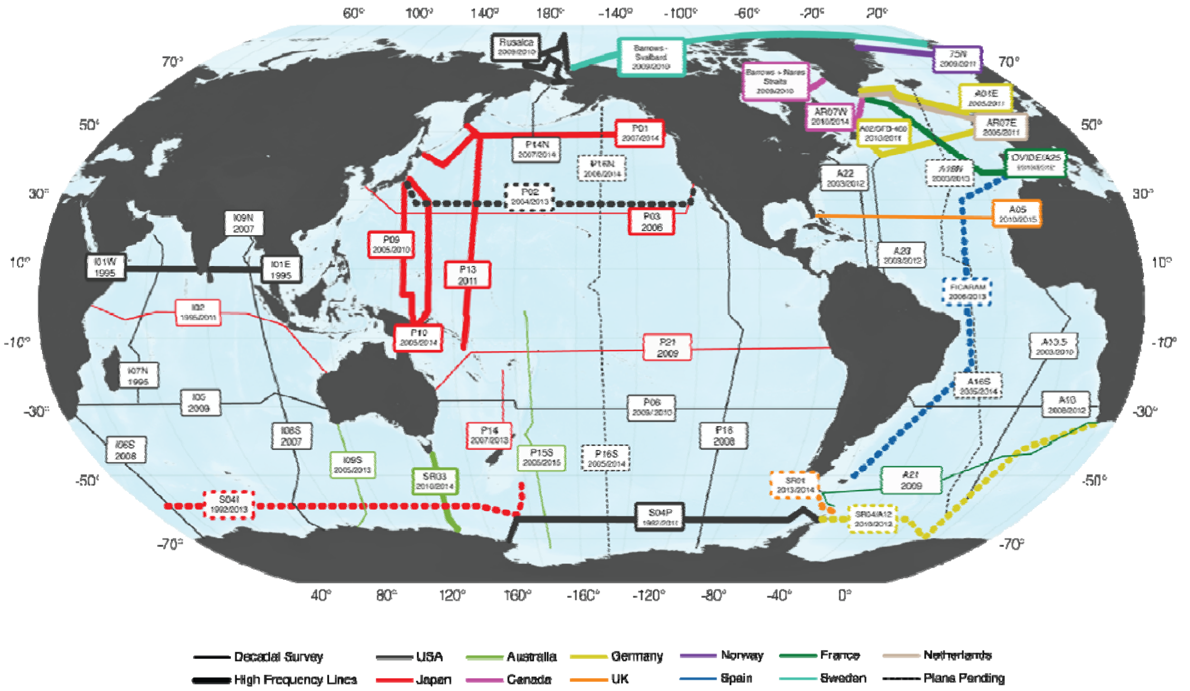

Figure 1: GO-SHIP sections most recently completed and planned occupations.

2. Planning for next global repeat.

The international community is now planning the next decadal global repeat. Information regarding future national plans is provided below.

ATLANTIC

Section	***Description (ship track)***	***Most Recent Occupations***	***Next Occupation***
A01E/AR7E	Greenland to Ireland	2011 H. van Aken Netherlands	
A01W / AR7W	From Labrador to Greenland 53°N 56°W to 61°N 48°W; 1/year (spring)	2011 M. Rhein Germany	2014
A02 (SFB-460)	~ 48° N, Ireland to St John’s Bay, Canada.	2007 (full line) M. Rhein Germany 2009 (western part) M. Rhein Germany	2010-13 M. Rhein Germany
A05	24° N (note: this line is part of the UK RAPID program with repeats	2010 Brian A King	2015

	every ~ 5 years).	UK, 2010 P. Velez Spain	
A9 1/2	24°S	2009 B. King UK	
A10	30°S	2011 M. Baringer USA	
A12	Capetown to the Antarctic continent along the prime meridian; often done in a pair with SR04.	2008 E. Fahrbach / H. De Baar Germany / Netherlands 2011 E. Fahrbach / M. Hoppema Germany / Netherlands	
A13.5	0°; Cape Town to Ghana	2003 M. Hoppema Germany 2010 J. Bullister USA	
A16N	20-25° W Iceland to 5° S	2011 Brian King UK	2012 R. Wanninkhof USA
A16S	25-35° W, 5° S to 60° S	2005 R. Wanninkhof USA	2013 R. Wanninkhof USA
A20	52°W	2003 J. Toole USA	2012 Michael McCartney USA
A21	Drake Passage	2009 E. McDonagh UK 2009 C. Provost France (full physics, chem., and tracers)	
A22	66°W	2003 T. Joyce USA	2012 Ruth Curry USA
FICARAM (A17)	Ushuaia - Cartagena (Spain), following part of the line WOCE A17 and from 10°S to 36°N along 28°W	2006 A. Rios Spain	2013 A. Rios Spain
OVIDE (A25)	Iberian Peninsula - Greenland	2008 A. Rios Spain 2010 H. Mercier France	
SR1b (eastern passage)	Drake Passage (note: SR1b repeated annually with CTD, SADCP, LADCP)	2010 E. McDonagh UK	2013/2014

SR04	Section from tip of Antarctic Peninsula to Kapp Norvegia (approx 12° W) along the northern edge of the Weddell gyre (nominally 60° S)	2011 E. Fahrbach / M. Hoppema Germany / Netherlands	

PACIFIC

Section	***Description (ship track)***	***Most Recent Occupations***	***Next Occupation***
P01	47° N	2007 T. Kawano Japan	2014
P02	30° N	2013 J. Swift USA	
P03	24°N; Okinawa to San Diego.	2006 Kawano, Murata, and Watanabe Japan	To be conducted by JMA. Japan
P06	30°S	2009/2010 Ruth Curry/A. MacDonald USA	
P09	137°E	2010 T. Nakano	
P10	147°E	2005 T. Kawano Japan	2011 Japan
P13	165°E	2011 T. Nakano Japan	
P14N	Aleutians intersection with P01 and Northward.	2007 T. Kawano and A. Murata Japan	Plan is for approximately decadal occupation of P14 by Japan.
P14S/C	174°E (done along with S04I / S04P)	2013 T. Kawano Japan	2013 T. Kawano Japan
P15S	Equator - 50°S 175°W (strategy calls for section to go to 67°S when possible).	2009 B. Sloyan Australia	2015/2016 Australia
P16S	150°W (55°N-15°S / 15°S to ice S)	2005 B. Sloyan and J. Swift USA	2014 R. Feely/J. Swift USA
P16N		2006 R. Feely USA	2014 R. Feely/J. Swift USA
P18	110° W	2008 J. Bullister and G. Johnson USA	
P21	17°S	2009 A. Murata Japan	Plan is for decadal occupations Japan

SR03	Tasmania to Antarctic Continent, 140 - 145°E	2010 S. Rintoul Australia	
S04P (modified)	Nominal 67°S; McMurdo to Punta Arenas; connects to S04I and SR04 (Atlantic)	2011 J. Swift USA	

INDIAN

Section	***Description (ship track)***	***Most Recent Occupations***	***Next Occupation***
I01E	8° N, Sri Lanka to Singapore	1995 H. Bryden USA	
I01W	8° N, Oman to Sri Lanka	1995 J. Morrison USA	
I02 + I10	I02 (10° S) + I10 (8° - 25° S at 111° E) *note: may be changed to I8N + I5E + I10 for security reasons	2011 A. Murata Japan	
I05	32° S, Durban to Freemantle	2009 J. Swift USA	
I06S	30° E Cape Town to Antarctic Continent	2008 K. Speer USA	
I07N	65° - 55° E, Oman to Mauritius	1995 J. Toole/D. Olson USA	Postponed indefinitely for security reasons
I08S	95 - 82° E from 27° S to Antarctic Continent	2007 J. Swift USA	
I09N	95° E, 28 - 4° S	2007 J. Sprintall USA	
I09S	115° E	2012 S. Rintoul Australia	
S04I	Section connecting I09S and S04P at ~ 60° S; S04/S04I + P14S, 62° S (33.5° E-168° E) + 174° E	2013 T. Kawano Japan	

ARCTIC

Section	***Description (ship track)***	***Most Recent Occupations***	***Next Occupation***
75*N	Iceland - Greenland.	2011 T. Johannessen and A. Olsen Norway	
Barrows and Nares Straits	Barrow Strait (74.09° N 90.44° W to 74.83° N 93.00° W); Nares Strait (occupied irregularly)	2010 J. Hamilton Canada	
Barrow to Svalbard	Barrow Alaska to Svalbard Norway	2012 L. Anderson Sweden	

Davis Straits	Baffin Island to Greenland	2010 C. Lee and K. Azetsu-Scott USA and Canada	
RUSALCA	Bering and Chukchi Seas	2010 R. Woodgate USA	

3. JCOMMOPS Ship Coordinator support for GO-SHIP

The GO-SHIP committee held a number of teleconference meetings in 2011 and 2012. These were organised by Maciej at IOCCP, whom provided valueable help to the GO-SHIP committee. Much of these discussion centred on completion of the program plan and defining the role of a project coordinator and how to fill and fund this position.

Over the last 3 years, GO-SHIP has demonstrated that without global coordination for planning and implementation of sections, significant gaps and duplications arise, and most sections do not measure the full suite of core variables. A program coordinator is needed to provide international coordination and implementation. Working with an international scientific steering committee, the program coordinator would be responsible for facilitating data release and sharing, and data management; facilitating collaborations to ensure that the full suite of core variables are measured on each cruise; providing technical support for meetings of the scientific steering committee; working with the other observing system components to harmonize and integrate observations and data streams; and serving as a central communications and information forum for the hydrographic community.

The GO-SHIP committee considered two options for support of the GO-SHIP co-ordinator. In September 2011 we held a meeting to discuss the offer of a ¼ time position that Albert Fischer (OOPC, and now GOOS director) had potentially available. This meeting resulted in a project description being developed. However, this avenue of support for a GO-SHIP coordinator was removed when US funding to UNESCO was withheld due to UNESCO's admission of Palestine as a Member State. This meant that the flexibility to place a part-time GO-SHIP coordinator at IOC, mixed with support to OOPC was compromised.

In parallel to the above discussions, Matthieu Belbeoch (JCOMMOPS) was actively pursuing the JCOMMOPS ship coordinator position. The GO-SHIP committee met in early 2012 to discuss, the option of the JCOMMOPS Ship coordinator filling some GO-SHIP coordinator goals and how to provide financial support for this position. It was agreed that GO-SHIP would provide financial support to the JCOMMOPS Ship Coordinator position. The GO-SHIP committee, via Bernadette Sloyan, worked with Matthieu and others to update the position description, and interview and recruitment of the Ship Coordinator. This process was concluded with Martin Kramp taking up the position on 4 February 2013.

Duties that GO-SHIP to be undertaken by the JCOMMOPS ship coordinator include:

- maintain regular communication with national points of contacts to keep abreast of developing plans for hydrographic sections;
- provide up-to-date information on GO-SHIP voyages activities to CCHDO for update of tables and reference map and GO-SHIP web site.
- liaise with CCHDO and other data repositories to ensure data delivery to data centres

4. Uptake and Usage of repeat hydrography: showing the value of the observing system

In March-April 2012, at the request of the US GO-SHIP, the international committee was asked to complete a survey of usage of repeat hydrography observations. The design of the survey was the result of a meeting between US Repeat Hydrography Steering Committee and the NSF and NOAA program managers at the Ocean Sciences meeting in Salt Lake City. The meeting was organised to discuss the future of the GO-SHIP cruises given the growing limitations on US ship time and funding. GO-SHIP was supported by everyone although the program managers were concerned about GO-SHIP's future for some reason. The program managers were most concerned about our claims that the data were being used by the community.

The survey was distributed to the GO-SHIP email list and in general there was a reasonable response. This report was provided to the US funding agencies.

While this survey has proven useful, GO-SHIP must improve the program visibility and highlight its importance as a component of the global ocean observing system to maintain national science funding. One way to do this is to track usage of data. It has been suggested that we maintain a database of customers (research, operations centres, …) who use the data. An example of the Argo data base can be found at http://www.argo.ucsd.edu/Uses_of_Argo_data.html. The 2012 survey is a start to this database, but it must be made more complete and updated regularly.

5. Audit of GO-SHIP data at CCHDO

With the completion of the global survey we are now working with CCHDO to undertake an audit of repeat sections completed and data availability at CCHDO. This is being coordinated by Bernadette Sloyan and Steve Diggs.

6. Other Comments

During 2013 The GO-SHIP committee meet via teleconferences. We are planning a face-to-face committee meeting attached to an international conference in 2014 (Ocean Science 2014 is a potential meeting).

We are working with Martin Kramp to establish a working relationship amongst the GO-SHIP committee, international partners and CCHDO.

APPENDIX G

INTERNATIONAL OCEAN CARBON COORDINATION PROJECT

Activity update for SOT-VII, April 2013

(Report submitted by Dr Maciej Telszewski, Director, IOCCP)

New IOCCP Project Office

The US National Science Foundation (NSF) has provided the International Ocean Carbon Coordination Project (IOCCP) staff salary support since the formation of the Project in 2005. Due to the vote of the UNESCO General Conference in October 2011 to admit Palestine as a Member State of UNESCO, the United States was required by federal law to withdraw all direct and voluntary contributions to UNESCO. As a result, NSF funding for IOCCP staff support through IOC was cut off on 2 November 2011.

IOC was able to identify emergency funding from the Global Ocean Observing System to continue the staff positions through 31 March 2012. Following multilateral negotiations, the Project office headquarters was relocated to the Institute of Oceanology of Polish Academy of Sciences (IO PAS) in Sopot, Poland beginning 1 April 2012. Since then SCOR provides the IOCCP staff salary support through a grant from NSF. Starting 1 October 2012, the IOCCP staff will be limited to one person until further financial support will be secured. The IOC and SCOR continue to co-sponsor the IOCCP by providing financial support for critical activities.

UPDATE ON MAIN ACTIVITIES

The Surface Ocean CO_2 Atlas (SOCAT) Project

The Surface Ocean CO_2 Atlas (SOCAT, (http://www.socat.info/) was initiated by the International Ocean Carbon Coordination Project, SOLAS and IMBER in April 2007 (IOCCP, 2007). The first public release of SOCAT (version 1.5) took place on **14 September 2011** (Bakker et al. 2012).

SOCAT version 1.5 has 6.3 million surface water CO_2 measurements from 1851 voyages in the global oceans, including the Arctic Ocean and coastal seas, between 1968 and 2007. The surface water fCO_2 (fugacity of carbon dioxide) data in SOCAT have been put in a uniform format and recalculated using transparent and fully documented methods (Pfeil et al., 2012). In addition, a mean monthly fCO_2 atlas has been constructed from this data set (Sabine et al., 2012). To make the dataset user-friendly, it is available on the web through a sophisticated online data visualisation and manipulation tool called the Live Access Server. The LAS provides interactive maps that enable users to interrogate the data. Gridded monthly data are also available via http://www.socat.info/.

The first SOCAT release strongly improves data access for global carbon scientists. Potential applications include carbon budgets, studies of seasonal, inter-annual and decadal variations in oceanic CO_2 uptake at meso-, regional-, and global scales, and of the processes driving these. SOCAT will help inform scientists of the minimum fCO_2 data coverage required for accurate quantification of the oceanic CO_2 sink, its variation and trends. Monthly, basin-wide maps of CO_2 air-sea fluxes can be created with e.g. statistical techniques, neural networks, modeling and data assimilation for constraining global atmospheric carbon budgets. SOCAT provides initialization and validation fields for ocean carbon cycle models.

An ambitious time table for SOCAT version 2 is being realized with data submission cut-off date on 31 December 2011, SOCAT quality control by the regional groups from August to October 2012 and a the public release in June 2013 (ICDC9). Regular (every 1-2 years), future updates to SOCAT are envisaged. Automation of data submission and quality control in SOCAT are essential for enabling future, prompt SOCAT releases. Several technical and practical aspects of the second release such as streamlining data submission procedures to incorporate agreed formats and automation of data quality control procedures have been implemented over the last 12 months. Another improvement to SOCAT may be the inclusion of additional carbon parameters relevant for ocean acidification research. The IOCCP is responsible for drafting the SOCAT Implementation Strategy to ensure a stable project development in the short to mid-term (3 to 5 years). Possibilities to fund a technical position focused on SOCAT issues will be investigated and will become an integral part of the SOCAT Implementation Strategy.

A Framework for Ocean Observing

A task team of limited duration was formed at the OceanObs'09 conference to develop recommendations on a Framework for Ocean Observing (FOO). Specifically, task team was asked to develop a framework for an enhanced global sustained ocean observing system over the next decade, integrating new physical, biogeochemical, and biological observations while sustaining present observations, and taking best advantage of existing structures. The Framework envisioned a biogeochemical observing panel led by the IOCCP. The framework document describes the main aims of this effort but the following are specifically relevant for ocean carbon and biogeochemistry science and involve active collaboration with other seagoing practitioners:

- Requirements for ancillary observations to link interannual CO_2 flux trends to underlying changes in the upper ocean physics and biogeochemistry as well as emerging sensor developments that support the above goals
- A re-assessment of the regional and global scale spatial and temporal sampling activities (VOS and others) in the light of:
    - Recent ideas that ΔpCO_2 is a small part of the overall error
    - Improved empirical approaches to deriving relationships linking remote sensing variables to pCO_2
    - Potential role for model data assimilation
    - Regionally and globally optimized sampling strategies
- Expansion of methodologies and QC systems to keep sampling error to < 1 µatm
- Data QC, assembly & Data – Model interfaces (data availability, quality and assimilation)
- Anticipated data & flux products
- Ancillary observations and modelling approaches that can provide a better grasp on sensitivities and drivers of the CO_2 flux trends
- Alignment of the surface ocean CO_2 observations with Ocean Acidification research and monitoring

The IOCCP feels this effort should involve other programs and is actively investigating how best to contribute to the FOO activity through dialogue between the IOCCP, GOOS, IGBP, SCOR, SOLAS, and IMBER. To this end, the IOCCP took on some coordination tasks for a wider range of biogeochemical parameters, in particular oxygen and nutrients. The IOCCP is well placed to incorporate coordination of nutrients and oxygen observations into its mission for at least two following reasons:

1) There is a tight relation between the carbon cycle and biogeochemistry in general in the ocean, so that a well-coordinated observational network for oxygen (hopefully leading to better data quality, availability and coverage) is beneficial also for the ocean carbon science.
2) There is currently no sustained body/organization for coordination of observations of oxygen and nutrients in the ocean explicitly (although we recognize that a number of groups have made significant progress over the years), and we believe that the observational network of biogeochemical variables in general would benefit from an experienced coordination body.

As a step in this process the IOCCP has decided to add two members to its Scientific Steering Group (SSG), one with expertise in nutrients and one in oxygen observations. The new SSG members started their duty on the panel at the beginning of 2013. Finally, the IOCCP co-organized two international stakeholders meetings to aid the alignment of interested communities with the Framework strategies.

Global Ocean Acidification Observing Network

In order to coordinate international efforts to document the status and progress of ocean acidification in open-ocean and coastal environments, and to understand its drivers and impacts on marine ecosystems, it is necessary to develop a coordinated multidisciplinary multinational approach for observations and modeling that will be fundamental to establishing a successful research strategy for ocean acidification. This will facilitate the development of our capability to predict present-day and future responses of marine biota, ecosystem processes, biogeochemistry, and climate change feedbacks.

Required research elements include regional and global networks of observations collected in concert with process studies, manipulative experiments, field studies, and modeling. Global and regional observation networks will provide the necessary data required to firmly establish impacts attributable to ocean acidification.

The IOCCP together with the NOAA Ocean Acidification Program, the Global Ocean Observing System, the Integrated Ocean Observing System, and the University of Washington supported the initial GOA-ON International Workshop which proposed an integrated global observing network for both carbon and ocean acidification that addresses the requirements of nations affected by this emerging environmental problem in response to societal needs. The 3-day workshop was held at the University of Washington on June 26-28, 2012 for a group of 64 international scientists and program managers from 21 countries. The workshop report will provide the strategy for the observing system for review and vetting and hopeful support by the member countries.

Workshop Goals

The principal goals of this international workshop were to: (1) design the components and locations of an international carbon ocean acidification observing network that includes repeat hydrographic surveys, underway measurements on volunteer observing ships, moorings, floats and gliders taking into account existing networks and programs wherever possible; (2) identify a minimum suite of measurement parameters and performance metrics for each major component of the observing system; (3) develop a strategy for data quality assurance and data distribution; and discuss requirements for program integration at the international level.

The focus of this workshop was to design a global ocean acidification observing network that will delineate the physical-chemical processes controlling the acidification of the oceans and its large-scale biological impacts (changes in productivity, nutrient distributions, etc.). The IOCCP coordinates the existing global oceanic carbon observatory network of repeat hydrographic surveys, time-series stations, floats and glider observations, and volunteer observing ships in the

Atlantic, Pacific and Indian Oceans. This network can provide a strong foundation of observations of the carbonate chemistry needed to understand ocean acidification. Enhancing these activities and expanding the global time-series network with new carbon and pH sensors on floats and gliders will provide additional important information on the changing conditions in both open-ocean and coastal environments that are presently under-sampled.

Ideally, this network would also have the capability to measure $CaCO_3$ saturation states, biological production rates and species functional group changes. Additional sensors for dissolved inorganic carbon and total alkalinity would also be beneficial for detecting changes in the marine inorganic carbon system including inputs of other non-CO_2 sources of acidification. Measurements of net primary production, either directly or from nutrient or oxygen inventories along with an understanding of water movements in coastal zones, are also important to identify biological adaptations to ocean acidification. These additional measurements are needed to predict ecosystem responses to ocean acidification.

These activities will require a coordinated and interdisciplinary research effort that is closely linked with the majority of international carbon research programs. Leveraging existing infrastructure and carbon monitoring programs will enable research to be conducted efficiently and quickly. Identification of new time series stations, repeat surveys and underway measurements are also urgently needed in under sampled open-ocean and coastal regions. Moored buoys equipped with carbon system sensors and ancillary technologies for ocean acidification should be added to the present carbon network as well as adding new sensors to the existing network. The global ocean acidification observing network must be developed in a collaborative international context in order to guide international coordination and infrastructure development.

The second workshop will be held in St. Andrews, Scotland, 24-26 July 2013. The website used for the first workshop is being turned into the ocean acidification observing network web-portal which will be launched during the second workshop.

Ocean Time Series

Biogeochemical ocean time-series represent one of the most valuable tools scientists have to characterize and quantify ocean fluxes of elements as well as accompanying biogeochemical processes, and understand their links to changing climate. They provide the long, temporally resolved data sets needed to characterize ocean climate, biogeochemistry, and ecosystem variability. However, in order to monitor and differentiate natural cycles and human-driven changes in the global oceans, time-series methodologies must be coherent and inter-comparable when possible. To review current shipboard biogeochemical time-series sampling and analytical methods, the International Ocean Carbon Coordination Project (IOCCP) and the Ocean Carbon & Biogeochemistry (OCB) Program convened an international ocean time-series workshop 28-30 November 2012 at the Bermuda Institute for Ocean Sciences (BIOS).

With representation from 17 countries and 33 time-series around the globe, the workshop brought together participants who possessed both an understanding of the scientific goals of their time-series and ample hands-on experience with sample collection and analysis. To set the stage for smaller group discussions, the workshop opened with a series of plenary talks that highlighted scientific insights derived from shipboard and fixed-point time-series, as well as the logistical challenges of maintaining time-series, particularly in developing countries. Participants then broke into nine smaller groups to discuss sampling and analytical protocols. Each working group comprised representatives from multiple time-series, and focused on a different set of biogeochemical parameters, including pigments, in line (bow intake) measurements, CTD parameters, inorganic macro- and micronutrients, biomass, carbonate system, rates (primary and bacterial production), sediment trap fluxes, and organic matter.

With a focus on sampling, standardization, nomenclature and data reporting, and quality assurance and control (QA/QC) protocols, the working groups compared established methods and developed a consensus ranking of methods (optimal/good/acceptable) for each parameter. With the recognition that not all time-series can easily adopt the optimal method for each parameter, working groups identified metadata (method details and descriptors) that would facilitate comparison of data derived from different methods. Working groups also discussed newly emerging technology that might improve data precision and accuracy in the future.

In the interest of improving internal consistency within individual time-series as well as data inter-comparability across multiple time-series, working groups highlighted ongoing community inter-comparison activities and devised simple, low-cost experiments to assess the efficacy of current sampling and analytical protocols. Suggested experiments and community inter-comparison activities included: Niskin casts with repeat particulate sampling at regular time intervals to quantify impact of particle settling and revisit sample extraction order if necessary; quantitative comparisons of chlorophyll extraction using different solvents; primary productivity incubation time (e.g., 12 vs. 24 hour) comparisons; flow cytometer count inter-comparisons; nutrient inter-comparison using both commercially available and secondary (internally calibrated) standards; and comparison of a suite of coulometer models being used for measuring dissolved inorganic carbon (DIC).

More information is available on the workshop web portal (http://www.whoi.edu/website/TS-workshop/) which will be gradually transformed into a web-based global network of shipboard biogeochemical time-series that will include detailed information about parameters being measured and methods being used at each time series.

FUTURE DIRECTIONS

IOCCP continues to execute specific actions developed during the Seventh Scientific Steering Group meeting (12-13 June 2012). In addition, more general actions are being implemented to meet new challenges dictated by changing needs of marine biogeochemistry community. As indicated in the first paragraph of this document, IOCCP office staff was recently reduced by 50% which causes deleys in delivery of several actions, nevertheless the following priority actions are being actively implemented:

Improved coordination of surface carbon observations

A more efficient and better coordinated network of surface ocean carbon observation platforms including voluntary observing ships and research ships remains one of the key objectives for IOCCP. To achieve a sustained, scientifically robust and cost efficient ocean carbon observing system, stronger implementation ties with other global observation programs, such as GOOS, GCOS, DBCP and Argo, are being developed.

Sensors and Instruments

IOCCP maintains a comprehensive directory of commercially available ocean inorganic carbon measurement technologies; which could be broadly categorized as benchtop/underway instruments and autonomous sensors. Calibration, standardization and Quality Control of measurements made on the benchtop/underway systems are relatively mature and traceable to standard gases or CRMs. A multitude of intercomparison experiments, fostered by UNESCO, IOCCP and other coordinating organizations, have been carried out for these instruments over the past several decades in order to bracket measurement errors for data reporting.

In contrast, none of the autonomous sensors listed on the IOCCP website would meet the quality management requirements set for the benchtop/underway systems or other environmental fields of study involved in generating “climate quality” data. The remote location of autonomous sensor deployments makes this undertaking one of the great challenges in modern oceanography. Consequently, data generated by in situ sensors are uploaded into databases with insufficient validation. As autonomous carbon sensors mature, the need for frequent and systematic in situ intercomparison experiments will sharply increase. Verification-Validation criteria need to be explicitly defined and associated with the various data quality levels defined in the metadata. The community needs are voiced with ever increasing frequency and strength. The IOCCP decided (during its Seventh SSG meeting) to add Sensors and Instruments panel member in order to strengthen its potential for coordination if this important aspect of marine carbon observations. The most urgent needs that IOCCP will try to answer to are listed below:

- Controlled laboratory test tanks should be supported by and coordinated as (internationally) shared facilities by IOCCP and other international organizations/agencies
- Field-based intercomparisons present a significant challenge and should be carefully planned with regularity and expert oversight for both coastal and open ocean locations.
- Laboratory and field testing should be coordinated to complement each other, with a clear statement of the tradeoffs and limitations of each. For example, lab testing is ideal for verification of sensor dynamic range and establishing calibration protocols while field testing is necessary to reveal true performance under real environmental stresses that cannot be simulated in the laboratory. As demonstrated by some of the previous attempts, sensor intercomparison, attempting to carry out dynamic range or accuracy assessments in the field (in the presence of biofouling and intense spatiotemporal gradients) is often insurmountable. In these tests, the sensor errors of interest were largely dwarfed by bottle sampling errors, likely due to the choice to carry out the tests in highly dynamic coastal settings with large spatiotemporal gradients, yielding results of limited value.
- Un-validated in-situ data are not necessarily low quality and should not be labeled at the same data quality level as data that are ostensibly bad. Yet, un-validated data must be identified as such in any database. Metadata defining a validation level in addition to a quality level may be of some utility.
- The results of routine intercomparison experiments will inform the IOCCP recommendations for verification/validation. For example, if bottle samples cannot be satisfactorily spatiotemporally aligned with sensors, IOCCP may recommend that only in-situ sensors with automated in situ validation systems would meet the highest validation quality level.
- Due to the wide price range of in situ systems, IOCCP could perform a needed service by posting recent price quotations of each sensor listed in the online directory. Furthermore, the directory could be modified into a formal database listing many other features such as deployment duration, size, weight, and manufacturer specifications for accuracy, precision, response time, drift, etc.

REFERENCES

Pfeil, B., Olsen, A., Bakker, D.C.E., Hankin, S., Koyuk, H., Kozyr, A., Malczyk, J., Manke, A., Metzl, N., Sabine, C.L., Akl, J., Alin, S.R., Bellerby, R.G.J., Borges, A., Boutin, J., Brown, P.J., Cai, W.-J., Chavez, F.P., Chen, A., Cosca, C., Fassbender, A.J., Feely, R.A., González-Dávila, M., Goyet, C., Hardman-Mountford, N., Heinze, C., Hood, M., Hoppema, M., Hunt, C.W., Hydes, D., Ishii, M., Johannessen, T., Jones, S.D., Key, R.M., Körtzinger, A., Landschützer, P., Lauvset, S.K., Lefèvre, N., Lenton, A., Lourantou, A., Merlivat, L., Midorikawa, T., Mintrop, L., Miyazaki, C., Murata, A., Nakadate, A., Nakano, Y., Nakaoka, S., Nojiri, Y., Omar, A.M., Padin, X.A., Park, G.-H., Paterson, K., Perez, F.F., Pierrot, D., Poisson, A., Ríos, A.F., Salisbury, J., Santana-Casiano, J.M., Sarma, V.V.S.S., Schlitzer, R., Schneider, B., Schuster, U., Sieger, R., Skjelvan, I., Steinhoff, T., Suzuki, T., Takahashi, T., Tedesco, K., Telszewski, M., Thomas, H., Tilbrook, B., Tjiputra, J., Vandemark, D., Veness, T., Wanninkhof, R., Watson, A.J., Weiss, R., Wong, C.S.,Yoshikawa-Inoue, H. (2012) A uniform, quality controlled Surface Ocean CO_2 *Atlas (SOCAT). ESSDD, (doi:10.5194/essdd-5-735-2012).*

Sabine, C.L., Hankin, S., Koyuk, H., Bakker, D.C.E., Pfeil, B., Olsen, A., Metzl, N., Kozyr, A., Fassbender, A., Manke, A., Malczyk, J., Akl, J., Alin, S.R., Bellerby, R.G.J., Borges, A., Boutin, J., Brown, P.J., Cai, W.-J., Chavez, F.P., Chen, A., Cosca, C., Feely, R.A., González-Dávila, M., Goyet, C., Hardman-Mountford, N., Heinze, C., Hoppema, M., Hunt, C.W., Hydes, D., Ishii, M., Johannessen, T., Key, R.M., Körtzinger, A., Landschützer, P., Lauvset, S.K., Lefèvre, N., Lenton, A., Lourantou, A., Merlivat, L., Midorikawa, T., Mintrop, L., Miyazaki, C., Murata, A., Nakadate, A., Nakano, Y., Nakaoka, S., Nojiri, Y., Omar, A.M., Padin, X.A., Park, G.-H., *Paterson, K., Perez, F.F., Pierrot, D., Poisson, A., Ríos, A.F., Salisbury, J., Santana-Casiano, J.M., Sarma, V.V.S.S., Schlitzer, R., Schneider, B., Schuster, U., Sieger, R., Skjelvan, I., Steinhoff, T., Suzuki, T., Takahashi, T., Tedesco, K., Telszewski, M., Thomas, H., Tilbrook, B., Vandemark, D., Veness, T., Watson, A.J., Weiss, R., Wong, C.S., Yoshikawa-Inoue H (2012). Gridding of the Surface Ocean CO2 Atlas (SOCAT) Gridded data products. ESSDD, (doi:10.5194/essdd-5-781-2012).*

Bakker, D.C.E., Pfeil, B., Olsen, A., Sabine, C., Metzl, N., Hankin, S., Koyuk, H., Kozyr, A., Malczyk, J., Manke, A and Telszewski, M. (2012). Global synthesis products for assessing changes in the ocean carbon sink. EOS, doi:10.1029/2012EO120001
