‘OceanScope’ – A SCOR/IAPSO Working Group

(approved in October 2008)

Summary

This proposal outlines a new paradigm for the systematic and sustained observation of the ocean through close collaboration with the merchant marine industry. The overall objective is to establish a global network of ocean observation platforms on selected commercial ships. The approach will be to encourage the maintenance, expansion and integration of existing volunteer observing ship (VOS) programs while developing in parallel VOS initiatives that use sophisticated new technology, with real-time data streams and data analysis facilities. The proposed SCOR/IAPSO working group would be unique in bringing together ocean scientists with experience in VOS and Ship of Opportunity (SOOP) programs, engineers, instrumentation experts, shipping company representatives and senior merchant marine officers as both Full and Associate members of the working group. Developing a partnership with the merchant marine will be mutually advantageous in that observations reported in real time will on the one hand be used to enhance ocean forecasting services for the industry, and on the other hand will improve our understanding of the ocean’s structure and variability, contributing to weather and climate understanding.

The ocean covers more than 70% of our planet and the commercial fleets have a presence on the high seas second to none covering millions of miles each year. In contrast, research vessel tracks annually cover only a tiny fraction of this distance. Freighters, tankers and cruise ships traverse all major ocean basins on a regular basis, often on well-defined schedules. In contrast, research vessels rarely repeat their tracks. Analogous to satellites probing the Earth’s atmosphere and ocean surface, merchant marine vessels could serve as ‘orbiting’ platforms for monitoring the interior of the ocean. We already do this to a limited extent, but do so rather inefficiently, in part because most of the tools available to us were developed for use on research vessels, not for long-term unattended service. But our experience has highlighted the enormous promise of such programs. Given today’s technical know-how we have an opportunity to make a quantum leap in our observation of the ocean interior. The approach we propose offers an extremely cost-effective way to obtain the very data sets so critically needed to address the challenge global environmental change poses to human society.

The development of an integrated approach to the monitoring of the global ocean is essential if we hope to develop a feasible plan of action to implement the concept and realize the promise. Focusing on four interlocking themes: **ORGANIZATION**, **OBSERVATION**, **COMMUNICATION**, and **INTEGRATION** the working group (with the assistance of other experts) will:

1. identify and prioritize the scientific challenges that can be best addressed by an integrated VOS program;

2. outline and promote appropriate and necessary sensor, instrument and software development;

3. develop an institutional framework that enhances the linkage between the merchant marine and ocean observation communities, including the incorporation and integration of present and planned VOS and SOOP programs; and

4. identify and develop an integrated framework for data management and distribution.

To ensure sustained interest and follow-through, a SCOR/IAPSO working group with international and multidisciplinary participation, well-defined terms of reference and a multi-year fixed term tasking is an ideal framework to achieve these objectives. Initial responses to the ideas presented above—from contacts at IOC and other international institutions—have been highly positive.

The Marine Environment

The extensive regions of the ocean interior continue—despite their enormous climatic and biogeochemical importance—to be extremely difficult to probe and monitor on a regular basis due to the high cost of research vessels and their specialized instrumentation, as well as the high operations and maintenance costs for permanent bottom-mounted or moored instrumentation. Not surprisingly there is a distressingly low density of measurements in the ocean's interior. This stands in stark contrast to the extraordinary ability of satellites to provide frequent and detailed views of the space-time evolution of the surface of the ocean, including its temperature, color, roughness and elevation. It has been said many times before that we know less about the ocean's interior than we do of the moon! Although oceanographers have sampled and studied the oceans from research vessels for well over a century, our knowledge of how the ocean behaves over a very wide range of space and time scales remains very poor. How do currents vary in time, shift in position, how much mass and heat do they transport, how do critical biogeochemical processes and biological distributions differ between ocean basins and regional seas - all questions of enormous importance to our understanding of the atmosphere-ocean system that regulates our climate.

Our inability to continuously sample and resolve fields in the ocean's interior continues to be a major challenge in oceanography. All the more so given that the very energetic meso-scale eddy field not only serves to maintain mean distributions in the ocean, but also to expel gradients to the perimeters of homogenized regions where strong physical and biochemical contrasts develop. While mixing can create uniform regions on the one hand (the standard view of eddy processes) on the other hand it can also create strong (but often transient) horizontal contrasts. Unfortunately we know very little about the latter due to the lack of high-resolution subsurface sampling techniques. To take but one example, we still know surprisingly little about spatial variability in zooplankton and myctophid abundance except in a very few areas of the upper ocean. We also see growing (and surprising) evidence that the shape of the ocean bottom can play a significant role in constraining ocean currents, not merely at depth, but also in the upper ocean. Concurrently measuring ocean currents, temperature, and a wide suite of biochemical properties concurrently at high horizontal resolution remains a fundamental challenge.

Background

For more than a century officers of the merchant marine have - as part of their watch duties - sent in regular weather reports. These observations of air and sea surface temperature, barometric pressure, winds and sea surface conditions have been of enormous importance to the forecasting services of neighboring countries. Further, the archives of these marine observations have formed the basis for much of what we know about the climate of the seas including the enormously important early charts of prevailing winds and ocean currents (e.g. Maury, 1855). But these early observations are largely limited to the ocean surface. Some 80 years later, starting in 1931, Alistair Hardy began a remarkable program to monitor plankton variability by arranging for freighters and ferries to tow Continuous Plankton Recorders on regular routes on a monthly basis (www.SAHFOS.ac.uk). These repeat tows along selected routes have allowed researchers to construct an accurate measure of biomass and identification of various species in the surface waters and how they vary spatially, seasonally and over longer periods of time. A little later in the century mechanical bathythermographs were developed, allowing observers to obtain upper ocean profiles of temperature from ships underway. This was followed by the development of the Expendable Bathythermograph (XBT) in the 1960s (e.g. Baker, 1981) that made it possible to develop an understanding of low-frequency variability in the ocean down to the depth of the main thermocline (e.g. Molinari, 2004). And more recently yet, a few commercial vessels have been equipped with Acoustic Doppler Current Profilers (ADCPs) to measure and monitor upper ocean currents and their variability, for example, across the Kuroshio (Hanawa et al., 1996) and the Gulf Stream (Rossby et al., 2005 and Beal et al., 2008). Similar repeat sections have been operated since the mid-1960s (but mostly later) and are now coordinated as part of the International Ocean Carbon Coordination Project (IOCCP) (See CAVASSOO website below.)

Repeat sampling along designated lines confers a tremendous advantage because patterns of change and their magnitudes can be identified and quantified with unparalleled accuracy. These above examples from VOS and SOOP ships indicate the enormous potential of the merchant marine fleet to provide otherwise unattainable data on critical ocean properties. Discussions that took place at a well-attended session on VOS-based observations held at the 2008 Ocean Sciences Meeting highlighted an increased interest in working with the merchant marine, while at the same time noting the difficulties and challenges in doing so. The research fleet cannot begin to provide comparable data gathering opportunities.

The above encouraging examples notwithstanding, the use of merchant marine vessels to observe the ocean synoptically is far from achieving its enormous potential. The reasons can be briefly summarized in a few words: lack of suitable instrumentation and lack of systematic access to ship platforms - each checkmating the other in a catch-22 loop. In terms of subsurface physical measurements, temperature profilers are not optimized for merchant ships, so XBTs are the only alternative. In most cases their deployment requires technical support aboard ship (although there are automated deployment systems that permit a small number of measurements to be made on specific tracks without such support) and the cost per profile is comparatively high. Widespread use of VOS has been discouraged by these high costs, in conjunction with the challenge of gaining the requisite very regular access to the merchant marine fleet. Because the “market” has remained small there has been little concerted effort to develop an automated inexpensive technique for profiling temperature, much less salinity or other water properties. ADCPs, although they work reasonably well on their own, are not really designed for the automated deployment aboard commercial vessels. For example, the computer controls and data storage of available ADCPs need to be ruggedized with industrial-strength uninterruptible power supplies (UPS). It is possible to build ruggedized instrumentation, but this won’t happen until a broader demand for such equipment develops. Fully automated ways of accessing and distributing the large data sets generated need also to be developed. A number of vessels have been equipped with ‘Ferryboxes' as part of an EU project (http://www.ferrybox.org/) that includes, for example, thermosalinographs, flurometers for chlorophyll and other instruments to measure turbidity, oxygen, nutrients and pCO_2 with real-time transmission of raw data via satellite. This has been a highly successful program and is seeking to move to an operational mode. While the Ferry Box program provides highly useful information about surface water properties, the equipment is expensive to install and requires regular technical support. Each installation typically requires a significant design effort and the installation cost has to be covered for each vessel with little economy of scale or generalizing of solutions.

The Concept

We propose a fresh start that addresses the need to develop sensors and systems that are optimized for the rigorous environment of routine operation on merchant ships, suitably packaged, completely standardized and easily maintained. To employ an obvious analogy, the atmosphere and ocean surface is probed on a routine and systematic basis with highly reliable instruments developed for satellite application; the same approach should be possible for the sub-surface ocean using ships as 'satellite' platforms. With fresh thinking, and taking full advantage of the possibilities offered by modern technology, a much-improved coverage of the ocean interior can be achieved for a comparatively small additional expense. Just to give a hint at what might be possible, with instruments mounted in the hull one could measure a wide range of physical, biological and chemical properties. Instruments topside could measure a wide range of atmospheric properties, providing ground-truth to satellite-based remote sensing systems. Some techniques exist today in prototype form; others would require considerable development. Much as was done in the satellite remote sensing area, we need to let loose our creative instincts and engineering skills to develop instrumentation that takes full advantage of these ocean platforms. As experience grows, expectations and requirements will evolve. All measurements could be forwarded to a central unit, which would handle shipboard data archiving as well as all communications between ship and shore. Communications could work in duplex mode: ship-to-shore (near-) real time transmission of data for post-processing, quality control and distribution to the user community and shore-to-ship for system performance analyses and corrective action when required. As with satellites, a very high level of hardware reliability and software robustness would have to be built into these systems so that they are capable of unattended operation over periods of many months to a year or more. We offer the following vision statement:

"In partnership with the merchant marine shipping industry we will develop an integrated approach to the observation of the global ocean on a regular and sustainable basis. This effort, entitled 'OceanScope' will equip commercial ships with fully automated unattended instrumentation to accurately measure and report upon both the currents and the physical, chemical and biological characteristics of the water column throughout the world ocean. These data will in time become a fundamental resource for studies of the climate and health of our planet."

Proposal

The above concept is feasible, but it cannot be implemented on an individual research project basis, it begs for concerted multi-institutional multi-disciplinary action. All the partner countries in SCOR share a common interest in the ocean, for reasons of commerce, optimal ship routing, fisheries, defense, and on longer (but increasingly urgent) time scales the ocean's role in climate. The SCOR approach to addressing issues of common interest seems eminently well suited to the challenge posed above. We propose to establish a formal working group to fully develop the concept of a merchant marine-based global observing system for the ocean interior. The working group would bring together experts from science, technology, and the marine industry to develop an entirely new paradigm for working with the merchant marine that incorporates and builds on the past and ongoing experience of current practitioners. Rather than thinking in terms of individual VOS or SOOP observing ships, we propose a pro-active or purposeful approach, namely the development of new technologies and new modes of cooperation with the merchant marine. A fundamental point needs to be emphasized here. Our experience has shown that the operators of commercial vessels are receptive to the presence of ocean and atmosphere observing instrumentation onboard their vessels. They see this as providing a service that will provide feedback to their own benefit as well as, in many cases, giving "green" credentials. Ship operators require only that the equipment makes no demands on their costs, insurance, time, people or operations. This is where the analogy with orbiting satellites comes in: satellite-borne instrumentation has been designed, optimized and tested for these platforms before they fly so that they can and will perform without any need for hands-on human intervention. The working group and its associates will identify suitable scientific objectives and translate these into what might be called 'mission' requirements. The group will be tasked with identifying mechanisms for stimulating the development of 'mission-proof' instrumentation as well as exploring and documenting necessary communications requirements and developing parameters for selecting vessels to be equipped (vessel type, route, hull shape, etc). And, perhaps most important of all, they will consider how to implement flexible, easy-to-implement international infrastructure for cooperation between the commercial fleets and the institutions responsible for the instrumentation. The primary goal of the working group will be to produce a development plan with specific implementation recommendations. This work will take some time, and in order to provide the nascent program both support and ongoing supervision it is recommended that the working group be active for at least three years or until such time that operational structures are in place that can assume both oversight and programmatic management responsibilities.

Issues and Organization

At this stage we propose that the SCOR/IAPSO working group be organized around four central themes: organization, observation, communication and integration. The first refers to developing appropriate frameworks for collaboration between the maritime industry and the marine research communities; the second to the development and implementation of observational programs; the third to shore-based supervision of shipboard systems, and data transfer, distribution and archiving; and the fourth to the integration of the proposed development with existing ocean observing programs (including current VOS or SOOP programs) into a global collaborative system that will significantly contribute to the Global Ocean Observing System (GOOS). Each of these areas spans a wide range and overlapping set of issues. The following topics—scientific requirements, instrumentation, networking, platforms and institutional links—show how intimately these themes are linked.

1. *Scientific requirements:* The working group would review emerging scientific questions in relation to our present observational skill. For example, what do scientists think are the most important issues with respect to the ocean's interior, for which more and better information is required? The intention will be to focus upon the desirability of particular measurements, sensors and technologies rather than their current availability. Historically, scalar or state variables have occupied center stage as researchers have endeavored to characterize the present state of the

ocean. However, vector information has much to offer as changes in currents and property fluxes can presage future changes in state—variations in currents and state tend to be out of phase, with the former leading the latter. For example, recent advances in modeling have shown that assimilating deep velocity profiles using Kalman filtering or 4D methods can be just as fruitful as assimilating temperature or salinity. To meet future scientific and operational forecasting needs, it will be essential to reach below the main thermocline to resolve the weakly sheared deep velocity field. Measuring currents at great depth is technically possible today, but additional development will be needed to become operational. Experience has taught us that long-term averages of Eulerian time series of currents do not settle down due to the "red" nature of the velocity spectrum. Eulerian current measurements also suffer from topographic biases. Averaging currents across space gets around both sources of uncertainty so that degrees of freedom accumulate far more rapidly.

Repeat sampling at suitably high-resolution of such biological parameters as upper ocean phytoplankton and mid- and upper ocean zooplankton is essential to characterize their temporal and spatial variability. High-resolution and long-term species data for these taxa are virtually restricted to the near surface northern North Atlantic Ocean sampled by the CPR, although CPRs are being deployed elsewhere also. Given the stress that is being put on marine living resources by commercial fisheries, in concert with climate change, there is a need to routinely measure biomass distribution in a wide range of size and type classes along selected routes. This information is needed to predict shifts in community composition that may profoundly affect the availability of the living marine resources constituting a major fraction of the protein diets in many nations, as well as providing information on the changing composition of the plankton that is so crucial for understanding the carbon cycle. Just as the towed plankton recorder opened the window to surface plankton distributions and documented population shifts related to environmental changes, acoustic and optical techniques might be able to do the same for the entire water column. This is just a brief hint of what could be done.

A supplementary need for improved information on the changing role of biota in the biological pump by use of new and existing technologies is also noted. Variability in the biological pump is not well understand on regional, much less sub-regional scales, although these appear to be the dominant modes of spatial variability. Quantifying the biological pump is crucial to an improved understanding of the oceanic uptake of atmospheric CO_2. The information provided will be invaluable to modelers and for validation of satellite remote sensing products.

2. *Instrumentation:* Here we would address the state of the technology from the perspective of application to commercial platforms (i.e. robustness, reliability and degree of automation) and explore avenues for future development. Focusing again on currents, what technologies might be available for their measurement at depth and at what tradeoff with respect to vertical resolution? What techniques might be developed to monitor thermocline biomass variability? Can we develop low cost (recall that unit cost is a very steep inverse function of production number) probes of temperature, conductivity, oxygen, biological pigments etc.) that can telemeter their data back acoustically to a dedicated hydrophone in the hull of the ship? With the entire circuitry for a multiple-sensor probe on a single silicone wafer, production costs could be reduced enormously. In addition to this one-way data transfer from expendable probes, ships can also serve as acoustic modems to receive and retransmit data from underwater instrumentation in their vicinity.

3. *Networking:* Several issues need to be addressed here. First, we need reliable communication within a vessel. This could be done through Ethernet communications between instrument sites and the bridge or wireless through a series of transmitters distributed throughout the ship. Some alternatives are easier to accomplish during the original construction while others make retro-fitting more feasible. Second, we need reliable communications with the outside world. Here, Iridium and Inmarsat will go a long way towards system monitoring and low-bandwidth data transfer, with wireless high data rates reserved for when a vessel arrives in port or between vessels to relay information back to port (an option already being explored in the U.S. research fleet). An appropriate integration between different technologies with different bandwidths is the likely answer. Large shipping companies (and cruise ships) most probably have standard communications methodologies already in place for vessel tracking, routing and data transfer, but if not, the option to promote this capability in conjunction with data messaging may be attractive to them. Communication issues also may involve shipboard data processing at various levels of detail, inclusion of data description and identification (metadata) and shipboard data archival and retrieval. Much has been done in this area in the satellite community, and further relevant technology will be available as a result of the nascent U.S. NSF-sponsored Ocean Research Interactive Observatories Network (ORION) program.

4. *Platforms:* This topic would include a review of vessel designs and an evaluation of the advantages and disadvantages of different hull forms. In so far as acoustic observations of the water column are concerned, a major requirement will be to identify vessel hull types that are relatively free of bubble sweep-down, including measures that might be employed to ameliorate this limitation. What comparatively inexpensive designs might be built into vessels during construction in anticipation of possible future inclusion in the VOS fleet? Here we have in mind features such as reserved hull plate areas for very low-profile external sensors, standard sea-chests with coffer-dams to accommodate expected hull-mounted instrumentation, seawater plumbing connections in anticipation of flow-through surface water analysis equipment and cable channels and pass-throughs for interior wiring (electrical and fiber-optic). At construction time these costs are very modest, but as retrofits they can become prohibitive. Vessels with particular silhouettes may be advantageous for some kinds of meteorological measurements requiring “clean” air and airflow. Consideration may also need to be given to superstructure arrangements and access for sensors requiring a clear view of the skies and options for fitting gyro-stabilized platforms for stable horizon requirements. The overarching consideration is that standardized procedures, technologies and approaches need to be developed to facilitate easy installation, removal and (when necessary) servicing, and to take advantages of economies of scale to enable the establishment of a large-scale integrated network of instrumented commercial vessels.

5. *Institutional:* This is a large and important topic with many subtopics. Institutional links are needed between research, government and international agencies charged with ocean and climate monitoring and the maritime industry. Almost certainly this will require a program office that searches for, develops and provides a liaison between appropriate ship operators and the scientific community. It will also require development of formal arrangements or letters of understanding between the parties to avoid misunderstandings and/or subsequent confusion. We understand that vessel operators may at any time shift vessels from one route to another for business necessity (or opportunity), but with proper lines of communications it may be possible to anticipate or

minimize the impact of such changes upon scientific operations. For example, given adequate warning (and stand-by response capability) even underwater hardware can be removed by scuba divers without a dry-dock. Conversely the same capability would permit equipment installation to take advantage of newly available commercial routes and opportunities. Third, given justifiably heightened security concerns it will be important for the scientists and technicians to be prepared in advance. Obtaining prior clearance (and documentation) to enter port facilities has become the rule rather than the exception. Fourth, it will be important to educate both communities (scientific and industrial) of the operational, personnel and logistical needs of the other. A key to success will be recognizing and honoring each other's needs and concerns.

Summary of Activities

	Organization	**Observation**	**Communication**
Scientific requirements	User community; real-time forecasting/ climate studies	Type of parameter; scalar/ vector; air/water; accuracy; sampling frequency	Real-time/ delayed/ distribution networks
Satellite validation	Remote sensing developers/ users/ tech. designers/developers	Atmosph/oceanic spectral parameters, chlorophyll fluorescence, currents	Real-time/ delayed/ processed products
Instrumentation	Developers/ users/ partnerships	Type of sensors/ atmosph/ oceanic/ acoustic/ optic/ towed systems	Development/ evaluation/ testing
Networking	Shipboard/ ship-to-shore/ user communities/ GTS?	Data collection/ software/ prewire ships at construction time	Transmission/ software
Platforms	Designers/ users/ vessel owners	Type of observable topside/ hull-based/ towed	Design and approval process
Institutional links	Merchant marine/ science/ gov't/ regulatory	Shipboard activities	Establish formal lines of communication

<u>Mode of Operation of the Working Group</u>

We believe that most of the work outlined above can be achieved by the working group over a two-year period with two face-to-face meetings, one in the early months of the group's formation and a second one after roughly a year. It is envisaged that at the first of these meetings the specific issues listed above will be elaborated in discussions building upon pre-prepared presentations and discussions. Lead writers will then be nominated to draft section contributions for an overall

Development Plan in collaboration with others as appropriate. This work will be reported and discussed at the second meeting of the working group. At this second meeting the members will be in a better position to determine the time scale for completing any remaining tasks, including a possible role in the supervision of the development and implementation of the recommendations in the Development Plan.

The Working Group

The proposed SCOR/IAPSO working group would include experts in all the areas addressed above. A key to success will be to find people who have the time and interest to contribute in a practical way to the objectives of the working group. We note that the response to discussions outlining the basic plans of the proposal, held with a wide cross-section of ocean science researchers, representatives of the instrumentation, communication and maritime industries, and more recently attendees at the JCOMM/SOT-IV meeting in Geneva (April 2007), has been strikingly positive. Additional voluntary or independently supported contributors to and associates of the Working Group well be sought by correspondence with, where appropriate, nominations from international organizations such as IAPSO, IOC, ICES, PICES, POGO, GEO and, of course, SCOR. Hopefully, we will be able to identify a willing and able environmental economist to provide an essential additional perspective to the working group meetings. In advance of each meeting, the basic agenda for the discussions, time and venue will be widely distributed to encourage participation of additional experts with relevant experience from countries adjacent to the meeting venue. Funding will also be sought, independently of SCOR, to enable additional participation by representatives from developing countries and by promising young scientists/engineers. The membership of the working group is listed in a separate document.

We should mention here a few companies that have been actively supporting sustained ocean observation and whom we expect will participate:

Maersk Line (Copenhagen, Denmark)
The Brittany Ferries (Roscoff, France)
The DFDS Tor Line (Copenhagen, Denmark)
P&O Ferries (Dover, U.K.)
The Royal Arctic Line (Nuuk, Greenland)
The Bermuda Container Line (Hamilton, Bermuda)
Royal Caribbean Cruise Line (Miami, Fl, USA)
The China Navigation Company (Hong Kong, China)
The Smyril Line (Torshavn, Faroes)

We also have contact with other shipping companies and related marine business concerns including:

Wallenius Marine AB (Stockholm, Sweden)
Neste Shipping Oy (Keilaranta, Finland)
Skaugen Marine Construction (Skaugen, Shanghai, China)
V.Ships Leisure S.A.M. (Monaco)
Color Line Marine (Sandefjord, Norway)
Teekay Shipping (Vancouver, BC, Canada)
Höegh Autoliners (Oslo, Norway)

Terms of Reference (ToR)
Our overall objective will be to develop an integrated implementation plan for systematic observation from merchant marine vessels. To achieve this means addressing and resolving the issues below, most of which were discussed above. That said, as soon as the working group convenes, its first order of business would be a review of the ToR and approval as stated or after appropriate refinement.

1. Identify ocean observation and scientific needs with respect to parameters and geographic location
2. Given these needs identify and prioritize marine routes for sustained ocean observation
3. Classify and identify commercial vessel types suitable for sustained observation
4. Identify available technologies that can enhance vessel capability for ocean observation
5. Identify and prioritize instrument needs to meet *future* mission requirements
6. Identify and develop procedures (hardware and software) to meet communication needs
7. Develop procedures and algorithms for managing data flow, handling, and archival. Address related issues of data ownership (e.g. when routes occur within national within Exclusive Economic Zones), data availability and data dissemination. In general, the expectation is that the data would be made freely and widely available to all interested users.
8. Address what kind(s) of organizational structure(s) will best serve to initiate, implement and sustain an integrated international merchant-marine based ocean observation program, linked closely to existing ocean observing systems and programs with access to appropriate and sufficient long term funding sources – e.g., an "Ocean (or Interior) Space Center"- hereafter termed an OSC.

Timeline (assuming a once/year meeting schedule)

Year 1:

- Review and adjust as necessary the TOR
- Produce three-year work/action plan for the Working Group
- Complete tasks as defined at first meeting
- Begin discussion and conceptual design of an appropriate organizational structure
- Review organizational paradigms in relation to existing ocean observing systems
- Explore funding sources/structures

Year 2:

- Complete and distribute first interim report
- Review and develop as necessary the Work Plan for years 2 and 3.
- Complete a proposal for the implementing body (e.g. an OSC).
- Develop funding (prepare and submit proposals to various national and international agencies and private sources based upon the interim report)

Year 3 (with or without WG meeting at this time; TBD):

- Issue final report

- Complete and submit a series of papers for a special edition of a journal or book.
- Revise – as appropriate – the implementation proposal
- Explore further funding sources. It is hoped by this stage that some funding will be in place to initiate the program including a startup of the final implementing body, and preliminary funding for commercial instrument and software development.
- Review and decide what structures will need to be put in place to carry forward the deliberations and plans of the Working Group into the future.

Deliverables

The ultimate deliverable of the Working Group will be an Implementation Plan for OceanScope. How it takes shape will be a dynamic process. At the end of the first WG meeting, we hope to have a moderately clear outline in hand, the specific subsections of which can be fleshed out by ad hoc technical subgroups. With the outline in hand, the WG should be able to give SCOR, IAPSO, and the larger community of stakeholders a reasonably clear idea of what the final product will look like. It will have sufficient substance for people to review and provide the WG with invaluable feedback. Depending upon when the first WG takes place, we would hope to solicit such feedback at the July 2009 IAPSO meeting in Montreal (this is most likely when the first WG meeting will take place) and the OceanObs09 in Venice in September 2009. The second WG meeting should take place at most one year after the first one, and should lead to a final draft relatively soon thereafter. A third face-to-face working group meeting may not be needed insofar as the Implementation Plan is concerned, and might better be held in reserve as an advisory group meeting with respect to the initial execution of the Implementation Plan. These opportunities for feedback, including the international meetings mentioned above should provide for ample interaction with and consideration for the interests of the larger ocean observing community and shipping industry. Again, we emphasize that OceanScope would represent a partnership between the merchant marine industry and the ocean observing communities and will be feasible only to the degree that the industry sees benefit in the partnership. We are confident that improved knowledge of ocean currents and weather will yield improvements in routing, safety and fuel usage and at the same time viable commercial opportunities will result from implementation and optimization of OceanScope (just as they did from the space programs).

To facilitate preparation for the first WG meeting, a set of questions will be prepared for each of the principal topics (ToRs). These will provide a reference frame for both the introduction of the topic and as a starting point for those who wish to address it. That is, the questions will serve to guide, but not constrain the discussion. To illustrate what we have in mind, consider ToR #1. One question might be: Given that measuring velocity is particularly feasible from MM vessels, how much emphasis should be put to resolving the upper ocean (ADCP) velocity structure vs. deeper reach at lower resolution (using towed electro-magnetic or acoustic correlation techniques – technologies that exist, but are not yet developed and tested for MM use)? These 'heads-up' questions will help set the stage by outlining options and possibilities. A webpage will be set up to provide these and other background materials, including regularly revised documents, including links to relevant supporting materials.

In Summary

There is little doubt that a partnership between the international oceanographic community and the merchant marine fleet to equip an appropriate set of vessels capable of systematically and repeatedly probing the ocean interior at high resolution, both horizontally and vertically, will have a fundamental impact on our knowledge and understanding of the marine environment and ocean interior. The time is right. First, activities by various groups have clearly shown that partnerships between vessel operators and the scientific community can work and can be sustained, in many cases over decades. Second, experience from both marine and satellite-based technologies show that systems can be developed for long-term reliable operation, an essential requirement for autonomous operation on merchant marine vessels. Third, (if we ever doubted it), the ocean is being shown to play a fundamental role in regulating and modulating our climate. The richness of circulation patterns in the ocean and their time scales of overturning imply a continuous spectrum of variability. The best way to understand how the ocean responds to and impacts our climate is through accurate measurement. The ocean scientific community and merchant marine, working together in partnership with the leadership provided by the SCOR Working Group, will provide the means to make the ideas presented in this proposal a reality.

Web Sites

Sir Alistair Hardy Foundation for Ocean Science
www.SAHFOS.ac.uk

CO_2 program: http://tracer.env.uea.ac.uk/e072/publications/first_annual_rep.pdf

Worldwide Merchant Marine Fleet
http://www.cia.gov/cia/publications/factbook/fields/2108.html

Information on present volunteer observing ship programs
www.bom.gov.au/jcomm/vos/vos.html

Two academic programs:
http://www.rsmas.miami.edu/rccl/
http://www.po.gso.uri.edu/rafos/research/ole/index.html

References

Baker, J.,1981. Chapter 14: Ocean Instruments and Experiment Design. In Evolution of Physical Oceanography, B. A. Warren and C. Wunsch, Editors. *MIT Press*.

Beal, L. M., J. M. Hummon, E. Williams, and O. Brown, 2008. Five years of Florida Current Structure and Transport from the Royal Caribbean Cruise ship Explorer of the Seas, *J. Geophys. Res.,* doi:10.1029/2007JC004154 In press

Hanawa, K., Y. Yoshikawa and T. Taneda, 1996. TOLEX-ADCP monitoring. *Geophys. Res. Lett.*, **18**, 2429-2432.

Maury, M. F., 1855. The Physical Geography of the Sea. *Harper & Brothers*, NY. 274 pp.

Molinari, R. L., 2004. Annual and decadal variability in the western subtropical North Atlantic: signal characteristics and sampling methodologies. *Prog. Oceanogr.*,**62**,33-66.

Rossby, T., C. Flagg, and K. Donohue, 2005. Interannual variations in upper ocean transport by the Gulf Stream and adjacent waters between New Jersey and Bermuda. *J. Marine Research*, **63**,203-226.

Appendix: Discussion of the WG's ToRs (see pp. 10-11):

1. Remarkably, water velocity is just about the easiest water column observable to measure accurately today; it can also be measured at very high horizontal resolution. This matters because the most energetic scales in the ocean (and where many of the energy transformation processes take place) are measured in 10s of km, that is, at scales comparable to or less than can be accurately resolved with satellite altimeters. Thus, vessels in regular traffic can extend satellite measurement of currents to horizontal scales as small as O(1) km from the surface down. Repeat sampling of currents will be a major complement to ongoing ocean-observing programs such as Argo. Argo has phenomenal global coverage but very limited horizontal resolution. Argo is primarily an ocean-state monitor. ADCPs on MM vessels track changes in the dynamic balance of the ocean. Concurrent measurement of temperature and other surface water properties is highly desirable, but except at the surface cannot be done at the same horizontal resolution (but see item 5 below). Other variables of high priority will most likely include biomass over a wide range of size classes. As with velocity, these can be measured remotely using optics (phytoplankton) and acoustics (zooplankton and nekton). Given that we have only fleeting knowledge of spatial/temporal variability of either we think these will be of great interest.
2. Identifying and prioritizing routes will be important. We envision soliciting input early on so this topic can be given shape and substance at the first WG meeting. To what extent should one focus on zonal vs. meridional routes? At first we envision this as a straight scientific/ocean monitoring question, and then ask what can be implemented. This is an excellent example of where partnering with the ICS will make a big difference to help identify possible shipping companies.
3. This is a fairly straightforward technical question that includes issues such as shape of bow and draft (to avoid drawdown of bubbles), vessel self-noise (that might limit performance of acoustic instrumentation), speed, ease of installing seachests (for hull-mounted instrumentation such as ADCPs), wiring (power and communications), plumbing (for water chemistry).
4. This item covers several potential points. First, ways to mitigate issues in the previous item such as 1) use of sound- and vibration-absorbing materials, 2) small acoustic domes for acoustic telemetry, 3) technologies/methodologies for attaching instrumentation externally ('limpet' approach), and 4) possibility of wireless communications *within* vessels (to obviate the need for wiring).
5. This is very exciting for this really opens the door to possibilities we haven't been in a position to consider for reasons of opportunity and cost. The list is open-ended but would certainly include 1) expendable probe technology; probes that telemeter T, S, O2, microstructure, pH, turbidity, and 2) towed techniques, not merely for plankton such as the CPR, but also suppressed water intake to routinely measure gradients of dissolved gases, measure deep currents, 3) acoustic techniques for profiling temperature, …

6. Standardize communications protocols between instrumentation and data centers on the bridge for shipboard processing and archiving and/or relay to shore. Given the very noisy electrical environment onboard ships, it seems likely that fiber-optic techniques will become the preferred mode of data transfer between points onboard. This means developing a methodology for ships to install fiber-optic wiring (or other equivalent methods) between points in the hull, the engine room and the bridge at construction time.
7. The focus will be on developing algorithms for the real-time automatic processing and quality control of shipboard data. This is a top-priority matter for the simple reason that the data flow is continuous, quite unlike that on a research vessel. So much information has been lost (ADCP especially) because of the special learning curve required to integrate the various data flows (raw ADCP data, GPS position and vessel heading), QC these and deliver the final product (water velocity over the ground) for dissemination. We anticipate that a new paradigm for handling ADCP data will need to be developed; specifically techniques to process and stream the data from ship to shore to user quickly, smoothly, and reliably. Some serious design work will be needed to facilitate archival and retrieval of large volumes of vector information.
8. We need to recognize that the proposed OceanScope paradigm will have to have a 10-year time line for full implementation. The initial spin-up may require at least 5 years.
9. One must view OceanScope as a new paradigm for the systematic observation of the ocean. Once the program is underway, the ocean observing community will soon identify the need for new instruments and technologies. It will take a major deliberate effort, and as a point of departure we envision what we called above an Ocean Space Center – modeled after an international space agency such as ESA – which could serve as the programmatic, operational and technical clearing house for OceanScope. Such a Center would have a ‘staying’ power individual investigators and institutions cannot match. Whatever the final form of the implementing body, if it received support from the numerous relevant government agencies around the world, the burden on any single contributor would be comparatively modest.