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SHIP OBSERVATIONS TEAM (SOT)

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REQUIREMENTS FOR SHIP-BASED OBSERVATIONS (RRR AND OOPC)

(Submitted by the WMO Secretariat and the OOPC Secretariat)

Summary and purpose of the document

This document provides information on the GOOS activities during the intersessional period in view of its contribution to meet the GOOS goals ad objectives, and provides a review of the requirements expressed by the GOOS / GCOS Ocean Observing Panel for Climate (OOPC), as required. The document also includes information on the WMO Rolling Review of Requirements and how non-climate requirements can be addressed by the Team.

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. Ocean Applications Statement of Guidance
- B. JCOMM Observations Programme Area Implementation Goals (as reported to JCOMM-IV)
- C. Excerpts of interest to the SOT from the Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP)

References:
- A. WMO Statements of Guidance as part of the WMO Rolling Review of Requirements: http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG
- B. Summary and conclusions from the fifth WMO Workshop on the Impact of Various Observing Systems on NWP (Sedona, Arizona (USA), 22 -25 May 2012). http://www.wmo.int/pages/prog/www/OSY/Meetings/NWP5_Sedona2012/Final_Report.pdf
- C Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP): http://www.wmo.int/pages/prog/www/OSY/Publications/EGOS-IP-2025/EGOS-IP-2025-en.pdf
- D. Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 update), GCOS-138, GOOS-184, http://www.wmo.int/pages/ prog/gcos/Publications/gcos-138.pdf

- A - DRAFT TEXT FOR INCLUSION IN THE FINAL REPORT

5.1.1 GCOS / GOOS / WCRP Ocean Observing Panel for Climate (OOPC)

5.1.1.1 The Team noted that the IOC through Resolution XXVI-8 'Strengthening and Streamlining GOOS' decided to recommit the IOC to a Global Ocean Observing System (GOOS) that is a holistic system of global, regional and coastal observations and products. The GOOS governance will be aligned with the OceanObs’09 working group’s Framework for Ocean Observing oriented to an Essential Ocean Variable approach.

5.1.1.2 At the first interim GOOS Steering Committee meeting, held in June 2012 (iGSC-I), the committee reaffirmed the importance of Ocean Observations Panel for Climate (OOPC) to the past and future GOOS and approved the OOPC as a component of GOOS, sharing co-sponsorship with GCOS and WCRP.

5.1.1.3 Following the IGSC-I, the OOPC was able to continue activities which had been suspended pending the reorganization of GOOS. Katherine Hill has been employed as OOPC Programme Officer and resides with the GCOS office at WMO in Geneva. The former OOPC chair, Eric Lindstrom, has stepped down in favour his position as chair of the GOOS Steering Committee. Pending confirmation by sponsoring bodies the OOPC co-chairs for the next term will be Dr. Mark Bourassa, Florida State University, and Dr. Toshio Suga, Tohoku University.

5.1.1.4 Anticipated actions for next term of OOPC include an Upper Ocean Thermal Review (UOT), which will follow up on improvements to XBT fall rate errors, Argo pressure corrections and the planned CLIVAR’s Global Synthesis and Observation Panel historical temperature project. The UOT will likely impact the planned Tropical Pacific Observing System Workshop which will be concerned with continuity of the TAO/TRITON array and other equatorial observation systems used over the past thirty years.

5.1.1.5 The Team noted that per JCOMM-4 decision, JCOMM will continue to rely on OOPC for observing requirements for climate, as expressed through implementation plan of GCOS and GOOS. JCOMM-4 called upon OOPC to revisit the requirements for upper ocean thermal observations. Meanwhile, the Team reaffirmed its decisions at the last SOT Session regarding its response to the GCOS 2010 Implementation Plan, and reflected in paragraph 5.1.1.6 of the final report of SOT-6.

5.1.2 WMO Rolling Review of Requirements update

5.1.2.1 The Team discussed latest developments with regard to the WMO Rolling Review of Requirements (RRR), stressing on non-climate requirements. It noted the most recent version of the Statement of Guidance for Ocean Applications[1].

5.1.2.2 The Team noted that the new Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP[2]) has now been approved by the Commission for Basic Systems at its fifteenth Session (CBS-15, Jakarta, Indonesia, 10-15 September 2012). The Team further noted JCOMM-4 decisions related to the WMO RRR, in particular urging Members/Member States to make sure that all ocean observations related actions which are part of the EGOS-IP should be properly addressed once the new EGOS-IP is approved by the WMO Executive Council (in principle EC-65 in 2013). The Team particularly noted the following SOT related actions from the EGOS-IP (see Appendix C for details):

- Action No. 49 recommending NMSs, and NMHSs (in collaboration with companies

1 http://www.wmo.int/pages/prog/www/OSY/SOG/SoG-Ocean.doc
2 http://www.wmo.int/pages/prog/www/OSY/Publications/EGOS-IP-2025/EGOS-IP-2025-en.pdf

operating commercial ships, RAs, JCOMM, CBS and CAS) to maintain and optimize the existing ASAP network over the North Atlantic, and develop similar programmes for the North Pacific and the Indian Ocean;

- Action No. 51 recommending Port Meteorological Officers (PMOs), NMSs, NMHSs and other NWP monitoring centres (in collaboration with companies operating commercial ships) to improve the quality of ship observations by more regular interactions with the NWP monitoring centres and more regular checks on the instruments onboard;
- Action No. 58 recommending NMSs, NMHSs, and national oceanographic institutions (in collaboration with JCOMM, international organizations and companies operating ships of opportunity, CBS and CIMO) to improve timely delivery and distribute high vertical resolution data for sub-surface temperature from Ships/XBT (for ocean and weather forecasting purposes).

5.1.2.3 The Team invited its members to take the following into account when planning their national ship observation programme activities (***action; SOT members; ongoing***):

i. To make sure that the gaps identified in the Statement of Guidance for Ocean Applications are taken into account;
ii. To address all ocean observations related actions of the EGOS-IP, and actions No. 49, 51, and 58 in particular;
iii. To make precipitation measurements from ships whenever possible;

- B - BACKGROUND INFORMATION

1 GCOS / GOOS / WCRP Ocean Observing Panel for Climate (OOPC)

1.1 The IOC through Resolution XXVI-8 'Strengthening and Streamlining GOOS' decided to recommit the IOC to a Global Ocean Observing System (GOOS) that is a holistic system of global, regional and coastal observations and products. The GOOS governance will be aligned with the OceanObs'09 working group's Framework for Ocean Observing oriented to an Essential Ocean Variable approach. A new emphasis will be placed on promoting GOOS's role in informing key societal issues as expressed in UN conventions, and reinforcing global participation through capacity development. The reformed governance structure of GOOS confirms that the IOC governing bodies are directly responsible for the governance of GOOS. It dissolves the Intergovernmental Committee for GOOS (I-GOOS), the GOOS Scientific Steering Committee (GSSC), and its subsidiary panels, with the notable exception of OOPC which has GCOS and WCRP co-sponsorship. In addition, the Assembly in its report "*asserted the importance of GOOS as a priority for the IOC; noted that geographically-balanced representation on the GSC should be assured; and emphasized the desirability of representation in the GSC of other IOC programmes as well as of, inter alia, POGO, SCOR, GEOSS, JCOMM and IODE*." The resolution created the GOOS Steering Committee (GOOS SC) and defined its terms of reference, which in summary are to:

- identify the essential ocean variables to observe, and develop and update the scientific, technical and implementation plans and targets for GOOS,
- monitor and promote the development of GOOS based on these agreed plans,
- assess the performance of GOOS in providing users with fit-for-purpose data and information,
- encourage research and operational programmes to enhance and improve GOOS, and
- advise on developing the capacity of all Member States to participate in and benefit from GOOS.

1.2 At the first interim GOOS Steering Committee meeting, held in June 2012 (iGSC-I), the committee reaffirmed the importance of Ocean Observations Panel for Climate (OOPC) to the past and future GOOS and approved the OOPC as a component of GOOS, sharing co-sponsorship with GCOS and WCRP. The OOPC is a scientific expert advisory group, charged with making recommendations for a sustained global ocean observing system for climate in support of the goals of its sponsors: the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the World Climate Research Programme (WCRP). It also reports to JCOMM on requirements; JCOMM groups including the Data Buoy Cooperation Panel (DBCP), the Ship Observations Team (SOT), and the Global Sea Level Observing System (GLOSS) Group of Experts (GLOSS-GE) coordinate a number of the in situ networks of the global module of GOOS, also the ocean component of GCOS. While the OOPC did not meet during the past year, the group remained actively represented at meetings of the WCRP, CEOS, OI'12 and JCOMM-4. Eric Lindstrom will step down as chair of OOPC. The future of OOPC is dependent upon recruitment of a motivated replacement and new infusions of energy for the panel.

1.3 JCOMM-4 decided to continue to rely on the OOPC for observing requirements for climate, as expressed through implementation plan of GCOS and GOOS. JCOMM-4 called upon OOPC to revisit the requirements for upper ocean thermal observations. The OOPC has written its latest recommendations on ocean observations for climate in the GCOS 2010 Implementation Plan[3]. These reflect a mild evolution of previous recommendations, expanding the number of Essential Climate Variables for the ocean and emphasizing integration. Of note for the Ship Observations Team were the following requested actions:

- [GCOS Action O3] Improve the number and quality of climate-relevant marine surface observations from the VOS [for both marine meteorological and oceanographic Essential Climate Variables]. Improve metadata acquisition and management for as many VOS as possible through VOSClim, together with improved measurement systems. Performance indicator: increased quantity and quality of VOS reports
- [Action O11] Implement a programme to observe sea-surface salinity to include Argo profiling floats, surface drifting buoys, SOOP ships, tropical moorings, reference moorings, and research ships. Performance indicator: data availability at International Data Centres.
- [Action O21] Establish plan for, and implement, global Continuous Plankton Recorder surveys [towed from commercial vessels]. Performance indicators: publication of internationally-agreed plans; establishment of agreements/frameworks for coordination of sustained global Continuous Plankton Recorder surveys; implementation according to plan.
- [Action O25] Sustain the Ship of Opportunity XBT/XCTD transoceanic network of about 40 sections. Performance indicator: data submitted to archive. Percentage coverage of the sections.

2. WMO Rolling Review of Requirements (RRR)

2.1. WMO, as part its Rolling Review of Requirements[4] (RRR) is addressing the following application areas:

- Global Numerical Weather Prediction
- High Resolution Numerical Weather Prediction
- Synoptic Meteorology
- Nowcasting and Very Short Range Forecasting
- Seasonal to Inter-annual Forecasts
- Aeronautical Meteorology

3 Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 update), GCOS-138, GOOS-184, http://www.wmo.int/pages/ prog/gcos/Publications/gcos-138.pdf

4: http://www.wmo.int/pages/prog/sat/RRR-and-SOG.html

- Atmospheric Chemistry
- Ocean Applications
- Agricultural Meteorology
- Hydrology
- Climate Monitoring (GCOS)
- Climate Applications (Other aspects, addressed by the Commission for Climatology)

2.2. The Rolling Review of Requirements basically consists of the following steps:

1) Compiling the list of requirements for each applications area and each required variable in terms of (i) horizontal resolution, (ii) vertical resolution, (iii) observing cycle, (iv) timeliness, and (v) accuracy. For each criterion, requirements are given in terms of threshold (value below which observations are worthless), breakthrough (proposed target for significant progress, and optimal cost/benefit), and goal (value beyond which improvement gives no additional value). The list of requirements is independent from the technology being used to observe the required variables (technology free).
2) Estimating the performances of the instruments for each observing system and variable in terms of (i) horizontal resolution, (ii) vertical resolution, (iii) observing cycle, (iv) timeliness, and (v) accuracy.
3) Conducting a critical review and gap analysis based on (i) critical review charts which are objectively comparing the performances of the instruments with the requirements, and (ii) results from impact studies based mainly on Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs).
4) The interpretation of the results from the critical review and gap analysis by experts from each of the considered application area, results in the elaboration of the Statements of Guidance[5] (SoG). The draft Statements of Guidance are then discussed, and possibly updated by the CBS Inter Programme Expert Team on Observing System Design and Evolution (IPET-OSDE) before being formally endorsed by the Team.
5) Based on the Statements of Guidance, the Vision for the Global Observing System (GOS) in 2025[6], cost-effectiveness of observing systems, and the assumed resources of WMO Members, the IPET-OSDE propose priorities, and updates the Implementation Plan for the Evolution of global observing systems (EGOS-IP)[7].
6) The EGOS-IP is used by WMO Members to plan the evolution of the observing systems nationally, and commit resources as appropriate.

2.3. The SoG for an application area provides for an assessment of the adequacy of the observations to fulfill requirements and suggests areas of progress towards improved use of satellite and in situ observing systems. Only the most significant variables in a given application area have been analyzed in the SOGs. SoGs are effectively gap analysis and propose priorities in terms of requirements for observations. The following terminology has been adopted. "Marginal" indicates minimum user requirements are being met, "acceptable" indicates greater than minimum but less than maximum requirements (in the useful range) are being met, and "good" means close to maximum requirements are being met.

2.4 More information on the RRR can be found at http://www.wmo.int/egos

3. Related JCOMM-4 decisions

3.1 Considering that the requirements for climate monitoring (GCOS) were already well taken into account as part of the JCOMM Observations Programme Area (OPA) Implementation Goals (OPA-IG), the Fourth Session of JCOMM (JCOMM-4, Yeosu, Republic of Korea, 23 – 31

5: http://www.wmo.int/pages/prog/sat/RRR-and-SOG.html#SOG
6: http://www.wmo.int/pages/prog/www/OSY/WorkingStructure/documents/CBS-2009_Vision-GOS-2025.pdf
7: The EGOS-IP corresponding to the Vision of the GOS in 2025 has been drafted and is currently being reviewed by the ET-EGOS. The previous version of the EGOS-IP responding to the Vision of the GOS in 2015 is available from http://www.wmo.int/pages/prog/www/OSY/Publications/TD1267_Impl-Plan_Evol-GOS.pdf

May 2012) requested the OPA to make sure that the ocean observational requirements for the following applications areas are also included in the OPA-IG:

- Ocean Applications, including Met-Ocean Forecasts and Services, including marine services, marine hazards warnings, ocean mesoscale forecasting, sea ice and iceberg warnings and forecasts, global and regional wave modelling, serving the needs of maritime transportation (e.g. safety, routing), fishing, and coastal and offshore areas activities;
- Global Numerical Weather Prediction;
- High Resolution Numerical Weather Prediction;
- Synoptic Meteorology;
- Seasonal to Inter-annual Forecasts;
- Climate applications and services.

3.2 In doing so, and taking into account the Statements of Guidance[8] for the above application areas, and identified key gaps, JCOMM-4 recommended the following JCOMM response:

i. OPA is requested to continue to evaluate the quality of wave observations, and the development of cost-effective wave observations from drifters through the DBCP-ETWS Pilot Project on Wave Measurement Evaluation and Test from Moored Buoys (PP-WET) and the DBCP Pilot Project on Wave Measurement from Drifters (PP-WMD) respectively;
ii. Commission members are invited to make precipitation measurements from moored buoys, including coastal moorings, tropical moorings, and OceanSITES;
iii. Commission members are urged to install barometers on all newly deployed drifters; and are encouraged to deploy more autonomous AWS on ships;
iv. The RAMA array of tropical moored buoys in the Indian Ocean should be completed;
v. More cooperation is encouraged between OPA and SFSPA Expert Teams in charge of marine services activities (e.g. ETSI, ETWS, ETOOFS).

3.3 JCOMM-4 emphasized the importance of an integrated approach between in situ and remotely sensed (space-based and surface-based) observations when considering requirements. Noting with appreciation that the WMO-CEOS database now contained a new sub-set relevant to marine meteorology and operational oceanography, allowing an accurate assessment of how the existing in situ ocean observing system was addressing JCOMM's own service requirements for such data, JCOMM-4 requested the Services and Forecasting Systems Programme Area (SFSPA) to ensure that the set of observational data requirements to support met-ocean applications continues to be reviewed and updated. Further noting that the SFSPA had participated in the WMO/CBS Rolling Review of Requirements (RRR) process and that an updated Statement of Guidance (SoG) for Ocean Applications had been produced (JCOMM-4/BM.5.4), JCOMM-4 requested that the existing SoG should continuously be kept updated (see also item 8.1).

3.4 JCOMM-4 recalled that the Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP), managed through JCOMM-4 for Basic Systems (CBS), was currently being drafted. This would be an important reference document in providing Members with clear and focused guidelines and recommended actions in order to stimulate cost-effective evolution of the observing systems. JCOMM-4 noted that good progress has been made in developing the new version of the EGOS-IP in response to the Vision of the GOS in 2025, WIGOS needs, GFCS requirements, and Ocean Application requirements. JCOMM-4 also noted that, through a Congress-XVI decision, a draft WIGOS Implementation Plan had been developed by the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS) for submission to Executive Council (EC-64) for approval. Execution of this plan would establish the WMO framework for managing observing component contributions of its Members in an integrated fashion and in collaboration with partner organizations. JCOMM-4 particularly thanked Dr Ali Mafimbo (Kenya) and the SFSPA for their substantial efforts in both regards. JCOMM-4 urged Members/Member States to make

8 http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG

sure that all ocean observations related actions which are part of the EGOS-IP should be properly addressed once the new EGOS-IP is approved by the WMO Executive Council (in principle EC-65 in 2013). JCOMM-4 emphasized the importance of working on a strategy for properly engaging JCOMM in various implementation plans, such as EGOS-IP, WIGOS-IP, GFCS, to avoid duplication of effort.

Appendices: 2

APPENDIX A

OCEAN APPLICATIONS STATEMENT OF GUIDANCE

(Point of contact: Ali Mafimbo, Kenya)
(Updated March 2012, by Ali Mafimbo, KMD)

This Statement of Guidance (SoG) was developed, through a process of consultation, to document observational data requirements for ocean applications and the present/planned observing capabilities. This version is based on the JCOMM User Requirement Document, which was prepared by the Chairpersons of the Expert Teams within the JCOMM Services Programme Area. It is expected that the Statement will be reviewed at appropriate intervals by the JCOMM Services Programme Area Coordination Group to ensure that it remains consistent with the current state of the relevant science and technology. This document therefore presents an analysis of the gap between user requirements and the available/planned observation capabilities to address these requirements.

1. INTRODUCTION

Marine Meteorology and Oceanography occupy a global role, serving a wide range of users, from international shipping, fishing and other met-ocean activities on the high seas, to the various activities which take place in coastal and offshore areas and on the coast itself. In preparation of analyses, synopses, forecasts and warnings, knowledge is required of the present state of the atmosphere and ocean. The three major met-ocean application areas that critically depend on highly accurate observations of met-ocean parameters are: (a) Numerical Weather Prediction (NWP); (b) Seasonal to Inter-annual Forecasts (SIA), and (c) Met-Ocean Forecasts and Services (MOFS), including marine services and ocean mesoscale forecasting.

The key met-ocean variables to be observed and forecast in support of NWP and SIA are addressed in the Numerical Weather Prediction and the Seasonal to Inter-annual Forecast Statements of Guidance. This Statement of Guidance provides a brief discussion on how well the present and planned met-ocean observing systems meet the user requirements for MOFS, concentrating on those parameters not covered by previous sections of this document, such as waves, storm surges, sea-ice, ocean currents, etc. Variables such as precipitation, air temperature, humidity and cloud cover, also required for marine services, are addressed in the global and regional NWP SoG.

The requirements for MOFS stipulated here are based on a consensus of the met-ocean modelling and forecasting communities. This statement builds on the requirements for global and regional wave modelling and forecasting, marine meteorological services, including sea-ice, and ocean mesoscale forecasting, and represents in addition those variables that are known to be important for initialising, testing and validating models and assimilation, as well as for providing services.

2. GAP ANALYSIS: DATA REQUIREMENTS AND OBSERVING CAPABILITIES

The following terminology has been adhered to as much as possible:

- *poor* (minimum user requirements are not being met),
- *marginal* (minimum user requirements are being met),
- *acceptable* (greater than minimum but less than optimum requirements are being met), and
- *good* (near optimum requirements are being met).

2.1 Wind-Wave parameters (significant wave height, dominant wave period, Wave 1D energy frequency spectrum, and Wave direction energy frequency spectrum)

Global and regional wave models are used to produce short- and medium-range wave forecasts (typically up to 7 days) of the sea state, with a horizontal resolution of typically 30-100km for global models, and down to 3-4km for regional models (with a natural progression to higher resolution expected). Marine forecasters use wave model outputs as guidance to issue forecasts and warnings of important wave variables (such as, significant wave height and dominant wave period) for their area of responsibility and interest, in support of several marine operations. Specific users usually require additional parameters that are obtained from the directional spectrum of wave energy density.

The observational requirements for global and regional wave modelling depend on the applications for which the data are required and are based on the need to provide an accurate analysis of the sea state at regular intervals (typically every 6 hours). These requirements include: (a) assimilation into wave forecast models; (b) validation of wave forecast models; (c) calibration / validation of satellite wave sensors; (d) ocean wave climate and its variability on seasonal to decadal time scales, and (e) role of waves in coupling. Additionally, wave observations are required for nowcasting (0 to 2 hours) and issuing / cancelling warnings, very-short-range forecasting (up to 12 hours) of extreme waves associated with extra-tropical and tropical storms, and freak waves (in this case, in combination with other variables such as ocean currents). Whilst nowcasting is largely based on observational data, very-short range forecasts are being generated using high-resolution regional wave models.

The key model variables for which observations are needed are: (i) significant wave height; (ii) dominant wave period; (iii) Wave 1-D energy frequency spectrum; (iv) Wave directional energy frequency spectrum, and (v) 2-D frequency-direction spectral wave energy density. Also important are collocated surface wind observations, which are advantageous for validation activities. Further additional parameters are of value for use in delayed mode validation (e.g. full time series of sea surface elevation).

The geographical coverage of *in situ* wave data is still very limited and most measurements are taken in the Northern Hemisphere (mainly off the North American and Western European coasts). The majority of these data are provided by *in situ* non-spectral and spectral buoys and ships with *acceptable* frequency and *marginal* accuracy. A limited number of *in situ* spectral buoys is available around the globe. Current *in situ* reports are not standardized resulting in impaired utility. Differences in measured waves from different platforms, sensors, processing and moorings have been identified. In particular, a systematic 10% bias has been noted between US and Canadian buoys, the two largest moored buoy networks. Standardized measurements and metadata are essential to ensure consistency between different platforms.

In situ measurements are currently too sparse in the open ocean (*poor* coverage) to be of particular value, but could potentially provide higher accuracy observations to complement and correct for biases in satellite products. For dominant wave period and significant wave height, the requirement for horizontal spacing for real-time validation and assimilation, as well as maritime safety services, ranges from 20km for regional to 60km for global models, with a minimum accuracy of 1 second and 0.25m respectively. The equivalent requirement for wave 1D energy frequency spectrum and wave direction energy frequency spectrum ranges from 100km for regional to 300km for global models with a minimum accuracy of $0.2m^2Hz^{-1}$ and $0.2m^2Hz^{-1}rad^{-1}$ respectively. The required observation cycle is 24 hours.

Satellite altimeters provide information on significant wave height with global coverage and *good* accuracy. However, horizontal/temporal coverage is *marginal*. A minimum of 20km and 60km resolution is required for use in regional and global wave models respectively. Along track spacing is likely to be adequate to meet this requirement; cross-track spacing is not. Multiple altimeters are therefore required to provide adequate cross-track sampling. Fast delivery (within 6 hours at most) is required with accuracy of 10% / 25cm for wave height, and 1 second for wave period. Long-term, stable time series of repeat observations are required for climate applications.

Information on the 2-D frequency-direction spectral wave energy density is provided by SAR instruments with *good* accuracy but *marginal* horizontal/temporal resolution. Horizontal resolution of 100km is required for use in regional models, with fast delivery required (within 6 hours). Real aperture radar capability is expected to be available within 5 years.

Coastal wave models require different observing methods to those used for the open ocean, due not only to their high resolution, but also due to limitations of the satellite data close to land. Hence for these models systems such as coastal HF radar are of particular importance. These radars provide information on significant wave height with limited coverage, *good* accuracy and *acceptable* horizontal/temporal resolution. High-resolution observations (up to 100m resolution) are required over coastal model areas.

Potential contribution from other technologies and platforms (e.g. navigation radar, other radars and shipborne sensors such as WAVEX) should be developed where they can contribute to meeting the specified requirements.

2.2 Sea Level

Traditionally, permanent sea level stations around the world have been primarily devoted to tide and mean sea level applications, neither requiring real or near-real time delivery. This has been the main objective of the Global Sea Level Observing System (GLOSS). Because of this focus, not only are wind-waves filtered out from the records by mechanical or mathematical procedures, but any oscillation between wind-waves and tides (e.g. seiches, tsunamis, storm surges, etc.) has not been considered a priority. In fact, these phenomena are not properly monitored (standard sampling time of more than 5 to 6 minutes). The main component of GLOSS is the 'Global Core Network' (GCN) of 289 sea level stations around the world for long term climate change and oceanographic sea level monitoring. Due to the increased demand for tsunami, storm surge and coastal flooding forecasting and warning systems, for assimilation of in situ sea level data into ocean circulation models, and for calibration/validation of the satellite altimeter and models, this part of the spectrum needs to be covered from now on, and should be considered when choosing a new instrument and in the design of in situ sea level stations. Additionally, there has been an emphasis on making as many GLOSS gauges as possible deliver data in real and/or near-real time, i.e., typically within an hour. An ongoing issue with these data is that sea level measurements have not been well integrated into National Meteorological and Hydrographic Services (NMHSs).

The aim of any tide gauge recording should be to operate a gauge which is accurate to better than 1cm at all times; i.e., in all conditions of tide, waves, currents, weather, etc. This requires dedicated attention to gauge maintenance and data quality control. In brief, the major requirements for *in situ* sea level stations are:

- For storm surge and tsunami forecasting a spacing of 10km is required, while for climate modelling 50km spacing will meet the threshold. This will therefore require a denser network than is available today.

- A sampling of sea level, averaged over a period long enough to avoid aliasing from waves, at intervals of typically 6 seconds or less if the instrument is to be used also for tsunami, storm surges and coastal flooding forecasting and warning.

- Gauge timing be compatible with level accuracy, which means a timing accuracy better than one minute (and in practice, to seconds or better with electronic gauges) – *marginal* accuracy.

- Measurements must be made relative to a fixed and permanent local tide gauge bench mark (TGBM). This should be connected to a number of auxiliary marks to guard against its movement or destruction. Connections between the TGBM and the gauge zero should be made to an accuracy of a few millimetres at regular intervals (e.g. annually) – *acceptable* accuracy.

- GLOSS gauges to be used for studies of long term trends, ocean circulation and satellite altimeter calibration/validation need to be equipped with GPS receivers (and monitored possible by other geodetic techniques) located as close to the gauge as possible;

- The readings of individual sea levels should be made with a target accuracy of 10mm – *acceptable* accuracy;

- Gauge sites should, if possible, be equipped for recording tsunami and storm surge signals, implying that the site be equipped with a pressure sensor capable of 15-seconds or 1-minute sampling frequency, and possibly for recording wave conditions, implying 1-second sampling frequency – *poor* accuracy; and,

- Gauge sites should also be equipped for automatic data transmission to data centres by means of satellite, Internet, etc., in addition to recording data locally on site.

Coastal sea level tide gauges are invaluable for refining tsunami warnings, but due to nearshore bathymetry, sheltering, and other localized conditions, they do not necessarily always provide a good estimate of the characteristics of a tsunami. Additionally, the first tide gauges to receive the brunt of a tsunami wave do so without advance verification that a tsunami is under way. In order to improve the capability for the early detection and real-time reporting of tsunamis in the open ocean, some countries have begun deployment of tsunameter buoys in the Pacific, Indian, and Atlantic Oceans and other tsunami-prone basins. Due to cost constraints, the number of DART buoys deployed and maintained is still limited – *marginal* geographic coverage and *good* accuracy.

The geographic coverage of the *in situ* sea level data is therefore *poor* for both studies of long-term trends and for forecasting storm surges and tsunamis. Basins prone to tsunamis and storm surges (e.g. Bay of Bengal, Gulf of Mexico and Pacific Islands) require a higher density of sea level observations. Sea level measurements should be accompanied by observations of atmospheric pressure, and if possible, winds and other environmental parameters, which are of direct relevance to the sea level data analysis.

Satellite altimeters provide information on sea surface height with global coverage and *good* accuracy, i.e. within 1cm over basin scales. However, horizontal/temporal coverage is *marginal*. The main limitation of the satellite altimeter in reproducing the non-long-term sea level changes is the spatial sampling: the repeat orbit cycle leads to an across-track spacing of about 300km at mid-latitudes. This sampling cannot resolve all spatial scales of mesoscale and coastal signals which have typical wavelengths of less than 100km at mid-latitude. The scales are even shorter at high latitudes (around 50km), but fortunately the ground track separation decreases with latitude. Thus, to cover the whole mesoscale and coastal domain it is necessary to increase the spatial sampling by merging (in an optimal way with cross-calibration) different altimetry data sets. The temporal changes in sea level are usually determined along the repeat tracks of altimetry satellites. In areas close to the coasts (less than 20km offshore) the difficulty is even larger because of the proximity of land, for which the track spacing is too coarse to resolve the short scales of the sea level changes. Thus, adaptive trackers and/or specific re-tracking of altimeter waveforms and near-shore geophysical corrections (such as coastal tide models and marine boundary layer tropospheric corrections) are needed.

2.3 Sea Surface Height Anomalies (SSHA or Sea Level Anomalies)

SSHA is a derived observation product used by all operational ocean forecasting systems. The observation products are processed by the space agencies and distributed to the forecasting centres. SSHA therefore not only involves the direct observation of the ocean topography, but also the accurate estimation of the reference mean dynamic topography, the ocean tides, sea state bias and several other atmospheric and solid earth corrections.

SSHA provides an estimate of the integrated distribution of mass within the ocean (the analogue of sea level pressure for the atmosphere) and therefore provides information of the specific volume anomalies of the water column. Combined with a data assimilation scheme to define the covariability of the temperature and salinity with SSHA, observations of SSHA have the greatest impact on ocean forecasting from the current observing system. Gradients in SSHA (or pressure) drive ocean circulation on spatial scales ranging from sub-mesoscale to gyre scale and temporal scales of hours through decades. The impact of SSHA includes nowcasting and forecasting the currents and salinity and forecasting the temperature for the upper ocean. In this case the depth scale of the upper ocean is defined by the covariability of temperature and salinity with SSHA, and varies in space and time. We also note that the nowcasting of temperature of the mixed layer is well served by remotely sensed sea surface temperature that observes the foundation temperature.

Improvements to altimetry, the cal/val process, the determination of correction terms and the verification of data assimilation statistical models will have a direct impact for ocean forecasting in the near term. The greatest improvements however will come from improvements in temporal and spatial resolution, each of which has to be traded-off against the other for any given satellite. Better temporal resolution (which comes at the cost of poorer spatial resolution) allows rapidly changing features (e.g. near fronts or major ocean currents) to be observed adequately: better spatial resolution (which comes at the cost of poorer temporal resolution) allows mesoscale features (e.g. eddies) to be resolved.

The present altimeter constellation consists of three main satellites. Two satellites, Jason-1 and Jason-2, fly in formation, allowing the same spot on the ocean to be observed relatively frequently (every 5 days) but with relatively widely-spaced ground tracks (315km at the equator). Envisat has a longer repeat cycle (currently 30 days), but tighter ground track spacing (90km at the equator).

The table below specifies the consolidated user requirements for ocean forecasting systems storm surge and tsunami forecasting.

Application	Spatial resolution (km)	Delivery timeliness (hours)		Accuracy (m)
		Target	Threshold	
Coastal Ocean forecasting	< 5	3	6	< 0.08
Open Ocean forecasting	5-10	6	24	< 0.08
Storm surge / tsunami forecasting	10	0.2	24	0.1

SSHA has been observed through a series of narrow swath instruments since 1992 (TOPEX-Poseidon, Jason-1, Jason-2, ERS, ERSII, Envisat, Geosat and GFO-1). Throughout this period, as many as four altimeters have been operational, with demonstrable improvements in higher spatial and temporal coverage. It is now commonly accepted that a minimum of two interleaved operational satellites is required to support ocean forecasting applications.

The timescale for scheduling satellite missions and the competition for budgets has threatened the continuity of altimetry over the past decade and into the future. Securing continuity of satellite altimetry is critical to national service providers delivering the reliable, quality ocean services that are required to generate the full spectrum of applications. Full integration of forecasts of SST and surface currents for NWP and wave forecasting cannot be realised until ocean prediction systems achieve homogeneous skilful performance. The future progression toward fully coupled ocean-wave-NWP systems for short-range prediction will similarly require high reliability and quality from the ocean observing system. SSHA is currently considered the most critical component of this observing system for ocean prediction systems.

SSHA is used in ocean models to provide adjustments to the sub-surface density structure of the ocean. It is also critical that a global *in situ* profiling system (e.g. Argo) be maintained to calibrate/validate these projections and further constrain the deep ocean through assimilation of density profiles. SSHA observations can also be exploited in the coastal regions. However the spatial and temporal requirements in the coastal zone place greater demands on the observing system. Wider-swath observations would add significant value in this zone as well as in the open ocean. Enhancing existing coastal tide gauges networks will also add significant value to ocean prediction systems in the shelf zone.

2.4 Sea-Ice parameters (thickness, coverage/concentration, type/form, movement)

Sea-ice charts containing information of sea-ice thickness, coverage/concentration, type/form and movement are produced in support of marine operations, validation of models and for climatological studies.

Although broad knowledge of the extent of sea-ice cover has been totally revolutionized by satellite imagery, observations from shore stations, ships and aircraft are still of great importance in establishing the “ground truth” of satellite observations. At present, observations of floating ice depend on instrumental and, to a lesser extent, on visual observations. The instrumental observations are made by conventional aircraft and coastal radar, visible and infra-red airborne and satellite imagery, and by more recent techniques, such as passive microwave sensors, laser airborne profilometers, scatterometers, side-looking (airborne) radar (SLAR / SLR) or synthetic aperture radar (SAR, satellite or airborne).

Visual observations from coastal settlements, lighthouses and ships can provide an ice report several times a day as the ice changes in response to wind and ocean currents, but the total area of ice being reported is very small (e.g., from a ship, observations can cover a radius of only 7-8km; from a coastal lighthouse, observations can cover a radius of up to 20km). In some marine areas, such as the Baltic Sea, visual observations may be present in sufficient numbers that a reasonable proportion of the ice cover can be reported each day by a surface network. In others such as the Gulf of St Lawrence, where the waterways are broad and the shores often unsettled, no shore reporting system can provide data on more than a very small percentage of the total ice cover. Although surface based reports can provide excellent detail about the ice, especially its thickness, it is generally recognized that for most areas, the surface reports are not really adequate to describe ice conditions fully.

Surface reports from shore stations, ships and drifting buoys provide accurate information on ice amount, thickness, movement and its deformation over rather small areas. When many vessels and fixed observing points are available accurate information can be provided in restricted waterways. Many areas of the Kattegat and Baltic Sea coastline fall into this category.

Reports about ice coverage taken from the air, i.e., helicopters and fixed-wing aircraft, have the advantage of a much better coverage, the platform’s flying speed allowing a great deal more of the sea-ice to be reported and problems of remoteness from airports or other suitable landing sites being overcome by using long-range aircraft. In the various stages of development of sea-ice, estimates of its amount; notes on its deformation and snow cover or stage of decay data are provided by visual estimation. Comprehensive aerial reporting has its own particular requirements beginning with an accurate navigational system when out of sight of land. Inclement weather – fog, precipitation and low cloud – will restrict or interrupt the observations and the usual problems of flying restrictions at the aircraft base may also be a factor even if the weather over the ice is adequate for observing.

Recent advances in technology are now permitting more accurate data to be obtained by aerial observations. SLAR and SAR can provide information which documents precisely the distribution and nature of the ice in one or two belts along the flight path of the aircraft for distances of up to 100km on each side. Unlike most other sensors, the radar has the capability of monitoring the ice under nearly all weather conditions.

When no fog or low clouds are present a laser airborne profilometer can be used to measure the height and frequency of ridges on the ice, and under similar conditions an infra-red airborne scanning system can provide excellent information with regard to floe thickness in the range below 30cm.

The advent of polar-orbiting meteorological satellites has added a third, and now the most important and predominant mode of observing sea ice, but again there are some restrictions. The spectral range of the sensors may be visible, infra-red, passive or active microwave or a combination of these. Satellite coverage may be broad at low resolution or cover a narrow swath at high-resolution. In the latter case, data from a particular location may be obtained only at intervals of several days.

In general, most meteorological satellites make 10–12 passes daily in the polar regions, i.e., complete broad-swath coverage once or twice a day. These satellites provide visible and infra-red imagery with resolutions of 250m–1km; and passive microwave and scatterometer data at coarser resolutions of 6–70km, i.e. *good* spatial/temporal coverage.

Visible and infra-red sensors do not have cloud-penetrating capability, while microwave data are practically cloud independent. Active microwave SAR data are characterized by improved ground resolution (approximately 10–100m) but a reduced coverage due to narrow swaths and greater revisit time between exact repeat orbits. Snow cover on the ice and puddles on the floes are other complicating factors. Interpretation of SAR images may be even more difficult due to the ambiguities associated with SAR backscatter from sea-ice features that vary by season and geographic region.

Space-borne sensors, especially radars, can provide precise data on the location and type of ice boundary, concentration and the presence or absence of leads, including their characteristics. Less accurate information can be extracted on the stages of development of the sea ice (including the First-Year/Multi-Year ratio) and its surface morphology. Flow motion over approximately 12–24-hour intervals can often be determined through the use of imagery from sequential orbits.

2.5 Sea-Surface Temperature (SST)

High-resolution sea-surface temperature (SST) observations are required for: (i) NWP (addressed in the global and regional NWP SoGs); (ii) Seasonal to Inter-annual Forecast (addressed in the SIA SoG); (iii) ocean forecasting systems (assimilation in and validation of ocean models); climate modelling; and, (iv) marine services.

Coastal and inland seas users are defined as those using SST data products for regional ocean modelling and marine services. SST in the coastal and inland regions has a large variability due to the diurnal cycle of solar radiation, which creates significant changes to the surface characteristics of the land and sea and forces land-air-sea interactions, i.e., land-sea breezes. Typically, this user group has a requirement for ultra-high resolution SST data sets (1km spatial resolution and <6 hours temporal resolution), with good accuracy (< 0.1K) and temporal coverage (hourly).

The table below specifies the consolidated user requirements for ocean forecasting systems and marine services.

Application	Spatial resolution Threshold (km)	Delivery timeliness (hours)		Accuracy (K)
		Target	Threshold	
Coastal Ocean forecasting	10	1	3	0.5

Open Ocean forecasting	25	1	3	0.5
Marine modelling	25	0.08	6	1
Maritime safety Services	10	1	3	1

Ships and moored and drifting buoys provide observations of SST of good temporal frequency and acceptable accuracy as long as required metadata are provided. For example, the depth of the measurement is essential for deriving the diurnal cycle and the foundation temperature. Coverage is marginal or poor over some areas of the global ocean. The goal for high quality SST in the open ocean is ideally 5km spatial scale with accuracy 0.5K, and fast delivery (availability within 1 hour). In coastal regions, the goal is 1km with a delivery delay of 1 hour (accuracy 1K on 10km spatial scale).

Drifting buoy and other in situ SST measurements are used for calibration/validation of satellite data, in the error estimation for observations products and in combined analysis products. They are critically important in providing bias correction of these data. Satellite biases can occur from orbit changes, satellite instrument changes and changes in physical assumptions regarding the physics of the atmosphere (e.g. through the addition of volcanic aerosols). Thus, drifting buoy and other in situ data are needed to correct for any of these changes.

Satellite measurements provide high-resolution SST data. Both infra-red and microwave satellite data are important. Microwave data have a significant coverage advantage over infra-red data because microwave data can be retrieved in cloud-covered regions while infra-red cannot. However, microwave SST is at a much lower spatial resolution than infra-red. In addition microwave SST cannot be obtained within roughly 50km of land. A combination of both infra-red and microwave data is needed because each has different coverage and error properties.

Instruments on polar-orbiting satellites provide global coverage in principle, good horizontal and temporal resolution and acceptable accuracies (once they are bias-corrected using in situ data), except in areas that are persistently cloud-covered, which includes significant areas of the tropics. High-resolution SST (1km) can be retrieved by polar-orbiting infra-red radiometers and rather degraded resolution SST (5km) from radiometers on board geostationary satellites. However, quantitative measurement of the SST diurnal cycle is still a challenging subject which currently only drifters can address. In addition, microwave radiometers cannot be used for coastal applications because of (a) rather coarse spatial resolution and (b) contamination by land signals.

2.6 Sea-Surface Salinity (SSS)

We note that the standard units for salinity have recently been changed following TEOS10 (http://www.teos-10.org/), which was adopted by the Intergovernmental Oceanographic Commission at its 25th assembly in June 2009. Practical Salinity Units (PSU) have been replaced by the SI unit Absolute Salinity SA, (g/kg).

High resolution and high quality Sea-Surface Salinity (SSS) observations are required for ocean forecasting systems (assimilation in and validation of ocean models).

Frequent SSS sampling with global coverage and sufficient accuracy will provide help constrain the temporal and spatial distribution of precipitation. The remote sensing instrumentation remains experimental and the full impact of these observations is yet to be determined. Nonetheless, there is a requirement to constrain this state variable at the surface where the variability is greatest and the mass fluxes are known to have large errors.

Coastal and inland sea users are defined (as per SST above) as those using SSS data products for regional ocean modelling and marine services. SSS in the coastal and inland regions have a larger variability due to coastal systems (e.g. upwelling/downwelling processes) and river discharge as well as enhanced evaporation in regions shallower than the optical depth or with weak circulation. Typically, this user group has a requirement for higher resolution SSS data sets

(1km-5km spatial resolution and <6 hours temporal resolution), with good accuracy (< 0.1-0.7SA) and temporal coverage (hourly). The spatial scales of variability in the open ocean are dominated by the mesoscale with a resolution of 10-25km and temporal resolution of 12-24 hours. The accuracy range represents thresholds of accuracy that will impact an analysis and depend on the region of the ocean being observed.

The table below specifies the user requirements for ocean forecasting systems and marine services.

Application	Spatial resolution (km)	Delivery timeliness (hours)		Accuracy (S_A)
		Target	Threshold	
Coastal Ocean forecasting	< 1 -5	3	6	< 0.1-0.7
Open Ocean forecasting	10-25	12	24	< 0.1-0.7

As long as the required metadata are provided (e.g. the depth of the measurement is important for deriving the freshwater lens effects), ship and moored and other in situ observations of sea-surface SSS are of good temporal frequency and acceptable accuracy. Coverage is marginal or poor over some areas of the ocean globe. There is a requirement for high quality SSS in the open ocean, ideally with accuracy < 0.1SA on a 10km spatial scale, and fast delivery (availability within 1hour). In coastal regions, higher density is required (accuracy < 0.1 SA on a 1km spatial scale).

2.7 Sub-surface Temperature, Salinity and Density

Sub-surface temperature, salinity and density observations are required for: (i) Seasonal to Inter-annual Forecasts (SIA) (addressed in the SIA SoG); (ii) testing and validation of ocean forecasting models, and (iii) marine services/modelling.

The Tropical Atmosphere Ocean (TAO) / TRITON moored buoy network provides data with *good* frequency and accuracy, and *acceptable* spatial resolution for the tropical Pacific. The TAO Tropical Moored Buoy Arrays provide data of *marginal* vertical resolution for marine services applications (~50m down to 500m), which require high vertical resolution data in the mixed layer. The tropical moored network in the Atlantic (PIRATA) is *acceptable*. The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) is being developed but is providing only *marginal* sampling at the moment. Sustained funding for the Tropical Moored Buoy Arrays remains a matter of concern.

Ships (XBT profiles) provide temperature profile data of *acceptable* spatial resolution over many of the targeted frequently repeated and high [horizontal resolution] density lines. However, sampling of about half of the targeted lines remains *poor*. Temporal resolution is generally *marginal*, but *acceptable* in some ship-specific lines. XBTs provide data with *good* vertical resolution (typically 1m) down to 1000m depth in delayed mode, but real-time data are constrained by limitations in the traditional GTS character codes being used at the moment.

Argo profiling floats provide near-global coverage of temperature and salinity profiles to ~2000m, mostly with *acceptable* to *good* vertical (every ~5m) and spatial resolutions, but only *marginal temporal* resolution, particularly for marine services. The accuracy is *acceptable* for assimilation by ocean models and for marine services.

The existing sampling is *adequate* for ocean prediction in regions of large spatial and temporal scales. However, there are many important regions where the spatial and temporal scales are shorter and the present sampling pattern is *poor*. Targeted deployments into these regions together with adaptive cycling patterns might be considered.

2.8 Ocean chlorophyll concentration

Ocean chlorophyll concentration observations are required for marine services applications and for validation of ocean models. Ocean chlorophyll concentration with high-spatial resolution (250m to 1km) can be deduced from remotely sensed images of biological and non-biological parameters. Ocean chlorophyll concentration data can signal several types of marine pollution, harmful algae and red tide plankton blooms. Parameter retrieval algorithms in turbid waters are not yet established, but developments of an observation system based on remotely sensed ocean chlorophyll concentration have presented promising results for a future operational observing system. In situ measurements are needed to complement satellite ocean chlorophyll concentration observations. These measurements should be accompanied by real-time daily observations of ocean temperature, surface wind and derived dynamic height.

2.9 3-D Ocean Currents

Observations of 3-D ocean currents are required for marine services applications, and for testing and validation of ocean models.

Inferred surface currents from drifting buoys are *acceptable* in terms of spatial coverage and accuracy and are *marginal* in terms of temporal resolution. Targeting deployments of drifting buoys into regions of high variability such as boundary currents and downstream geostrophic turbulence would help enhance their impact on ocean prediction systems. Moored buoys are *good* in temporal resolution and accuracy, but *marginal* or *poor* otherwise. The Acoustic Doppler Current Profiler (ADCP) provides observations of ocean currents over a range of depths, with *acceptable* accuracy. Coverage is *marginal* or *poor* over most areas of the ocean globe, with *marginal* vertical resolution for marine services applications, which require high vertical resolution data in the mixed layer.

Satellite altimetry is being used to infer the distribution of ocean currents (geostrophic velocity). Satellite altimetry provides more homogeneous space and time coverage than *in situ* observations, permits to derive the ageostrophic motion (e.g. centrifugal, Ekman, ageostrophic submesoscale) and the time-mean motion. Satellite altimetry also permits to detect geostrophic eddies. Global mean dynamic topography can be obtained by combining information on the geoid, altimeters, drifters, wind field, and hydrography. These products are *poor* in terms of timeliness required for marine services applications. HF Radars provide for *good* temporal and spatial resolution in coastal regions, with *marginal* accuracy.

2.10 Bathymetry, Coastal Topography and Shorelines

Observations of bathymetry, coastal topography and shorelines are required for ocean and coastal modelling. Very high resolution data are required due to the gradual changes of the coastline through erosion and accretion processes relating to coastal meteorological and oceanographic phenomena (e.g. waves, storm surges and sea ice). Visible and infrared imagers (i.e. Landsat, SPOT), synthetic aperture radar (SAR) and aerial photography provide good information on the coastline and coastal topography.

Many sonar techniques have been developed for bathymetry. Satellite altimeters also map deep-sea topography by detecting the subtle variations in sea level caused by the gravitational pull of undersea mountains, ridges, and other masses. These provide global coverage and *acceptable* to *good* accuracy.

2.11 Surface Wind Vector over the Ocean and Coastal Areas

High-resolution surface wind vectors over the ocean and coastal areas are required as an input field to ocean models (including wave models) for marine services, marine modelling and atmospheric modelling. The surface wind-field is a key variable for driving ocean models and to nowcast and forecast marine meteorological and oceanographic conditions. It is strongly influenced by the coastal topography and land-sea surface conditions. Traditional global and regional NWP products do not have adequate spatial resolution for marine services applications, as well as for coastal modelling.

Voluntary Observing Ships (VOS) and meteorological and oceanographic moored buoys provide observations of *acceptable* frequency and accuracy   Coverage is *marginal* or *poor* over large areas of the ocean globe. The tropical moored buoy network has been a key contributor to surface wind measurements over the last decade, particularly for monitoring and verification, providing both *good* coverage and accuracy in the equatorial Pacific. Fixed and drifting buoys and VOS outside the tropical Pacific provide observations of *marginal* coverage and frequency; accuracy is *acceptable*. Wind observations from drifting buoys are *poor*.

Polar-orbiting satellites provide information on surface wind, with global coverage, *good* horizontal resolution, and *acceptable* temporal resolution and accuracy. Microwave scatterometers have *marginal* spatial resolution (25km), whereas the wide swath SAR measurement has *marginal* temporal resolution (one measurement every few days) and provides no wind direction.

2.12 Surface pressure

Ships and buoys take standard surface observations of several atmospheric variables, including surface pressure. In relatively shallow waters, oil platforms do the same, but the frequency and spatial coverage are *marginal* for marine services applications. Mean sea level pressure is vital to detect and monitor atmospheric phenomena over the oceans (e.g. tropical cyclones) that significantly constrain shipping. As stated in the SoG for Synoptic Meteorology, even very isolated stations may play an important role in synoptic forecasting, especially when they point out differences with NWP model outputs.

2.13 Surface heat flux over the ocean

High-resolution surface heat flux observations over the ocean are required as input fields to ocean models and for marine services. Surface heat flux is of critical importance to improve the skill of forecasts of sea surface temperature and entrainment of heat into the surface mixed layer. Improved performance will have impacts on NWP forecasts and sonar prediction, as well as reduce background errors in ocean data assimilation. Total heat flux is composed of downward shortwave, net longwave, latent heat and sensible heat fluxes. Accuracy strongly depends on both cloud and radiation physics parameterisations, and adequate atmospheric observing systems. NWP products are reliable and provide *adequate* products for current applications.

High quality marine meteorological stations are required to more accurately observe fluxes over the ocean and to enhance the physical parameterisations contained in the NWP products. Deployment of meteorological stations in mid- and high-latitudes will further enhance this development over the range of conditions that occur at the air-sea interface.

2.14 Visibility

Poor visibility is a major hazard to all vessels because of the increased danger of collision. Surface visibility observations are made primarily by ships, and at coastal stations (mainly at harbours, where VTS (Vessel Traffic Services) is usually available). This parameter can vary substantially over short distances. Accuracy is *acceptable* in coastal areas and *marginal* in the open ocean. Horizontal / temporal resolution is *poor* over the most of the global ocean. Typically, visibility is deduced from the output of regional atmospheric models (see regional NWP SoG).

2.15 Summary of the Statement of Guidance for Ocean Applications

The following key points summarize the SoG for Ocean Applications:

- A large part of marine and ocean observing systems is currently maintained by research funding with limited duration. This has the potential of leaving observational gaps unless ongoing funding for sustained observing networks is guaranteed. The ocean observing community should therefore ensure sustained funding for the key observing systems (e.g. tropical moorings, Argo, surface drifters with barometers, as well as altimeter, scatterometer, microwave SST and sea ice measurements from satellite missions);

- The uneven geographical coverage of the *in situ* ocean observing network is also an ongoing issue for ocean applications. Considering the regional variability in requirements as well as to ensure optimized planning for observing networks with limited resources, the need for studies on geographical variability in spatial/temporal resolution for ocean observations should be emphasised;

- Ocean observing communities should also improve geographical coverage of ocean observing systems, particularly for measuring SST, SSHA, SSS and visibility, along with higher resolution geometry and extend open-ocean and coastal wind-wave observing networks (e.g. 400 time-series reporting in open ocean), possibly developing other existing observing sites (e.g. global sea level and tsunami monitoring network) into multi-purpose stations;

The critical met-ocean variables that are not adequately measured (more accurate and frequent observations and better spatial/temporal resolution are required) by current or planned systems are:

- Sea surface height anomaly - noting the high impact of this observation on ocean forecasting systems to derive both the ocean state and circulation of the upper ocean, supporting a large number of applications, it is recommended that the requirements for this variable be given high priority and that a minimum service level target be agreed and sustained;

- Wave parameters (significant wave height, dominant wave period, Wave 1-D and wave directional energy frequency spectrum) - noting that extreme wave and wind gusts events significantly constrain shipping and other marine operations, it is recommended to collocate of wind and wave sensors;

- Sea level – noting the wide range of requirements for sea level data, depending on the application area (from early detection of tsunamis to long-term trends of sea level rise), the requirements for this variable should be carefully addressed;

- Surface pressure – noting that sea-surface pressure data from drifting and moored buoys are still limited, particularly in tropical regions where these data are vital to detect and monitor atmospheric phenomena over the oceans (e.g. tropical cyclones) that significantly constrain shipping, it is recommended to install of barometers on all deployed drifters (1250); and

- Visibility – noting that visibility data are critical for harbours operations and as these are still very limited, the NMHSs are encouraged to measure visibility.

It is therefore recommended that ocean observing communities should (i) ensure that state-of-art technologies are employed to improve accuracy for all measurements; (ii) extend collaboration among themselves at national/regional levels to enhance wave measurement networks (e.g. moored buoy networks) for validation and evaluation; (iii) install barometers on all newly deployed drifting buoys (target 1250 units), and (iv) develop visibility measurement capability over the ocean (consultation needed with JCOMM experts on how to practically achieve this).

Satellite data are the only means for providing high-resolution data in key ocean areas where *in situ* observations are sparse or absent. In general, *in situ* met-ocean data and observations are *poor* for marine services (in particular, for monitoring and warning marine-related hazards) and *marginal* for assimilation into ocean models, including wave models. Better integration of met-ocean measurements into NHMSs and their sustainability are needed.

There is a need for satellite operators to ensure (i) a combination of both infra-red and microwave measurements for better coverage of SST observations; (ii) improved observations in coastal regions (altimetry, SST); (iii) a minimum of two interleaved operational satellites providing SSHA observations to support ocean forecasting applications, and (iv) the development satellite measurements of SSS on an operational basis.

APPENDIX B

JCOMM OBSERVATIONS PROGRAMME AREA IMPLEMENTATION GOALS (AS REPORTED TO JCOMM-4)

JCOMM OBSERVATIONS PROGRAMME AREA IMPLEMENTATION GOALS

(as reported to the fourth Session of JCOMM, Yeosu, Republic of Korea, 23-31 May 2012)

1. INTRODUCTION

The Observations Programme Area (OPA) work plan is aligned with the ocean chapter of the GCOS *Implementation Plan for the Global Observing System for Climate in support of the UNFCCC* (GCOS-138 in its 2010 update). The implementation goals provide specific implementation targets for building and sustaining an initial global ocean observing system representing the climate component of the Global Ocean Observing System (GOOS) and the ocean component of the Global Climate Observing System (GCOS). Although the baseline system proposed under the implementation goals was designed to meet climate requirements, non-climate applications, such as NWP, global and coastal ocean prediction, and marine services in general, will be improved by implementation of the systematic global observations of Essential Climate Variables (ECVs) called for by the GCOS-138 plan.

Sixty-two percent of the initial composite ocean observing system is now completed (Figure 1), and three components have achieved their initial implementation target: the drifting buoy array (at JCOMM-II, in September 2005), the Argo profiling float programme (November 2007), and the VOS Climate Project fleet (June 2007).

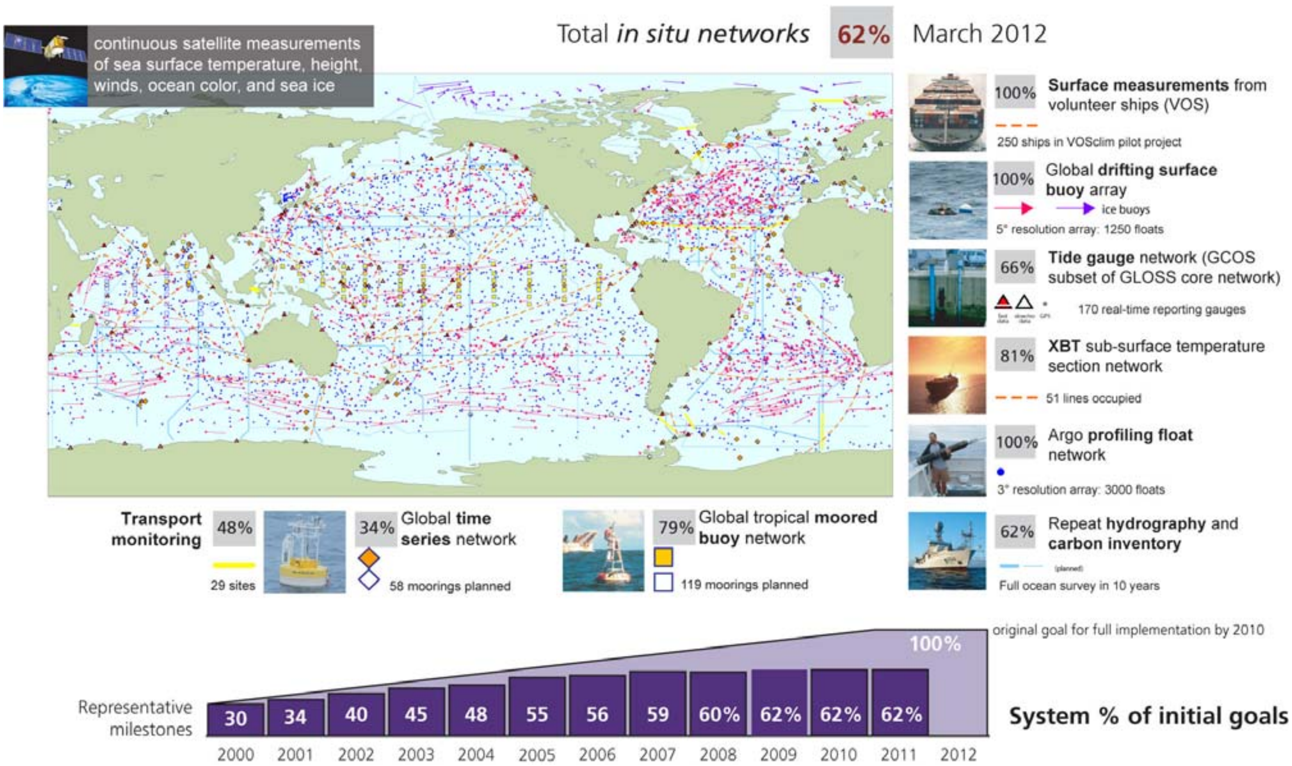


Figure 1 – A schematic of the initial composite ocean observing system design, including the current status against the goals of the GCOS Implementation Plan 2010 (GCOS-IP).

2. DATA BUOY COOPERATION PANEL (DBCP)

Implementation Goals	• Sustain global coverage (each 5x5 degree region outside the near-equatorial band) of the drifting buoy array (total array of 1250 drifting buoys equipped with ocean temperature sensors), and obtain global coverage of atmospheric pressure sensors on the drifting buoys • Complete implementation of and sustain the Tropical Moored Buoy network of 125 moorings in the Pacific, Atlantic, and Indian Oceans
Metrics now used by OCG	• number out of 1250 drifting buoys, as reported on the GTS • number implemented out of 125 tropical moored buoys, as reported on the GTS

2.1 Overview of DBCP activities

At its inception in 1985, the DBCP was charged with improving the quantity, quality and timeliness of data buoy observations from the global oceans, and with persuading the research community to make their considerable body of data available in near real time for use by the global forecasting community (i.e. data formatting and insertion on to the GTS). Success in this area was achieved through the employment of a Technical Coordinator (TC) and the creation of a number of regional and application-specific Action Groups (currently eleven in number) that were able to coordinate their activities under the general guidance of the DBCP. By 2000, the initial objectives laid before the Panel had largely been met and become routine, and the Panel gradually turned towards the identification of new challenges that would pave its way forward and make best use of the skills, knowledge base, resources and goodwill, that the Panel enjoyed and could exploit in developing data buoy activities worldwide.

Central to the new working practices of the DBCP are four key elements:

- The creation of an Executive Board, supported by a number (currently five) of focused task teams, to ensure that the mission of the Panel could progress effectively during the intersessional period;
- The sponsoring of Pilot Projects to evaluate in detail emerging technologies that might ultimately enhance the capabilities of data buoy networks;
- The initiation of outreach and Capacity Building activities both to enable developing regions to successfully implement and manage data buoy programmes, and to assist the Panel in recovering increased numbers of buoy observations from data-sparse areas. This approach is consistent For example, the Panel ran two successful training workshops for key regional participants in 2011 and 2012, and has an active task team to take matters forward;
- The streamlining of the Panel's annual sessions to make better use of participants' time and experience by concentrating on those issues that require the Panel's attention and decision.

In common with many other observing networks, the mission of the DBCP can only be achieved through the employment of its TC. The retention of the TC is vital to the success of the Panel, and there are a number of difficulties to be overcome in this regard.

The issue of inadequate deployment opportunities is now the major difficulty affecting the global dispersion of the drifter array, an issue which is shared with the Argo programme. The Southern Ocean, Gulf of Guinea and the NW Indian Ocean continue to prove particularly troublesome. The DBCP and Argo TCs are working together to identify shared deployment cruises, and the solidified SOT/vessel coordinator position will strengthen this ability.

In measuring performance against requirements, in all three areas (quantity, quality and timeliness of observations) the trend in performance is one of steady improvement. Where there are instances of the trend not being followed (e.g. in the regional distribution of buoy coverage, or in regional anomalies in data timeliness), the Panel is notified by its TC and suitable remedial actions agreed where possible.

Until recently, the numbers of buoys reporting data on the GTS was exceeding the target of 1250 specified in the OPA implementation goals (see Figure 2), There is a dip in the numbers (1205 for February 2012) having to do with lower lifetimes of drifters. It is important to note that nearly 50% of the drifters on the GTS now report atmospheric pressure, in large measure that is a tribute to the barometer upgrade scheme operated by the Global Drifter Programme that has successfully encouraged the addition of barometers to standard SST-only drifters (SVPs). Figure 3 shows the global distribution of both moored and drifting buoys, with the Tropical Moored Buoy array clearly evident. Figure 4 shows the distribution of air pressure observations and the lack of data from the tropics (an intentional gap, as the pressure signal from this region is in general weak). Recently expressed user requirements indicate that this coverage needs to be improved.

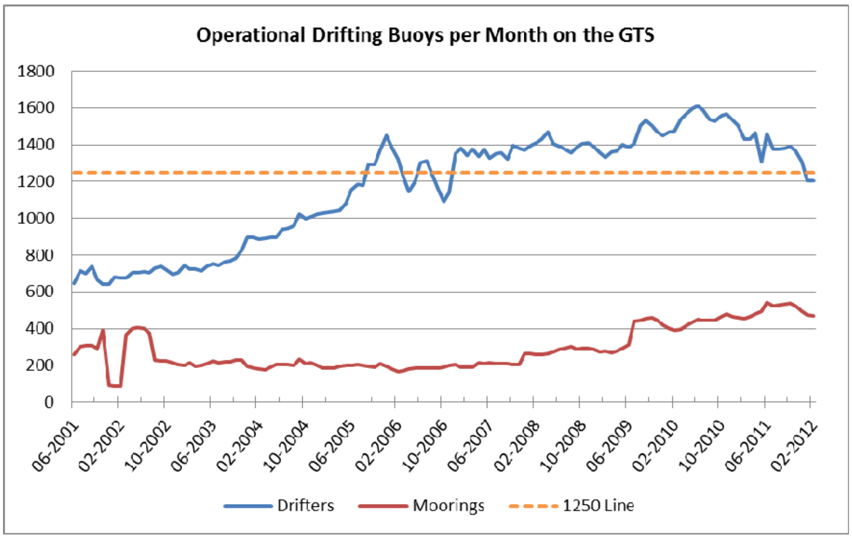


Figure 2 – Monthly evolution of the number of operational drifting buoys reporting on GTS from June 2001 to February 2012. Operational moored buoys are also included (Data derived by statistics computed from GTS in situ marine data provided by Météo-France – Source: JCOMMOPS).

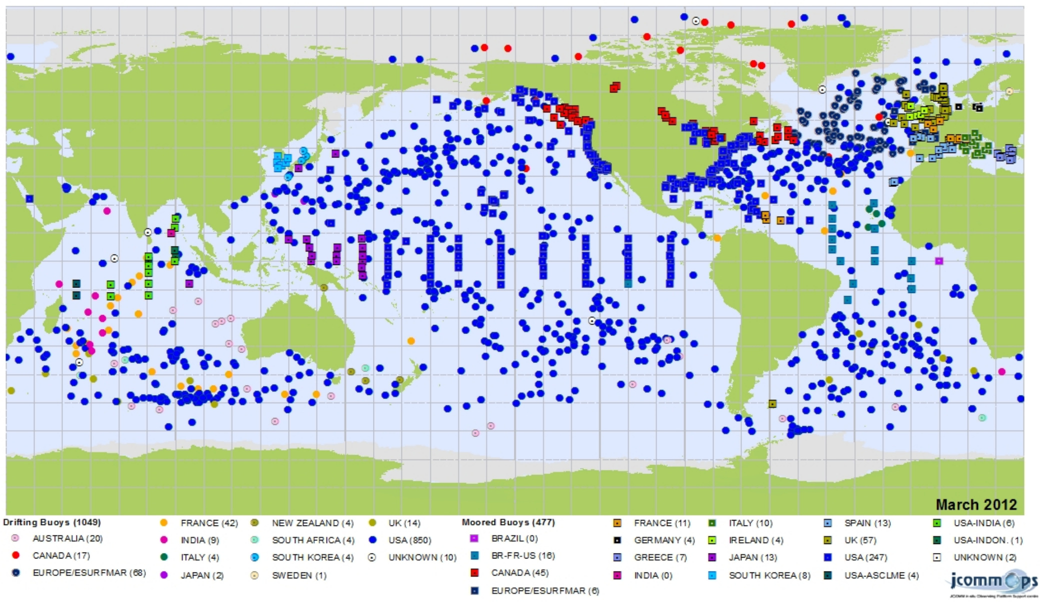


Figure 3 – Total numbers of buoys (moored and drifting) reporting on the GTS in March 2012 (Source: JCOMMOPS).

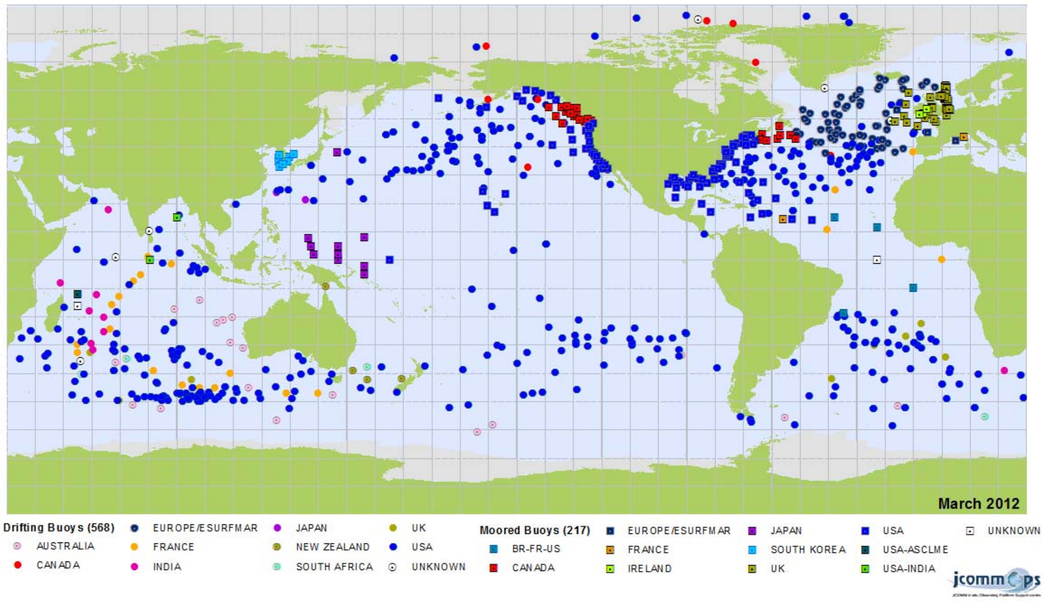


Figure 4 – DBCP barometer buoy monthly status by country for March 2012 (data buoys reporting pressure on the GTS via Météo-France – Source: JCOMMOPS).

Figure 5 shows the evolution of the Tropical Moored Buoy Array between October 1999 and April 2012. The programme has grown substantially in scope and capability since the community wide survey of ocean measurements as part of the OceanObs'99 Conference, in 1999. New challenges and opportunities exist to build on successes over the past 10 years. Most critical is the need to complete the network and maintain climate quality time series in all three ocean basins for the future. The Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) has expanded and been enhanced since 2005. The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) was initiated in the Indian Ocean (beginning in 2000) and is now about 65% complete, Flux Reference Sites were established in all three oceans (beginning in 2005) as part of OceanSITES, and additional biogeochemical measurements were added in the Pacific and Atlantic (beginning in 2003).

In general, the quality of buoy observations (moored and drifting) continues to improve, as measured by the deviation from background fields or by the numbers of observations ingested by NWP models. The quality of wind spectral data from moored buoys continues to be an area of concern, and the Panel has joined with the JCOMM Expert Team on Wind Waves and Storm Surges (ETWS) to initiate a pilot project to examine ways of making improvements in this area .

The delays between the time of an observation and its publication on the GTS continues to improve, both through the extension of the Argos regional antenna network and the increasing use of Iridium as a communications channel, stimulated in part by the DBCP Iridium Pilot Project. Nonetheless, improvements can still be made (e.g. Tropical Moored Buoy array, and in the S Atlantic and S Pacific) through: (i) connecting more Local User Terminals to the Argos System; and (ii) fixing the ongoing blind orbit issue caused by the non-optimal geographic distribution of global ground stations for the NOAA polar orbiters that carry the Argos payload.

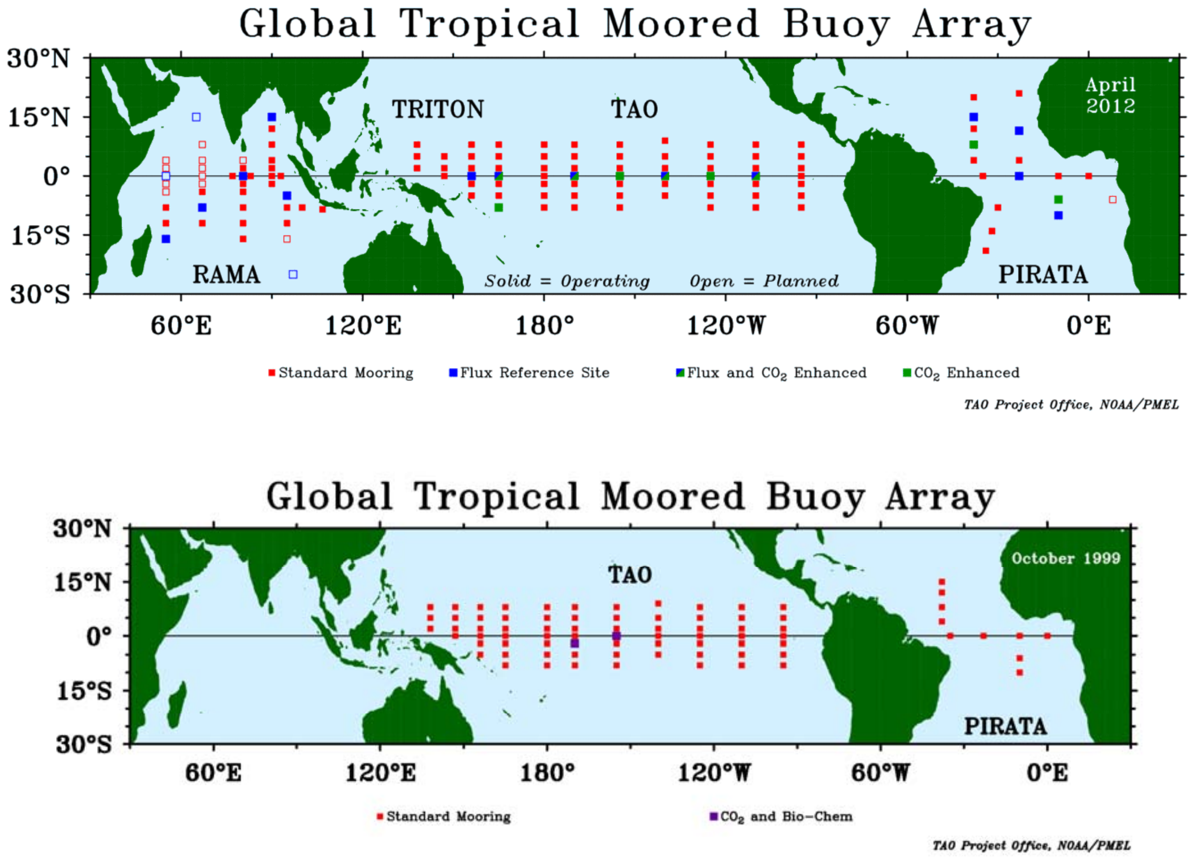


Figure 5 – The global tropical Moored Buoy Array in April 2012 (top) and October 1999 (bottom) (Source: NOAA/PMEL, USA).

3. SHIP OBSERVATIONS TEAM (SOT)

3.1 Overview of SOT activities

The Ship Observations Team (SOT) was created to build on synergies between the three Panels involved in coordinating global ship-based observing programmes: the Voluntary Observing Ship (VOS) Scheme, the Ship-Of-Opportunity Programme (SOOP), and the Automated Shipboard Aerological Programme (ASAP), with a view to an eventual possible full-integration of ship-based observing systems on commercial and research vessels.

Progress has been made to integrate the three programmes under one umbrella, although monitoring and coordination of SOT activities has been limited during the intersession period due to not having a dedicated Technical Coordinator. This situation will change in 2012 with a pilot project to combine the TC functions with activities of a “Ship Logistics Coordinator” dedicated to securing and coordinating vessels for deployment of multi-platform observing system activities.

The efforts of the SOT have resulted in a more cost-effective way of collecting observations through observing systems that are now better standardized and addressing a wide range of meteorological and oceanographic applications. Because of the ongoing commitments and the dedication from Members/Member States, a number of challenges have been successfully addressed through the SOT:

- Consideration of requirements from a wide range of users (e.g. NWP, climate applications, OOPC, marine climatology, ocean modelling, satellite validation and bias correction, GHRSST);
- Completion of the VOSClim network, and its integration into the wider VOS;

- Strong collaboration with the DBCP in supporting and benefiting from the JCOMMOPS office facilitating ship networks monitoring, the resolving of technical issues, and the use of ship opportunities for the deployment of drifters;
- Close relationships with associated programmes making ship observations such as the International Ocean Carbon Coordination Project (IOCCP), the Shipboard Automated Meteorological and Oceanographic System Project (SAMOS), the Ferrybox Project, the SeaKeepers Society, the Alliance for Coastal Technologies (ACT), and the SCOR/IAPSO OceanScope Working Group;
- Addressing ship owners and masters concerns with regard to availability of VOS information on public websites. This led to the WMO Executive Council adopting Resolution 27 (EC-LIX) authorizing Members to implement ship masking schemes. The SOT has been coordinating the different masking schemes proposed, and made sure that the user requirements could continue to be met;
- Routine collection of ship metadata through the management of WMO-No. 47, and strong collaboration with the Water Temperature metadata Pilot Project (META-T) for the delivery of ship metadata in real time via BUFR reports;
- The undertaking of Capacity Building activities, including the organization of a fourth international workshop for Port Meteorological Officers (Orlando, USA, December 2010);
- Reviewing satellite data telecommunication systems, and the testing and evaluation of Iridium for the transmission of marine/ocean observations from ships;
- Addressing instrument standards, and the conduct of e-logbook intercomparisons leading to specific recommendations being made to improve coherence and quality of the data;
- Addressing the recruitment of ships in times where the shipping industry is facing economic difficulties, where ships are changing routes, staff, and owners.

3.2 Voluntary Observing Ship (VOS) scheme

Implementation Goal	Improve number and quality of climate-relevant marine surface observations from the VOS. Improve metadata acquisition and management for as many VOS as possible through VOSClim, together with improved measurement systems.
Metric now used by OCG	Number out of a target of 250 ships in the VOSClim Fleet (proposed future metric of 25% of VOS in VOSClim Fleet), with metadata reported in WMO Pub. 47

The VOS Scheme (see http://www.bom.gov/au/jcomm/vos/) is a unique network in that does not have a target network size, primarily because it depends on the support of commercial shipping companies that are subject to commercial/financial pressures (including sale, re-routing and scuttling). The VOS Scheme consists of national VOS fleets (VOF), each of which consists of a mix of commercial, research, fishing, passenger and private vessels. VOS data support a wide range of applications, including: the analysis of weather systems and storm tracking and the provision of high quality maritime safety services; NWP and local weather forecasts; ground-truthing of satellite derived data; validating coastal and island observations; climate research, modelling and forecasts. In addition, VOS data support other industries and users including: fishing, transport, coastal engineering, search and rescue, marine pollution, offshore drilling and mining.

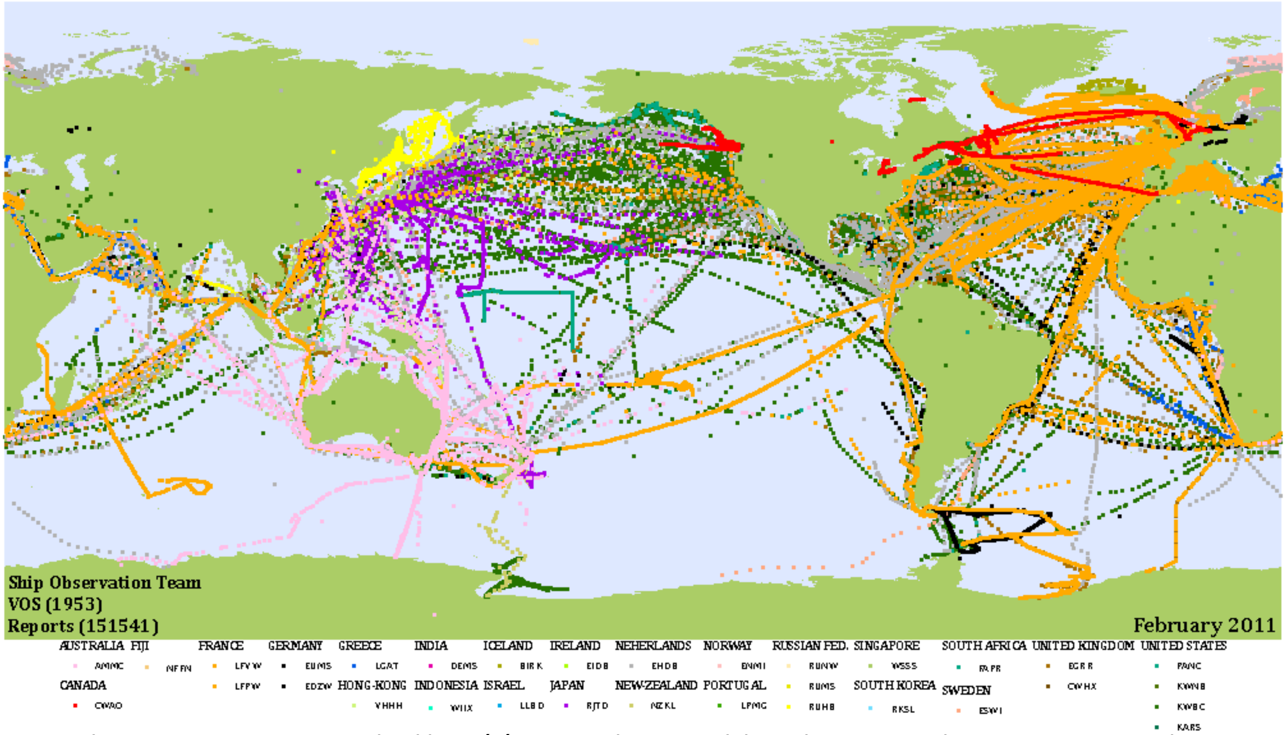


Figure 6 – VOS reports received by Météo-France by GTS origin, February 2011 (source: JCOMMOPS).

On average, in excess of 100,000 VOS reports from more than 2,000 ships are distributed on the GTS per month (see Figure 6), predominantly in the Northern Hemisphere. Delayed-mode meteorological data, i.e. observational data in an electronic logbook or the traditional paper logbook are also routinely collected as part of the Marine Climatological Summaries Scheme (MCSS) and distributed to the Global Collection Centres (GCCs) in the UK and Germany. Metadata relating to the individual ships and the installed meteorological equipment and observing program are collected by a Port Meteorological Officer (PMO) at recruitment and updated as required at subsequent inspection visits. Metadata in support of WMO-No. 47 are requested from Members/Member States every quarter.

VOSClim has evolved into the preferred meteorological class of reporting ship to maintain on ongoing network of Climate Reference Ships, with a goal of 25% of the VOS fleet achieving that status. The VOS Ancillary Pilot Project, aimed at allowing a greater number of ships to join the global VOS Scheme without some of the constraints of being part of a national VOS fleet, will continue their work with a view to add a new class of reporting vessel in the next intersessional period.

VOS Programme Managers receive monthly monitoring reports from the Regional Specialized Meteorological Centre (RSMC) in Exeter (UK), and the VOSClim Real Time Monitoring Centre (RTMC), also operated by the UK. VOS Programme Managers and PMOs can also perform near real-time monitoring of their ships with the VOS Monitoring Tools provided on the Météo-France website.

The global VOS is underpinned by the international PMO network, which plays a crucial role in ship recruiting, training of observing staff and calibration of the instruments. Fixed budgets and increasing costs are affecting the ability of some Members/Member States to maintain adequate levels of serviceable equipment. To address these challenges, the fourth PMO workshop launched two initiatives: i) the PMO Buddy Programme to match experienced PMOs with less experienced ones to share practical knowledge; and ii) the VOS Donation Programme to install a buoy on the deck of a ship to act as an autonomous self-contained AWS for countries wanting to start VOS activities.

3.3 Ship of Opportunity Programme Implementation Panel (SOOPIP)

Implementation Goal	Sustain the Ship-of-Opportunity XBT/XCTD transoceanic network of 51 sections
Metric now used by OCG	Number of yearly XBT profiles taken out of 37 000 (needed to sustain the network), as reported on the GTS

The Ship of Opportunity Programme (SOOP) addresses both scientific and operational goals for building a sustained ocean observing system with oceanographic observations mainly from cargo ships. These observations are mainly obtained from eXpendable BathyThermographs (XBT), but also from eXpendable Conductivity Temperature Depth (XCTD), Acoustic Doppler Current Profilers (ADCP), ThermoSalinoGraphs (TSG), Continuous Plankton Recorders (CPR). Presently, only the XBT programme is based on recommendations from international and regional panels, and involves repeat sampling at more or less regular intervals along pre-determined routes (transects).

XBT operations are the main component of the SOOP. There are two modes of spatial sampling: Frequently Repeated (FR, 12-18 transects per year and 6 XBT deployments per day), and High Density (HD, 3 to 5 transects per year, 1 deployment every 10-50 km). The accomplishment and maintenance of the OceanObs'09 recommended transects (Figure 7 and Table 1) are highly dependent on funding, ship traffic, and recruitments. However, similar to the Volunteer Observing Ships (dedicated to meteorological observations), the SOOP is currently encountering problems in achieving its objectives primarily because of unforeseen ship route changes or the suspension of trade on some routes.

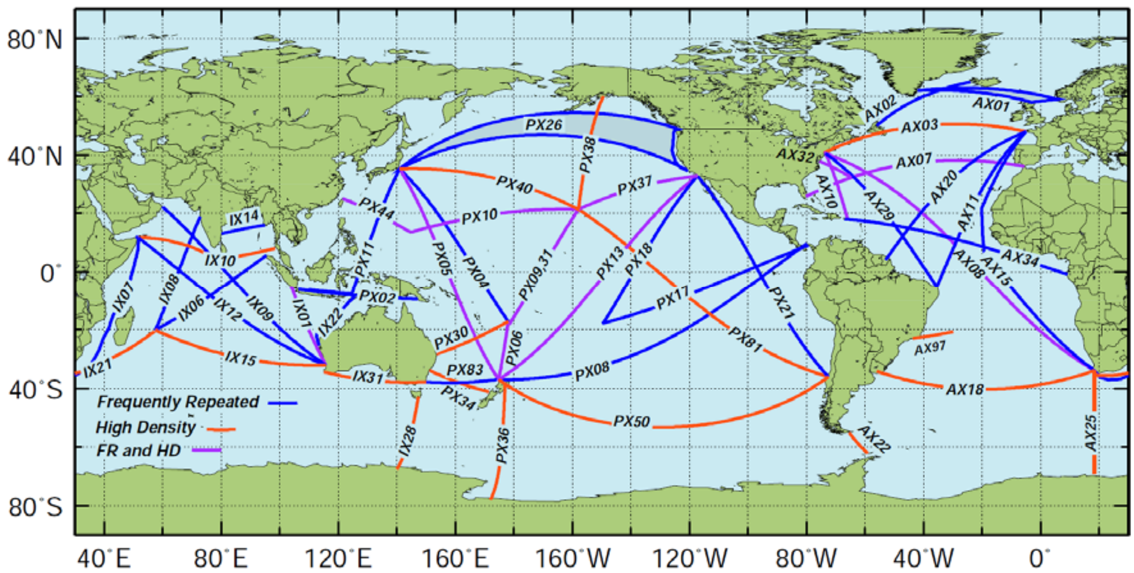


Figure 7 – Location of the High Density and Frequently Repeated XBT transects recommended by OceanObs'09 (above) and countries leading the efforts to carry out each transect (below).

SOOP addresses both scientific and operational goals for building a sustained ocean observing system. XBT observations represent approximately 25% of the upper ocean thermal observations. The main objective of XBT observations are linked specifically to the three modes of deployment. Data along fixed transects are of critical scientific value and used to (1) investigate for example intraseasonal interannual variability in the tropical ocean (Low Density mode), (2) measure seasonal and interannual variation of volume transport of major open ocean currents (Frequently Repeated Mode), and (3) measure meridional heat advection across ocean basins

(High Density mode). During the last decade the goal of XBT observations has shifted from the monitoring of the upper ocean thermal structure to investigating the variability of critical surface and subsurface currents using High Density XBT observations along repeat transects.

Transect	Agency	Status	Year
AX01	5, 1, 23	Active	
AX02	1, 3, 23	Active	
AX03	10	Active	
AX04		Active	
AX07	1	Active	1995
AX08	1, 6	Active	2000
AX10	1	Active	1997
AX11	10	Active	
AX15	5	Active	
AX18	1, 11, 6	Active	2002
AX19	1	Active	
AX20	5, 1	Active	
AX22	2, 1, 11	Active	1996
AX25	1, 6, 20	Active	2004
AX29	1		
AX32	1, 3	Active	1981
AX34			
AX97	1, 13	Active	2004

Transect	Agency	Status	Year
IX01	9, 1	Active	1987
IX02		Active	
IX06	6		
IX08	12		1992
IX09	14, 17		
IX10	14, 16, 17		
IX12	9	Active	1986
IX14	12	Active	1990
IX15	2, 4, 6	Active	1994
IX21	2, 4, 6	Active	1994
IX22	9	Active	1986
IX28	4, 2	Active	1993
IX29		Active	
IX31	2		
MX01	21, 9, 1	Active	2007
MX02	21, 9	Active	2007
MX04	21, 9, 1	Active	2007
MX05	21, 22	Active	
MX07	21, 24	Active	

Transect	Agency	Status	Year
PX02	9	Active	1983
PX04	7		
PX05	2, 16, 17, 7	Active	2009
PX06	2, 7, 1	Active	1986
PX08	2, 1	Active	2004
PX09	2, 1	Active	1987
PX10	2, 1	Active	1991
PX11	9	Active	1986
PX12	7	Active	
PX13	2, 7, 1	Active	1986
PX30	4, 2, 7	Active	1991
PX31	2, 7, 1	Active	1986
PX32	4	Active	
PX33	4	Active	
PX34	4, 2	Active	1991
PX37	2, 1	Active	1991
PX38	2	Active	1993
PX39	25	Active	
PX40	8, 17	Active	1998
PX44	2, 1	Active	1991
PX45	8, 16	Active	
PX46	16		
PX50	18, 2		1993
PX53	9		
PX81	2		1997

Agency key

1 USA-AOML
2 USA-SIO
3 USA-NMFS
4 AUS-CSIRO
5 FRA-IRD/BREST
6 ZAF-UCT
7 FRA-IRD/NOUMEA
8 JPN-TOHOKU-U
9 AUS-BOM
10 GER-BSH
11 ARG-SHN
12 IND-NIO
13 BRA-FURG
14 UK-UKMO
15 IND
16 JPN-JMA
17 JPN-JAMSTEC
18 NZL-MSNZ
19 JPN
20 UK-BAS
21 IT-ENEA
22 IT-INOGS
23 FRA-UP
24 CY–U.Cyprus
25 CAN-DFO

Table 1 - XBT transects performed by the international community during 2011, including their current status and the year in which operations on these transects started.

Approximately 22,000 XBTs are deployed every year, of which 15,000 are transmitted in real-time and ingested into operational data bases. There are approximately 40 ships participating in the XBT network. A large number of XBTs deployed by non-US agencies are the result of donations from the US (NOAA), thereby making the operation highly dependent on the continuing support of one single institution. International collaboration is key to the success to the implementation of the XBT network, where the operations are related to ship recruiting, deployment of probes, data transmission, data quality control, and archiving.

There are approximately 30 ships transmitting TSG data, most of which are operated by French institutions and by the US/NOAA research and SOOP fleet.

Web tools to monitor real-time data flow from XBTs (http://www.aoml.noaa.gov/phod/GTS/XBT/) and TSG (http://www.aoml.noaa.gov/phod/GTS/TSG/) into the GTS have been developed. Other sites, such as http://goos142.amverseas.noaa.gov/db/xbtplotapp.html permit the monitoring of SEAS transmissions into the GTS. These tools are routinely used to monitor and track the deployment of XBTs and of TSG observations.

4. GLOBAL SEA LEVEL OBSERVING SYSTEM (GLOSS)

Implementation Goal	Implement the GLOSS Core Network of about 300 tide gauges, with geocentrically-located high-accuracy gauges; ensure continuous acquisition, real-time exchange and archiving of high-frequency data
Metric now used by OCG	Number out of 300 real-time data-transmitting tide gauges in the GLOSS Core Network, as reported at the data archive

The GLOSS GE-XI in 2009 marked the 25th anniversary of the Global Sea Level Observing System (GLOSS). GLOSS has expanded beyond the original aim of providing tide gauge data for understanding the recent history of global sea level rise and for studies of interannual to multi-decadal variability. Tide gauges are now playing a greater role in regional tsunami warning systems and for operational storm surge monitoring. The GLOSS tide gauge network is also important for the ongoing calibration and validation of satellite altimeter time series, and as such is an essential observing component for assessing global sea level change.

Significant milestones for the programme are as follows:

- A Waves & Water Level workshop was held in Paris as part the GLOSS GE-XII (November 2011) to try and build stronger ties between GLOSS and surge and wave community.
- GLOSS has advocated a digitization program for data recovery of historic tide charts.
- The status of the GLOSS Core networks will be made more transparent to outside users, and this will serve as a *de facto* metric for the health of the program.
- The quality control manual for sea level data was completed for GLOSS GE XII meeting and will be published in 2012.
- IOC/GLOSS hosted the WCRP workshop “Understanding Sea Level Rise and Variability” (6-9 June 2006. The proceeding/book from that workshop was published in June 2010 and has been widely cited. A follow on workshop WCRP/IOC Workshop on Regional Sea Level Change was convened from 7 - 9 February 2011 at IOC (Report available http://www.ioc-cd.org/index.php?option=com_oe&task=viewDocumentRecord&docID=7252).
- The IOC Manual on Sea Level Measurement and Interpretation has been translated to Arabic and will be published in 2012.

An update of the GLOSS Implementation Plan has been completed. The plan will provide a blueprint for the next 5 years. Some of the aims of the plan are:

- Expand the number of continuous GPS stations co-located with sea level stations in the GLOSS Core Network
- All sea level stations in the GLOSS Core Network to report data in near real time
- Monitoring in support of water level hazards (e.g., tsunamis, storm surge)
- Improved database capabilities

The number of sea level stations reporting to the GLOSS Data Centres has increased markedly over past last ten years, particularly for stations that report in near real-time (see Figure 8). Just over 75% of the GLOSS Core Network (GCN) of 293 stations can be considered operational, and there are focused efforts to address the remaining 25% of stations not currently on-line. Since that GLOSS has adopted a common metadata standard (GLOSS Data Centers meeting, Honolulu 2010), and is in the process of implementing across all data centers. The next steps are to adopt common services for distributing the data.

The current goal is to improve data integration for the benefit of end users. Towards this end GLOSS work will include:

- Development of a single source for obtaining data from all GLOSS data suppliers.
- Development of a metadata rich format to help users to better understand the data.
- Use of netCDF "aggregation" techniques to allow users to side-step handling many files.
- Insuring that data can be used by more communities, for more purposes.
- Insuring that data will be more readily found through popular search portals.

GLOSS contributes actively in the development of tsunami warning systems in the Pacific and Indian Oceans, and in the Mediterranean and the Caribbean. Following the 2004 Indian Ocean Tsunami, more than 50 GLOSS stations in the Indian Ocean were upgraded to real time data reporting. Several Indian Ocean countries further densified their national sea level networks (India, Indonesia, Kenya, Maldives and Mauritius). GLOSS is working to develop the sea level networks in the Caribbean and North Africa. Progress is slower here due to a lack of funding.

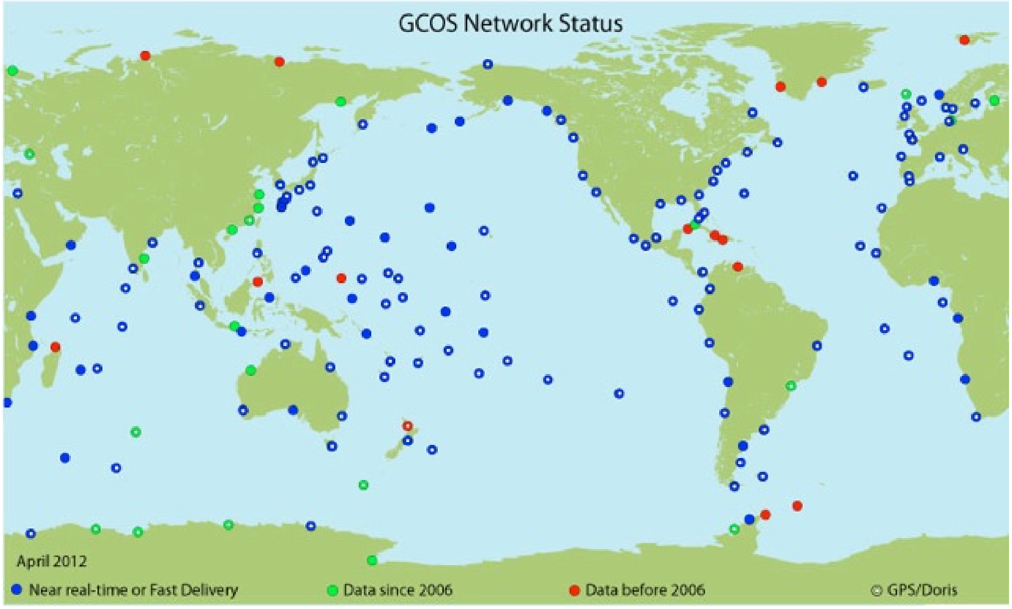


Figure 8 – Configuration of the GLOSS/GCOS Core Network. There have been important improvements in the number of tide gauges reporting high-frequency data in near real-time (typically within 1 hour), although challenges remain.

Some additional highlights of progress during the last interessessional period:

- GLOSS has participated and contributed to the report from the Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG): Inter-ICG Task Team 1 on Sea Level Monitoring for Tsunami (http://unesdoc.unesco.org/images/0019/001939/193911e.pdf)
- IOC/GLOSS has organized sea level network maintenance in the Indian Ocean Tsunami Warning System through contract with University of Hawaii Sea Level Center (2009-2011).
- GLOSS has also participated in several tsunami related proposals that have had a sea level component (i.e., ESCAP proposal for Comoros, Tanzania and Mozambique). GLOSS also participates in projects under the IOC/IOCARIBE-EWS to enhance sea level networks in the Caribbean.
- India now provides real time sea level data from a number of GLOSS Core Network stations in support of tsunami monitoring.
- The IOC Sea Level Station Monitoring Facility web service has been widely used by the tsunami community. For example, during the 11 March 2011 Japan tsunami the web site

received 2,901,945 web hits (about 65 times more than a normal day). High hit rates were also encountered during the 2010 Chile tsunami.

GLOSS has sought to define land motion at tide gauges through collaborations with IGS (originally the International GPS Service for Geodynamics, now the International GNSS Service) and the TIGA project (Tide Gauge Benchmark Monitoring Project). GPS and DORIS (Doppler Orbitography Integrated by Satellite) measurements at tide gauges are expected to increase in the coming years through specific initiatives and by the continued overall growth of the ITRF (International Terrestrial Reference Frame). TIGA provides an important linkage of the tide gauge and geodetic communities in this effort. Results from a status survey on co-located tide gauges and continuous GPS stations are available at http://www.sonel.org/-CGPS-TG-Survey-.html. In connection with the eleventh session of the GLOSS Group of Experts (GLOSS-GE-XI, May 2009), a Workshop on Precision Observations of Vertical Land Motion at Tide Gauges was convened. The aim of the workshop was to develop a coordinated plan for a new initiative to install and upgrade continuous GPS stations co-located with critical sea level stations in the GLOSS Core Network and Long-term Time series (LTT) networks. Detailed information is available at http://ioc-goos.org/glossgexi.

The GLOSS programme has benefited recently by the collaboration of the UNESCO/IOC and the Flanders Marine Institute (VLIZ, Kingdom of Belgium) to develop the earlier mentioned web-based global sea level station monitoring service (see http://www.ioc-sealevelmonitoring.org). The web portal provides a view of the GLOSS and other sea level datasets received in real time from different network operators and different communication channels. The service provides information about the operational status of real time sea level stations as well as a display service for quick inspection of the raw data stream. The number of real time sea level stations that the IOC Sea Level Station Monitoring Facility tracks has grown from about 320 stations (1 Jan 2010) to 468 stations (31 Dec 2011).

The GLOSS programme continues to support training and technical advisory activities carried out with national tide gauge agencies and partner programmes including the regional tsunami warning systems.

Some activities include:

- Training organized for one Nigerian scientist at UK National Oceanography Center
- Tide gauge equipment provided for Comoros, Pakistan, Haiti, Nigeria, Mozambique, Iran.
- Technical maintenance missions were organized to Takoradi (Ghana), Nouakchott (Mauritania), Djibouti and Mozambique.
- Technical missions to Oman and Caribbean have been carried out to provide advice on network development and in preparation of installations/upgrades of national/regional sea level networks in 2012/2013.
- A one week training course was organized for hydrographers from Pakistan at the National German Research Centre for Earth Sciences (June 2010). A GLOSS Sea Level training course was also organized for Caribbean sea level station operators (January 2011).

5. OVERVIEW ACTIVITIES - ASSOCIATED PROGRAMMES

5.1 Argo profiling float programme

Implementation Goal	Sustain the global 3x3 degree network of 3000 Argo profiling floats responding to its core mission, reseeding the network with replacement floats to fill gaps, and maintain density (about 800 per year)
Metric now used by OCG	Number out of 3000 Argo floats reporting in real time, on the GTS

Argo is a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. This allows, for the first time, continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours after collection. Currently, over 3300 Argo floats are operating globally (Figure 9). Special care is being taken to rate float deployments based on various factors like float density or probability to survive (Argo Information Centre tools and services). In addition to planning where to deploy floats, it can be difficult to find ships and coordinate float deployments. The Argo TC has created a mailing list to help circulate cruise information more quickly to scientists who have floats they need to deploy (ships@jcommops.org). The Argo TC has also helped in recruiting the *Lady Amber*, a 20 m sailing vessel, which can be chartered to deploy Argo floats anywhere in the world ocean excluding high piracy zones. The *Lady Amber* has already completed several successful cruise across the Indian Ocean to deploy floats, and is planning additional cruises, perhaps with other platforms also being deployed.

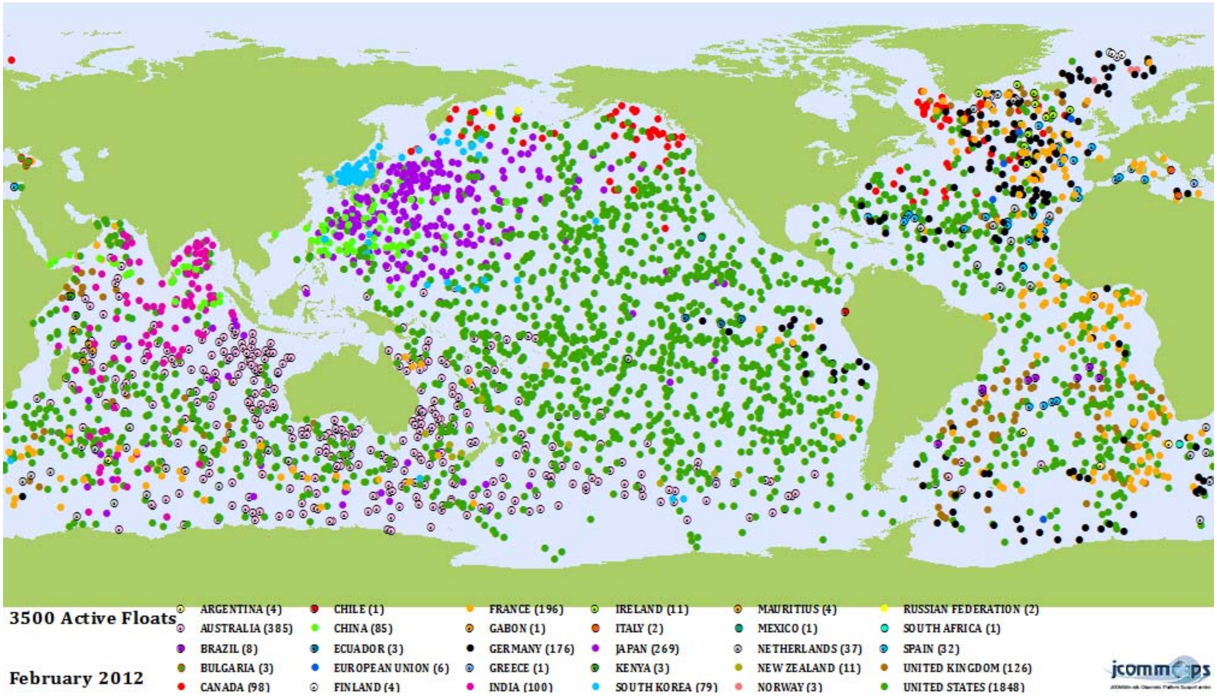


Figure 9 - Twelve nations maintain the global array and twenty more fill regional gaps

Almost 90% of Argo profile data are available to users within 24 hours of a profile being made. In the past year, work was done at the GDACs to reduce delays for data from some of the DACs. The real-time data are subject to similar integrity and quality checks as the real-time XBT data stream. However, some salinity sensors drift with time due to biological fouling and physical deformation. The backlog of data needing these delayed mode corrections has been reduced. Currently, 79% of floats needing to be put through the delayed mode quality control process have been completed. This number is up from last year's 63% and is getting close to being up to date. More work still needs to be done to try and reduce the small backlog of floats left. Many of the floats left are difficult as they are either older and thus lacking detailed information about sensors, or are deployed by countries into areas of the ocean where the scientists do not have as much expertise, making it difficult to quality control the floats. These issues are being addressed by the Argo Data Management Team. As it is important to carefully review files in a timely manner, an additional quality control check that compares sea level anomalies from satellite altimetry to dynamic height anomalies from Argo floats is done by S. Guinehut four times a year. This additional quality control check helps scientists identify potential problematic floats even before delayed mode quality control can be done. Other such methods are under development to help detect large scale problems with the float data.

Float technology is an important part of the Argo array and there have been significant developments over the past year to float technology. In 2010, 18% of floats deployed were equipped with Iridium communications. It is expected that this number will continue to grow as more floats switch over to Iridium or other high bandwidth communication systems. Iridium allows for more data to be sent in less time. Both the SOLO and the PROVOR have new generation floats available. The SOLO-II is smaller, more efficient and uses Iridium communications. About 60 SOLO-II floats are expected to be deployed this year. ARVOR floats are also smaller and more efficient than their PROVOR predecesser, but come with ARGOS communications. Currently both Iridium and Argos-3 outfitted ARVOR floats are under development. Additionally, the Deep NINJA float is being developed to profile to at least 3000m. Besides deep profiling, new sensors are being piloted on Argo floats.

Following direction from OceanObs'09, Argo is exploring how to expand to new sensor types and to new areas of float coverage, both on the surface and below. With the addition of two-way communications, Argo is also analyzing changing sampling schemes after deployment. Several individuals or groups within or associated with Argo have agreed to explore various options including expanding to the seasonal ice-zone, changing the near surface temperature sampling scheme, making floats capable of a deeper range, and establishing a more uniform method of sampling for Iridium floats. Even with the increased number of delayed mode profiles available, Argo still continues to focus on improving the quality and timeliness of both real-time and delayed-mode data. Analysis continues to be done on the effects of the pressure bias within Argo with the goal of recovering as much data as possible.

Demonstrating the value of Argo data remains a high priority of the Argo program. With a global array in place since 2004, researchers are able to use Argo data to investigate global and regional phenomena, with over 100 papers published using Argo data in 2011 already. The broad range of research topics includes water mass properties and formation, air-sea interaction, ocean circulation, mesoscale eddies, ocean dynamics, and intra-seasonal to multi-decadal variability. Secondly, Argo is the core subsurface dataset for ocean data assimilation modeling, used by modeling centers around the world in ocean reanalyses and for initializing seasonal-to-decadal prediction. (See http://www-argo.ucsd.edu for links to all operational centers known to be using Argo data). Already, operational centers including NCEP, ECMWF, and the U.K. Met Office are reporting improvement in their products due to the impact of Argo data. Additionally, Argo recently developed a Google Ocean layer which includes data for each float, stories on a smaller subset of floats, an animation showing the cycle of an Argo float and property plots overlaid onto the globe showing various properties from Argo data. The use of Argo in secondary and tertiary education is growing rapidly, as students anywhere in the world can now explore the global oceans from their desktop.

5.2 OCEAN Sustained Interdisciplinary Timeseries Environment Observation System (OceanSITES)

Implementation Goal	Complete and maintain a globally-distributed network of 30-40 surface moorings as part of the OceanSITES Reference Mooring Network
Metric now used by OCG	Number of platforms reporting in the year in the NDBC or Coriolis OceanSITES GDAC [baseline requires further definition].

OceanSITES is the research-driven international project working towards the coordination and implementation of a global system of sustained multi-disciplinary timeseries observatories. Operational applications of such data include detection of events, initialization and validation of assimilation products, delivery of constraints or reference data for forecasts (especially biogeochemical and ecosystem relevant ones). In addition, there are a variety of technical applications, such as calibration and validation of data and products from other observing system elements.

The focus of OceanSITES is on sustained, Eulerian time series with high temporal resolution was reaffirmed by the group. Long-term goals remain to secure sustained support, upgrade existing stations to multidisciplinary sampling, install new stations in key unsampled regions, and make the data rapidly available to the scientific community and the public. OceanSITES will begin to develop metrics for the completion and effectiveness of the network, working with diverse groups that use the data, such as the operational weather forecasting and modeling centers and the IPCC teams.

To demonstrate the value of OceanSITES, each site will develop key products, with attention to potentially key or iconic results. The Scientific Steering Team will then look for the next level of products; those that draw from more than one site and demonstrate the additional impact of the array. OceanSITES will also seek to facilitate addition of new sensors and defining best practices that can be shared across existing and potential new site operators.

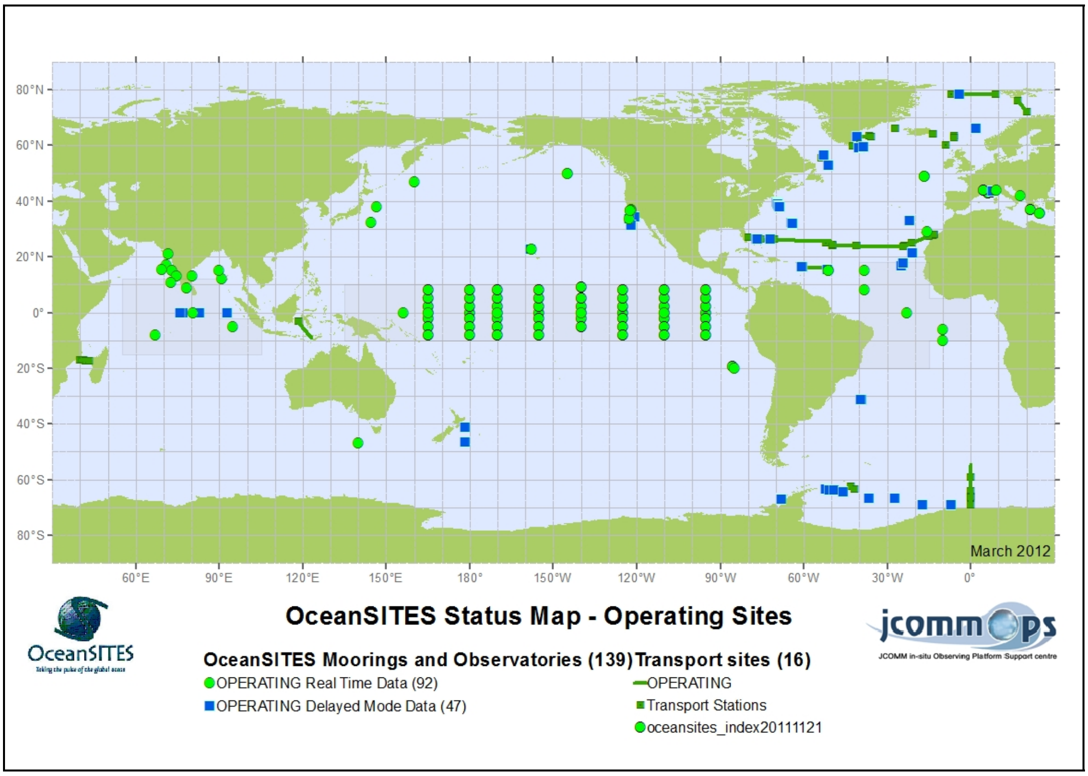


Figure 10 - The present status of OceanSITES summarized in this new map, with an updated table of OceanSITES located http://www.oceansites.org/network/index.html.

OceanSITES has set two near-term objectives. First, it advocates the establishment of a core, backbone network with homogeneous, multidisciplinary instrumentation (see Figure X). Second, in response to a need identified at OOPC Deep Ocean Observing Strategy Workshop (Paris March 2011), OceanSITES is moving to deploy deep (deeper than 2,000 metre) temperature/salinity recorders at as many sites as possible.

The OceanSITES data system uses a common NetCDF Data Format, and provides (http://www.oceansites.org/data/index.html) a user manual, a sample data set, and cdl file to the community. OceanSITES operators are provided assistance if needed and a format tester to facilitate preparation in the NetCDF formatted data. Each operator is aligned with or serves as a DAC (Data Assembly Center) to see that the data is formatted correctly; IFREMER Corilois and NDBC serve as mirrored GDACs (Global Data Assembly Centers) to collect data from the DACS and serve data to users. The OceanSITES Data Team works to identify the correct CDF variables names and metadata, and as the sites increasingly carry more multidisciplinary sensors, the effort is expanding the CDF variable name lexicon to be used with time series stations.

As a basically volunteer aggregation of observatory operators, OceanSITES has embarked on improving documentation and sharing of best practices. Further, OceanSITES is discussing the best way forward for new sensors to be deployed across the array, especially in the case where a given operator may lack expertise in that sensor. OceanSITES is considering a mentoring program, where best practices and capacity building for special sensor types would be provided by the experienced users to new users. This could be expanded to other areas of sustained time series technologies.

Moving forward OceanSITES will focus on a number of issues: i) demonstrating the value of sustained time series and of a coordinated network of sustained time series stations; ii) continuing the success of the collection and free and open distribution of data thus far achieved by OceanSITES with the support of IFREMER Coriolis (France) and NDBC (USA) ; iii) developing a subset of the OceanSITES equipped with deep temperature/salinity sensors to answer the need for that data from depths greater than 2,000 metres; iv) developing a backbone subset of OceanSITES with common multidisciplinary sensors; and v) pressing for documentation and sharing of best practices for observatory operators, over topics ranging from data formats and metadata to instrument calibration and deployment. OceanSITES will be working on improved website material, asking each operator to provide select high impact results.

5.3 International Ocean Carbon Coordination Project (IOCCP) and the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP)

Implementation Goal	• Implement a systematic global full-depth water column sampling through repeat hydrography for ocean physical and carbon variables in a decadal survey • Implement and sustain a global network of surface carbon flux observations (through VOS and research ships) and carbon time series stations (see also OceanSITES)
Metric now used by OCG	• Number of repeat hydrographic sections in the decadal survey submitted to data archive [baseline requires further definition: proposed rolling index of ship days secured to maintain repeat hydrography lines] • No metric has been set for surface carbon flux or carbon timeseries observations

The IOCCP promotes the development of a global network of ocean carbon observations for research through technical coordination and communications services, international agreements on standards and methods, and advocacy and links to the global observing systems. The IOCCP is co-sponsored by IOC and the Scientific Committee on Oceanic Research (SCOR).

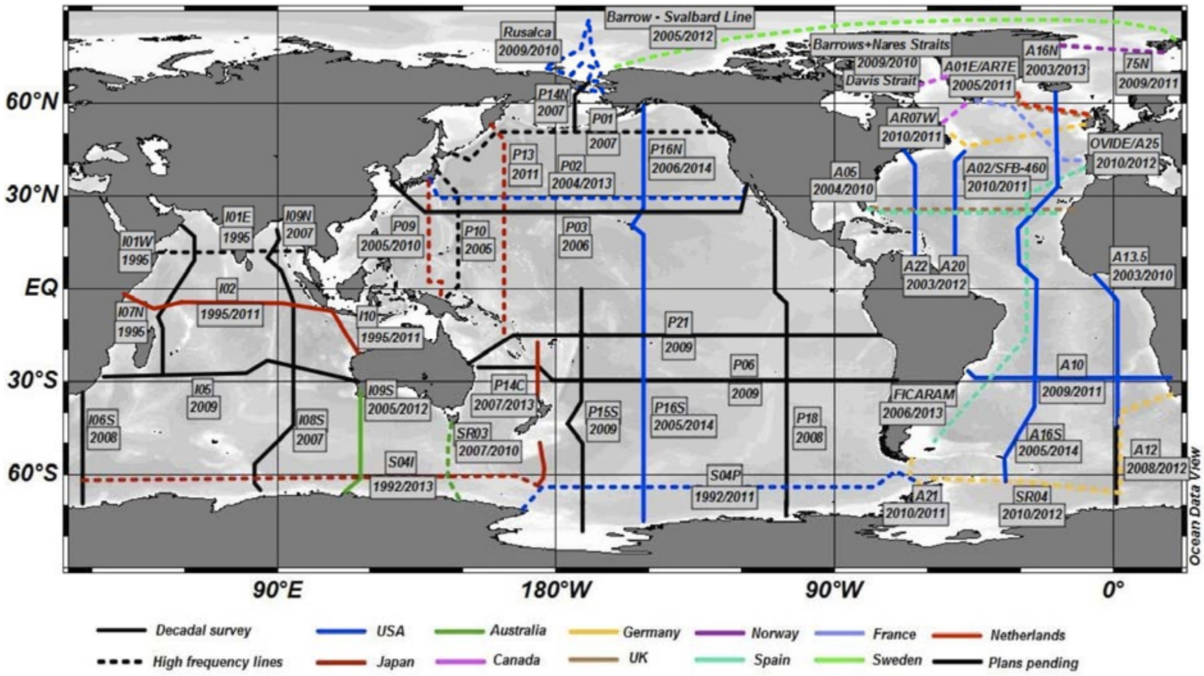


Figure 11 - The status and plans of repeat hydrographic sections coordinated by IOCCP and GO-SHIP in late 2011.

The IOCCP continues to coordinate a highly diverse set of activities to facilitate the development of globally acceptable strategies, methodologies, practices and standards, homogenizing efforts of the research community and scientific advisory groups as well as integrating ocean carbon programs and activities into globally integrated Earth system observing networks. Coordination and communication activities of IOCCP relate to hydrographic survey cruises, development of a global network of surface ocean carbon observations and time-series observations. IOCCP is also actively involved in helping to develop international agreements on standards and methods, such as the recently completed GO-SHIP: Repeat Hydrography Manual and the Guide to Best Practices for Ocean CO_2 Measurements, and facilitates data collection, management and data synthesis activities.

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, will be developed. In addition, the IOCCP will continue collaboration with the World Ocean Council, a high-profile advocacy group aiming at improving ocean understanding through the involvement of ocean user industries (e.g., shipping, oil and gas, fisheries, tourism) in ocean observations. The IOCCP will take an active role in designing the Industry - Global Ocean Observing and Data System (I-GOODS). This system, based on experience of IOCCP and other global ocean observing networks, would be designed to incorporate opportunities from various industries into scientific efforts and would allow synergies between ocean users' industries, technology industry and key national, regional and global ocean observing coordinators.

There is growing momentum around the concept of “Blue Carbon” as a key component of climate change mitigation options. Blue Carbon is a new concept describing the carbon storage and sequestration potential of coastal (‘blue’) ecosystems, namely, mangroves, sea grasses, and salt marshes, although other coastal and marine ecosystems might also be of interest. Clear demonstration of the carbon storage and sequestration services provided by coastal ecosystems may transform the effectiveness of conservation, management, and restoration of coastal ecosystems. A fundamental barrier to this is a global lack of consistent, reliable, and interoperable spatial datasets of ecosystem extent, and carbon stock and flux, that are available at the required spatial and temporal resolutions and readily accessible by a range of communities around the globe. Blue carbon ecosystems constitute an interface between the ocean and the land, an area

often disregarded by both marine and terrestrial carbon communities. The IOCCP with its extensive experience in facilitating data collection, management and data product development is well placed to support evolving efforts, to generate the technologies, networks, and partnerships required to increase the availability of key coastal carbon data.
Following the public release of Surface Ocean CO_2 Atlas (SOCAT) version 1.5 in 2011, SOCAT 2 has a tentative release in late 2012. 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 will be coordinated over the next 12 months. 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.

The IOCCP will continue to serve as a resource for the ocean carbon hydrography through collaboration with the Carbon Dioxide Analysis Center (CDIAC) at the US Oak Ridge National Laboratory. Resources provided will include information on cruise plans, continuously updated cruise maps and reference section tables including measurement being made at each location.

The IOCCP will further develop its relationship with OceanSITES and the ocean carbon and biogeochemistry community to better understand the needs of the community and support improved coordination of time-series observations. One of the primary activities will be for IOCCP and OceanSITES to develop a guide to best practices and instrument user guide for carbon data and to develop consistent terminology based on SeaDataNet vocabulary. The overarching objective is to incorporate carbon and biogeochemical data into OceanSITES.

Ocean acidification is an emerging issue that requires more research and monitoring efforts. The 4^{th} Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that ocean acidification has the potential for major impacts in coastal areas. Wind-driven, seasonal upwelling of subsurface waters in coastal margins brings CO_2-enriched waters onto the shelf and, in some instances, into the surface ocean. This water contains a high level of CO_2 resulting from natural respiration processes in the subsurface layers and is also significantly contaminated with anthropogenic CO_2. Some of the world's most productive fisheries are located within coastal zones. As a result impacts on marine food webs caused by ocean acidification could be more severe than previously anticipated. The IOCCP plans to organize (with a set of international partners) a workshop focused on increasing observations of the carbonate system in coastal waters to better monitor its seasonal and interannual variability in order to mitigate ocean acidification impacts on coastal ecosystems.

6. PERFORMANCE METRICS

Observing System Status reports are developed and used to monitor progress and evaluate the effectiveness of the system for observing ECVs (see Figure 12). A major goal of the OCG workplan for the next intersessional period will be to work with the Ocean Observation Panel for Climate (OOPC) on metrics for ECVs.

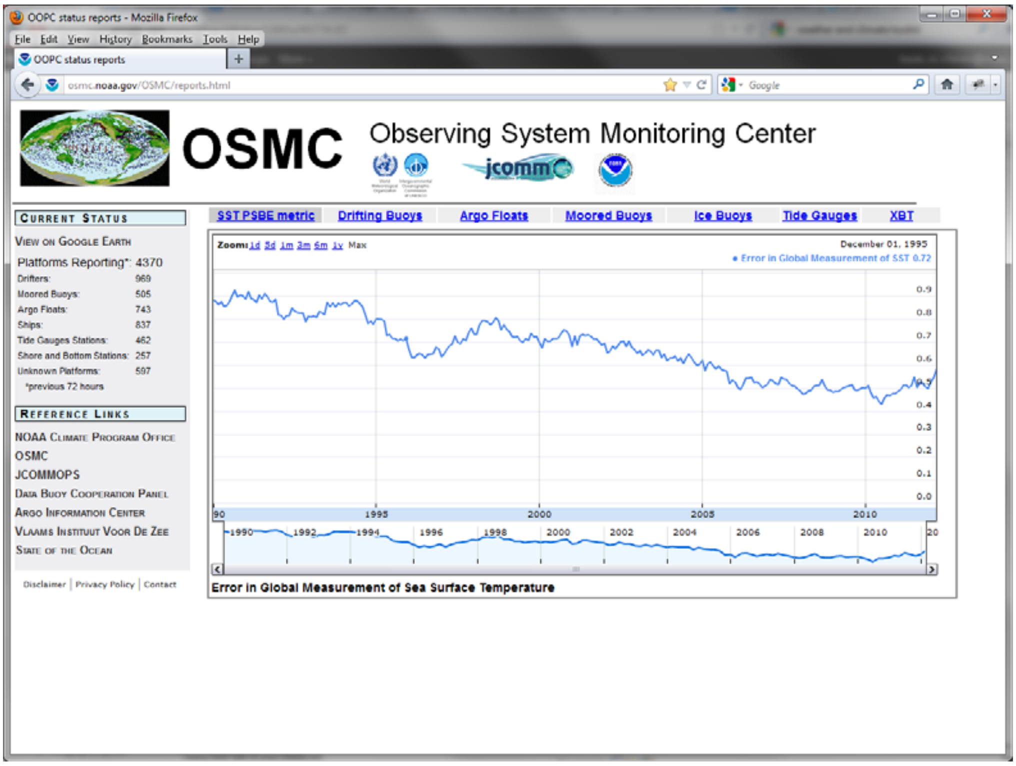


Figure 12 – The SST metric reports error in global sea surface temperature

7. OPA INTERACTIONS WITH OTHER OBSERVING COMMUNITIES

7.1 Interactions with the Satellite observing community: the DBCP-GHRSST pilot project

Over the last few years the DBCP has turned some of its attention to a number of pilot projects, with the aim of evaluating new technologies that might in due course transition to operational use. It has also tried to strengthen its links with other observing system groups, from both the *in situ* and remote sensing communities. In the particular case of the satellite SST community, the DBCP has engaged with the Group for High Resolution SST (GHRSST) to fully understand the needs for high resolution *in situ* SST, on which the community depends for its satellite SST retrieval validations, and has worked with GHRSST in helping to equip the future drifting buoy fleet with sensors that meet its requirements. Initial practical steps have been taken by Météo France over the past 24 months within the context of the DBCP-GHRSST Pilot Project to equip a fleet of drifters with HRSST-1 sensors. These now routinely report on the GTS in near real time. More recently, the UK Met Office has taken delivery of a number of HRSST-2 drifters, partially funded by the DBCP. These incorporate a more advanced HRSST sensor module, and are due to be deployed in the tropical north Atlantic in the first half of 2012. The joint pilot project will come to an end in 18 months, and moves will soon have to be made to evaluate its success or otherwise, and to develop proposals for follow-on activities if deemed worthwhile. In this context, early involvement with the calibration/validation team for the ESA Sentinel-3 satellites, the first of which is due to be launched in 2014, has highlighted the synergies that will flow from much stronger collaboration between the two communities

7.2 Interactions with the International Telecommunication Union and the submarine cable community

Guided by recent resolutions from its governing body, the International Telecommunication Union (ITU) convened a workshop (Rome, September 2011) to draw together intergovernmental bodies, scientists and cable operators to investigate the potential of submarine telecommunication cables for climate monitoring and disaster warning. JCOMM interests were promoted by delegates from both the IOC and WMO. In particular, the high potential value of future cables in supplementing the existing vandal-prone tsunameter network was well appreciated, alongside the possibility of using cables to monitor temperature changes in the deep ocean. A task team is being established under joint ITU-IOC-WMO sponsorship to progress towards a pilot project

8. TECHNICAL COORDINATION AND MONITORING (JCOMMOPS)

The JCOMM in situ Observing Programme Support Centre (JCOMMOPS) provides technical coordination across the OPA observing networks, following the direction of the DBCP, SOT, Argo Steering Team, and the OceanSITES program (see http://jcommops.org). The third session of JCOMM reinforced the role of JCOMMOPS in to promote an integrated framework for deployment and further development of ocean observing networks. Specifically, JCOMMOPS shall:

(a) Act as a focal point for implementation and coordination of observing programmes by clarifying and assisting in resolving technical issues between platform operators, data centres, manufacturers and satellite data telecommunication providers;

(b) Assist in demonstrating the scientific value of global ocean observing programmes in support of WMO and UNESCO/IOC Programmes and co-sponsored Programmes by compiling materials and assisting ocean observation science teams as appropriate;

(c) Maintain information on relevant observational requirements in support of the Global Ocean Observing System, the Global Climate Observing System and the World Weather Watch as provided by the appropriate international scientific panels, JCOMM experts participating in the Commission for Basic Systems Expert Team on Satellite Utilization and Products, and other JCOMM Expert Teams and groups;

(d) Routinely collect and distribute information on: (i) the performance of the observing system networks relative to requirements, in cooperation with the Observing System Monitoring Centre; (ii) instrumentation and telecommunication systems; and (iii) functional status and data quality of individual observing platforms;

(e) Act as a focal point for instrument and data management standardization by collecting and distributing information on current and best practices from across all elements of the observing system and by representing the observing system interest in international standardization processes;

(f) Facilitate free and unrestricted data and metadata exchange in real time, by providing appropriate technical assistance to platform operators, and serving as a collection and distribution point for select platform/instrument metadata and as a source of information on other metadata and data distribution services;

(g) Facilitate the flow of data and metadata to the archiving centres;

(h) Provide a gateway for information on observing platform deployment plans and servicing opportunities, and on operator contact information, to maximize deployment opportunities and sharing of resources;

(i) Encourage cooperation between communities, observing programmes and Members/ Member States to develop synergies between and to promote the observing systems.

JCOMMOPS has been successful in providing rigorous monitoring of the networks; improving day to day assistance; providing a key focal point to oceanographers and marine meteorologists worldwide; and encouraging cooperation with developing countries (e.g., through platform donor programmes and training workshops). JCOMMOPS is funded through national contributions from Members/Member States; however JCOMMOPS requires a more stable financial base to strengthen the integration of the observing system. The Observing Panels supporting JCOMMOPS will keep seeking new and broadened contributions to sustain the existing level of support. In addition, the ability of JCOMMOPS to extend technical coordination to support other observing networks, such as gliders, is possible only with increased financial resources. The OCG will continue to work in concert with the individual panels, and to provide overall guidance of the JCOMMOPS workplan and budget.

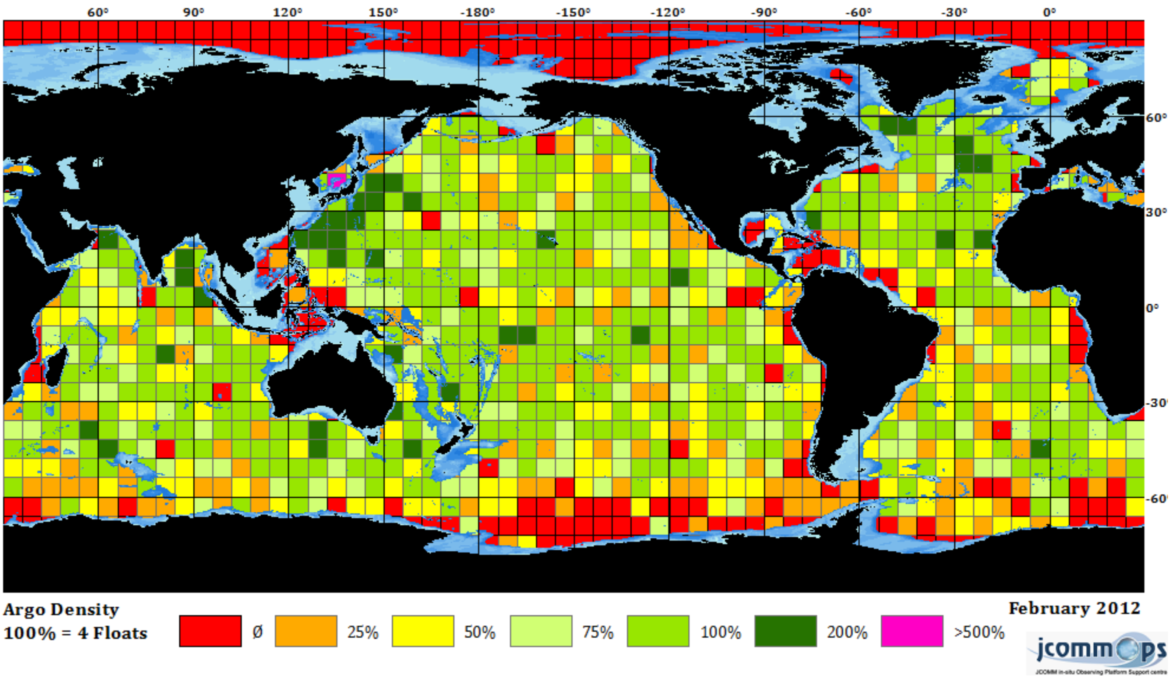


Figure 13 – Argo Network Density on a 6°x6° grid normalized on the 3°x3° Argo standard (100% means here 4 floats operating in a box).

JCOMMOPS and the OCG have developed standard base maps showing required global coverage against what is presently in place to evaluate observing system status and effectiveness; and to develop summary reports illustrating how advancements toward global coverage improve the adequacy of the observation information (see Figure 13).

JCOMMOPS and OCG have identified resources to support a two-year pilot project for a "Ship Logistics Coordinator" to be the international focal point for ship logistics for the implementation of global observing networks. All the observing programmes would benefit from this technical coordination, and Members/Members States are urged to support this effort.

JCOMMOPS has already reported success in this area with its innovative work with the South African education sailing ship, *Lady Amber*, to deploy Argo floats in parts of the Southern Indian Ocean in areas otherwise seldom visited by research or cargo vessels (Figure 14). The *Lady Amber* has operated for one year in the Indian Ocean with direct support from Argo Australia and under IOC and JCOMM sponsorship. A similar capacity is available in the Atlantic Ocean (France to West Africa) via a partnership established with "Voile Sans Frontières". The Commission charged the OCG and JCOMMOPS to pursue this innovative approach to deployment challenges, especially in ship-sparse areas, and noted the operational, educational and promotional opportunities.

Figure 14 – JCOMMOPS innovation has successfully enlisted the Lady Amber to deploy Argo floats in parts of the Southern Indian Ocean in areas otherwise seldom visited by research or cargo vessels.

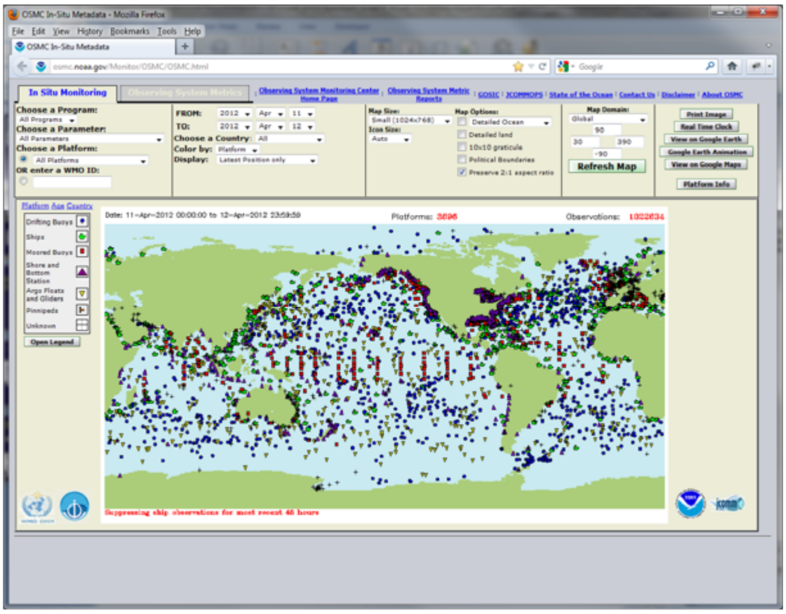
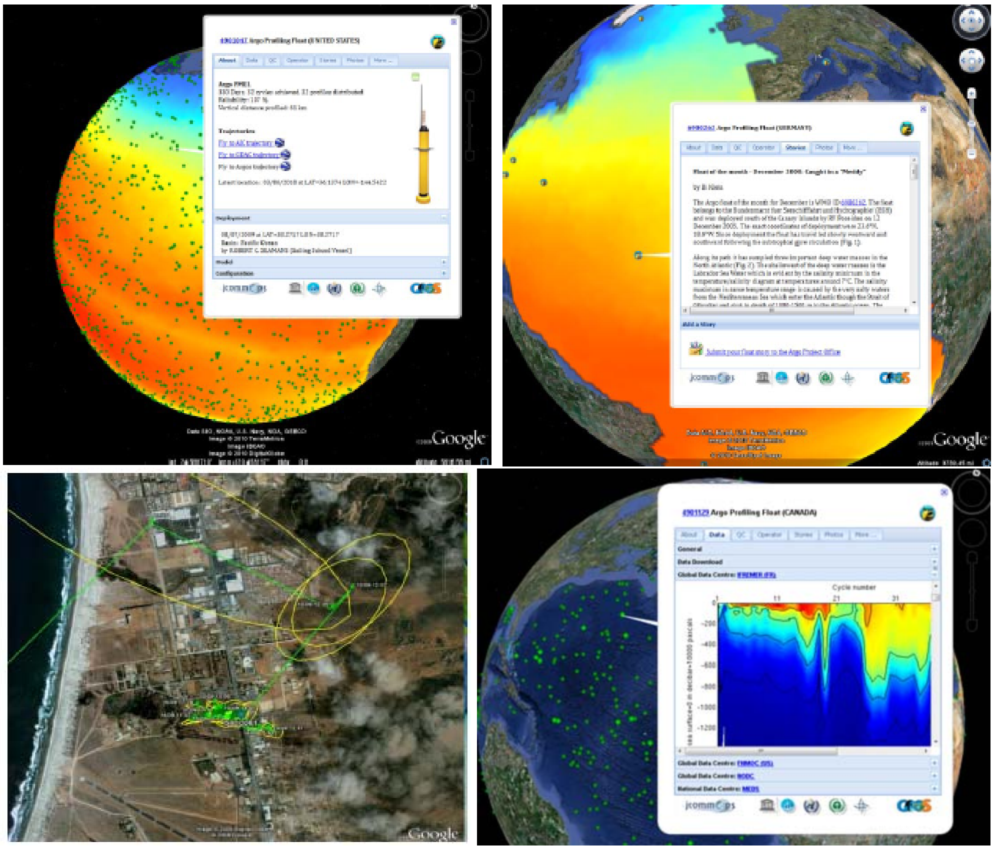


Figure 15 – The OSMC allows users to monitor observing system status in near-real-time (the database is updated daily) and sort platform reports by country, variable, time frame and platform type.



Figures 16: http://argo.jcommops.org/argo.kml - a new Google Earth toolbox for Argo has been developed by the Argo Information Centre.

JCOMMOPS cooperates closely with the Observing System Monitoring Centre (OSMC – see http://osmc.info) to develop near-real-time monitoring tools for use by observing system managers. Both of these centres access different data streams for monitoring (GTS and Global Data Centres) so can compare and check for discrepancies and synchronize their metadata. While JCOMMOPS maintains each individual platform metadata and provides the status of each network, the OSMC focuses on reporting the state of the ocean by demonstrating how the requirements are met in terms of variables and timeframes across all *in situ* ocean observing systems (see Figures 15 and 16).

Members/Member States are urged to strengthen their support for the JCOMMOPS, which has demonstrated its value to the technical coordination and integrated implementation of the ocean observing networks it supports.

8. INTERSESSIONAL MEETINGS INVOLVING THE OPA

2010 March	OceanSITES DMT	Paris, France
April	RMIC-(RA-IV)-I	Stennis, USA
June	GHRSST-XI	Lima, Peru
September	IFSOO-TT-2	Paris, France
October	DBCP-XXVI	Oban, Scotland
	JTA-XXX	Oban, Scotland
November	MAN-VIII	Paris, France
December	PMO-IV	Orlando, USA
2011 March	AST-XII	Buenos Aires, Argentina
April	SOT-VI	Hobart, Australia
	OCG-IV	Hobart, Australia
May	DBCP-WIO-II CB workshop	Balaclava, Mauritius
June	GHRSST-XII	Edinburgh, Scotland
July	RMIC-II	Tianjin, China
September	ITU cables-for-climate workshop	Rome, Italy
	MAN-IX	Geneva, Switzerland
	DBCP-XXVII	Geneva, Switzerland
October	JTA-XXXI	Geneva, Switzerland
November	GLOSS Group of Experts XII	Paris, France
	OceanSITES 2011	La Jolla, USA
December	WOC workshop	Paris, France
	JCOMMOPS-I	Toulouse, France
2012 March	GHRSST workshop	Melbourne, Australia
	Sentinel-3 cal/val workshop	Frascati, Italy
April	DBCP-WIO-III CB workshop	Mombasa, Kenya
	Preparatory workshop for a satellite communications forum (SATCOM-I)	Toulouse, France

APPENDIX C

EXCERPT OF INTEREST TO THE SOT FROM THE IMPLEMENTATION PLAN FOR THE EVOLUTION OF GLOBAL OBSERVING SYSTEMS (EGOS-IP)

5. SURFACE-BASED OBSERVING SYSTEM

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5.3 Issues specific to each observing system component

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5.3.5 Upper-air observing system over the oceans. Automated Shipboard Aerological Programme (ASAP) ships

All the Actions documented in section 5.3.1.1 related to radiosonde observations over land, except those for GRUAN (5.3.1.1.2), are relevant for ASAP. These Actions refer to:

- The importance of isolated radiosonde data for removing the biggest gaps in data coverage;
- The appropriate coding of the total radiosonde information in the vertical, followed by a rapid real-time dissemination;
- The possibility to optimize the data coverage by adapting the launching time, taking into account the ensemble of the radiosonde network, but also other observation systems providing vertical profile observations (AMDAR for example).

For the North Atlantic area (with very few islands which can provide fixed radiosonde sites), EUMETNET[9] has developed a European component of the Automated Shipboard Aerological Programme (ASAP), called E-ASAP (EUMETNET – ASAP). See information on E-ASAP by going to the home page of EUMETNET. Between 15 and 20 ships regularly operate radiosonde launches in the North Atlantic on commercial line services from Western Europe to North and Central America. These ASAP ships contribute to about 10 to 15 radiosonde observations per day on average (situation of 2012), most of these observations being made at 00 or 12 UTC (possibility to make them at a different time, in order to optimize space-time coverage). In the year 2011, the E-ASAP programme contributed about 4500 radiosonde launches over the Atlantic Ocean. Concerning the impact of ASAP ships on numerical forecasts, the Proceedings of the 2008 WMO workshop states (see reference in footnote of section 4): “Even a very limited number of radiosondes located in data sparse regions in the oceans can have a significant impact on the forecast”. The North Atlantic ASAP network has not only a direct impact on forecasts, but it helps the use of satellite data by providing in-situ reference observations with a lot of vertical details. More than 80% of the total ASAP launches in 2011 were performed in the Atlantic Ocean. Therefore, for other oceanic areas, and especially for the North Pacific and Indian Ocean, there is potential for improving very significantly the overall quality of the composite observing system through the development of a very limited number of observing stations (typically 10 or 20). Dropsondes launched from reconnaissance aircrafts are an equivalent system which is used both in the Pacific and in the Atlantic, but very irregularly, to support severe storms forecasts.

Action G49

Action: Maintain and optimize the existing ASAP network over North Atlantic, and develop similar programmes for the North Pacific and the Indian Ocean.
Who: NMSs, NMHSs, in collaboration with companies operating commercial ships, RAs, JCOMM, CBS and CAS. JCOMM to lead.
Time-frame: Continuous.

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[9] http://www.eumetnet.eu/

Performance indicator: Volume of ASAP data available in real-time (usual NWP monitoring indicators).

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5.3.6 Surface observing systems over the oceans

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5.3.6.3 Voluntary Observing Ships Scheme (VOS)

The list of meteorological and marine variables which is normally observed by VOS ships is the same as the one observed by sea stations (5.3.6.2.). The main practical difference is that ships are mobile: this can be an advantage for a better space-time data coverage, but it is a drawback for climate users interested in long time series.

Many recommendations made for land surface synoptic stations are also valid for VOS ships, especially those concerning: global exchange of hourly data (**Action G30**) and coding and transmission of metadata (**Action G32**). For the atmospheric pressure measurement onboard ships, a particular attention should be given to the barometer height, its correct value, correct coding and correct transmission. Indeed atmospheric pressure (often reduced to sea level in this case) is the most important ship observation for NWP, and it is also very important for marine and aviation applications, as well as synoptic meteorology and nowcasting. The global NWP monitoring of ship data shows that some ship observations are affected by important biases in atmospheric pressure measurements, which is obviously linked to incorrect barometer heights (and/or erroneous reduction to sea level). There are also potential improvements on the quality of ship air temperature, SST and wind observations, improvements which could be obtained by more regular interactions of the observation operators with the NWP monitoring centres. See for example the UK Metoffice Website[10].

Action G51

Action: Improve the quality of ship observations by more regular interactions with the NWP monitoring centres and more regular checks on the instruments onboard.
Who: Port Meteorological Officers (PMOs), NMSs, NMHSs and other NWP monitoring centres in collaboration with companies operating commercial ships. CBS and JCOMM to lead the action.
Time-frame: Continuous.
Performance indicators: Usual NWP monitoring indicators.

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5.3.7 Sub-surface oceanic observing systems

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5.3.7.3 Ships of opportunity

With XBT instruments, ships of opportunity can provide oceanic temperature profile data with a good vertical resolution (about 1m) down to 1000m. They are used by several applications in the same way as profiling floats (see 5.3.7.1), and there is also a lot of potential to improve their real-time delivery.

Action G58

Action: For ocean and weather forecasting purposes, improve timely delivery and distribute high vertical resolution data for sub-surface temperature from Ships/XBT.
Who: NMSs, NMHSs, national oceanographic institutions, in collaboration with JCOMM, international organizations and companies operating ships of opportunity, CBS and CIMO.

10 http://www.metoffice.gov.uk/research/monitoring/observations/marine

JCOMM to lead the action in cooperation with CBS.
Time-frame: Continuous.
Performance indicators: Volume of XBT data available in real-time (usual monitoring indicators).

The action of the GCOS-IP, aimed at improving and sustaining the existing network and coverage of the ships of opportunities should be supported.