Report of the

1st Joint GOSUD/SAMOS Workshop

2-4 May 2006
Boulder, Colorado, USA

13 September 2006

1st Joint Global Ocean Surface Underway Data (GOSUD) Shipboard Automated Meteorological and Oceanographic System (SAMOS) Workshop

2-4 May 2006

UCAR Center Green Campus
Boulder, Colorado, USA

SAMOS Chair : Shawn R. Smith

Center for Ocean-Atmospheric Prediction Studies
The Florida State University
Tallahassee, FL 32306-2840 USA
smith@coaps.fsu.edu

GOSUD Co-chairs : Robert Keeley[1] and Thierry Delcroix[2]

[1]Department of Fisheries and Oceans
Marine Environmental Data Service
1202-200 Kent Street
Ottawa, Ontario K1A OE6 CANADA
keeley@meds-sdmm.dfo-mpo.gc.ca

[2]IRD/LEGOS
14, avenue Edouard
Belin, Toulouse, 31400 FRANCE
thierry.delcroix@legos.cnes.fr

Sponsored by Michael Johnson
NOAA Office of Climate Observation

Local logistics arranged by Jill Reisdorf
UCAR Joint Office for Science Support

13 September 2006

Table of Contents

Acknowledgements

The SAMOS chairman (Shawn R. Smith) and GOSUD co-chairs (Robert Keeley and Thierry Delcroix) wish to thank Mike Johnson and the NOAA Office of Climate Observation for funding the 1st Joint GOSUD/SAMOS Workshop. We also wish to extend our gratitude to Jill Reisdorf and the UCAR Joint Office for Science Support for arranging and hosting the workshop in Boulder. We also wish to thank Mark Bourassa, Ben Moat, Steve Rutz, Janet Sprintall, Scott Woodruff, and Steve Worley for their constructive review of the report.

Executive Summary

On 2-4 May 2006, the NOAA Office of Climate Observation sponsored the 1st Joint Global Ocean Surface Underway Data (GOSUD)/Shipboard Automated Meteorological and Oceanographic System (SAMOS) Workshop in Boulder, CO, USA. The workshop focused on establishing collaboration between GOSUD and SAMOS and addressing the need of the research and operational community for high-quality underway oceanographic and meteorological observations from ships. The SAMOS initiative is working to improve access to calibrated, quality-controlled, surface marine meteorological data collected in-situ by automated instrumentation on research vessels (primarily) and merchant ships. GOSUD focuses on the collection, quality evaluation, and distribution of near surface ocean parameters (salinity and sea temperature) from vessels.

The workshop organizing committee (Shawn Smith, Robert Keeley, Thierry Delcroix, Mark Bourassa, and Christopher Fairall) brought together representatives from the scientific and operational marine observational communities. Participants from the U.S. government represented NOAA (ESRL, AOML, NDBC, NODC, and OMAO), the Army Cold Regions Laboratory, and the U.S. Coast Guard. The U. S. university community was represented by the Woods Hole Oceanographic Institution, the Scripps Institution of Oceanography, the University of Miami, University of Alaska, Oregon State University, the National Center for Atmospheric Research, and the Florida State University. A significant international presence included representatives from the CSIRO (Australia); CNRS, IRD, IFREMER, and Mercator Ocean (France and New Caledonia); Environment Canada and MEDS (Canada); Tokai University and JAMSTEC (Japan); and the NOC (UK). Finally, the private sector was represented by Raytheon Polar Services, ADA Technologies, Earth and Space Research, and the International Sea Keepers Society.

The workshop was organized into three sessions: (1) parallel SAMOS and GOSUD technical working group meetings, (2) invited talks and posters focusing on applications of SAMOS and GOSUD observations and potential collaborations between marine observing programs, and (3) a plenary discussion encompassing sessions (1) and (2). A primary discussion topic was the scientific user's need for high-quality, automated, near-surface ocean and atmosphere measurements to achieve objectives ranging from satellite calibration and validation, ocean data assimilation, polar studies, air-sea flux estimation, and improving analyses of waves, precipitation, and radiation. The quantification and reduction of measurement bias and uncertainty was also addressed. The SAMOS and GOSUD working groups addressed both issues internal to each program as well as future interaction between SAMOS, GOSUD, and other international marine observing programs. The result of the workshop was a series of action items (Appendix A) and five recommendations.

Recommendations

1. Funding agencies should increase their support for training and retention of marine technicians to improve the quality of measurements and reap the most benefit from the capital investment on underway measuring systems. Increased funding would allow an increase in the number of technicians; thus affording more complete attention to the underway data systems.
2. CFD modeling should be conducted during the design of new vessels to ensure proper exposure of meteorological instrumentation used for both scientific data collection and navigation of the vessel. Assessment of flow for existing ships could also result in instrument redeployments to superior positions.
3. Encourage one-on-one visits to vessels by liaison from the SAMOS initiative. Liaison would work with vessel technical group to improve sensor exposure and subsequent data accuracy.
4. Research vessels are encouraged to participate in VOS and VOSClim programs.
5. Encourage both public and private sector investment into development of lower cost automated wave recorders and encourage ship operators to install and operate wave recorders.

Meeting summary (as submitted to EOS on 10 July 2006)

The National Oceanic and Atmospheric Administration (NOAA) Office of Climate Observation sponsored the 1st Joint Global Ocean Surface Underway Data (GOSUD)/Shipboard Automated Meteorological and Oceanographic System (SAMOS) Workshop in Boulder, CO, USA on 2-4 May 2006. The workshop initiated collaboration between the GOSUD project (http://www.gosud.org/), the SAMOS initiative (http://samos.coaps.fsu.edu/), and other international programs interested in providing high-quality automated surface oceanographic and meteorological observations from ships to the research and operational community. The goal of the workshop was to stimulate interest in applying these automated observations to applications such as satellite and model product evaluation, air-sea flux analyses, and ocean process studies.

The centerpiece of the workshop was a series of speakers providing insight into current and potential applications of high-quality observations collected by the SAMOS and GOSUD projects. Validating available satellite observations of wind and sea surface temperature requires in-situ observations that span the full range of atmosphere and ocean conditions. Winds greater than 20 m/s are rarely observed by merchant vessels as they are routed to avoid such conditions; thus, high wind data from research vessels are essential to improve satellite retrieval algorithms. Later in this decade, the Aquarius and the Soil Moisture and Ocean Salinity (SMOS) satellites are scheduled to launch with the capability to measure sea surface salinity (SSS). In-situ observations of SSS from a wide range of salinity environments (e.g., regions of low and high spatial variability in salinity) will be needed to validate data obtained by these new SSS sensors. The meeting focused on the advantages of SSS retrieved from shipboard thermosalinographs (TSGs), which are complementary to SSS fields derived from profiling floats; however, the latter cannot detect surface gradients or provide observations in regions of surface divergence. A preliminary analysis noted that the SSS bias in simulated SMOS data is related both to bias in wind speed and sea surface temperature (SST) and that high accuracy (on the order of 0.3˚C for SST and 0.2 m/s for wind speed) in-situ meteorological data will be needed to understand and improve SSS retrievals. Through the use of in-situ observations, improvements in satellite retrievals will result in better products for validation of and assimilation into ocean and atmosphere models.

The polar science community can also benefit from high-quality shipboard measurements. The location of the Antarctic Polar Front, identified by infrared and microwave satellite sensors, responds to meridional shifts in the wind fields, which can also be determined from satellite. Both the frontal location and winds from satellites need to be validated with in-situ observations. The upper ocean heat budget in the Southern Ocean also can be addressed using shipboard measurements. Well-understood surface heat flux products (known biases and uncertainties) are essential to determine the upper ocean heat budget. In-situ validation data are needed to assess the quality of existing flux products and to reduce the large uncertainties in all terms of the upper ocean heat balance for the Southern Ocean. In addition, the complex upper ocean processes near strong gradients are not well-resolved using existing measurements (either satellite or in-situ). The Southern Ocean provides a challenge for in-situ measurements, but increases in high-quality shipboard data are possible by better utilizing research and re-supply vessels. The upcoming International Polar Year (http://www.ipy.org/) provides an opportunity to improve coordination between many countries' Antarctic and Arctic marine observing programs.

Researchers studying air-sea fluxes, radiation, precipitation, waves, and swell are interested in high-quality surface marine observations. A number of research groups are developing in-situ, satellite, and blended air-sea flux products that require independent validation data from all ocean basins. Radiation measurements over the ocean are necessary to close the heat budget at the earth's surface. Precipitation contributes to the overall heat budget and is a key component of the fresh water flux. Developing better wave products has a variety of applications, from the impact on fluxes to structural engineering concerns for vessels and marine platforms. In many cases, high-quality in-situ winds are equally important to wave measurements as the wave community uses the wind data to model the wave field.

The panel convened for the workshop addressed how collaboration between SAMOS, GOSUD, and other programs would improve the accuracy of and access to the in-situ ocean and atmospheric observations needed to address the topics outlined above. The workshop organizing committee (Shawn Smith, Robert Keeley, Thierry Delcroix, Mark Bourassa, and Christopher Fairall) brought together representatives from the scientific and operational marine observational communities. Participants from the U.S. government represented five NOAA organizations, the Army Cold Regions Laboratory, and the Coast Guard. The U.S. university community was represented by the Woods Hole Oceanographic Institution, the Scripps Institution of Oceanography, the University of Miami, the University of Alaska, Oregon State University, the National Center for Atmospheric Research, and the Florida State University. A significant international presence included representatives from the Commonwealth Scientific and Industrial Research Organisation (Australia); Centre national de la recherche scientifique, L'Institut de recherche pour le développement, Institut français de recherche pour l'exploitation de la mer, and Mercator Ocean (France and New Caledonia); Environment Canada and Marine Environmental Data Services (Canada); Tokai University and Japan Agency for Marine-Earth Science and Technology (Japan); and the National Oceanography Centre, Southampton (UK). Finally, the private sector was represented by Raytheon Polar Services, ADA Technologies, Earth and Space Research, and the International SeaKeepers Society.

Planned Activities

A planned data exchange between the SAMOS and GOSUD data centers will facilitate enhanced quality evaluation and availability of underway observations. The exchange will send meteorological data collected by GOSUD to the SAMOS data center while TSG and other underway data collected by SAMOS will be provided to the GOSUD data center. These data will then be recombined through a joint distribution system. A pilot project to exchange observations will begin in 2006. The SAMOS and GOSUD data centers will establish a method of versioning and uniquely identifying data sets that will allow for the separated ocean and atmospheric data to be recombined through a joint distribution system for users and archival. A dialog will be undertaken with the NOAA National Oceanographic Data Center (NODC) to explore the options for mirroring or other forms of distributed data access and archival. The SAMOS and GOSUD centers will also compare metadata specifications to identify gaps in information and plan to exchange quality control techniques.

Beyond their joint collaboration, SAMOS and GOSUD will work with the International Ocean Carbon Coordination Project and Climate Variability and Predictability program to expand ocean and atmospheric carbon measurements. The carbon community has a need for high-quality meteorological and underway water measurements to compliment the automated pCO2 observations. SAMOS will expand evaluations of surface radiation measurements through a new collaboration with the Baseline Surface Radiation Network Oceanic Working Group. Expansion of data collection for SAMOS and GOSUD from the community of polar vessel operators (including research, re-supply, and tourist) will be initiated through the Council of Managers of National Antarctic Programs (COMNAP). COMNAP is interested in a routine in-situ sampling program that will improve marine forecasts and safety at sea while providing high-quality observations for research science. SAMOS will join the GOSUD effort to collaborate with the Joint World Meteorological Organization - Intergovernmental Oceanographic Commission Technical Commission for Oceanography and Marine Meteorology (JCOMM) Ship Observations Team (SOT) in areas of real-time data distribution (via the Global Telecommunication System) and metadata standards, and by providing participants in the Voluntary Observing Ship Program with clear guidelines for collecting data needed by the scientific community. For example, several panelists noted that, while most research vessels are equipped with separate bridge and science instrument systems, it is not always clear which system they use for standard bridge weather reports. In some cases, the bridge crew may pull data from the science system instead of using manual or bridge sensors. Problems arise during data analysis and blending into large marine archives (e.g., the International Comprehensive Ocean-Atmosphere Data Set) because the source of the data is rarely reported. There appears to be a need for JCOMM to explore new mechanisms to ensure that the vessel operators adequately report the source of the observations.

Properly locating meteorological sensors on a vessel can have a profound impact on the quality of the observations. Through collaboration with the National Oceanography Centre, Southampton (UK) and NOAA's Earth System Research Laboratory, the SAMOS initiative plans to undertake a program of computational fluid dynamics (CFD) modeling of research vessels. The primary focus of the CFD modeling is to identify the accelerations/decelerations of the wind flow over the vessel structure, allowing sensors to be moved to the "best" possible exposure on the vessel. The program will evaluate existing techniques and new methods to model the maximum number of vessels for the lowest cost.

Both GOSUD and SAMOS plan to provide practical guidance to operators on the front line of data collection that emphasizes the importance of the observations for future research. In the fall of 2006, the "Guide to Making Climate Quality Meteorological and Flux Measurements at Sea" will be published as a joint effort of SAMOS and the World Climate Research Program Working Group on Surface Fluxes. An effort will be made to link this guide to the technical manuals created for TSG observations by GOSUD. The marine technicians at the workshop encouraged the SAMOS and GOSUD projects to consider establishing ship visits by persons well versed in the marine technology. Discussions noted that visits would build a human connection with the vessels, provide motivation for making the observations, and allow a quick opportunity to review instrument exposures and locations.

SAMOS working group report

The SAMOS working group convened to discuss technical issues related to the continued advancement of the goals established in the first two SAMOS workshops (http://www.coaps.fsu.edu/RVSMDC/Workshops/). The group meeting began with status reports from active SAMOS projects and continued throughout the day with open round-table discussions led by the SAMOS chairman. Topics of discussion included the roving standard instrument suite, marine handbook, computational fluid dynamics (flow) modeling of vessels, radiation standards, participation at upcoming meetings, and collaborations with GOSUD, and other international activities.

Shawn Smith reported on the status of the SAMOS data assembly center (DAC) activities. At the time of the workshop, the DAC had completed a pilot project with WHOI and was now receiving meteorological and thermosalinograph observations daily from the R/V *Knorr* and *Atlantis*. The DAC had completed a metadata specification and established a ship profile and data tracking database for all incoming observations. A SAMOS web page (http://samos.coaps.fsu.edu/) was up and running, including access to preliminary data and metadata profiles for participating vessels. The fact that data users can access quality-evaluated observations from participating vessels, with approximately a 24 hour delay from collection, is a big selling point for the SAMOS activities. The DAC was working to implement research quality data processing, including merging of delayed reports, duplicate elimination, and visual data inspection. The biggest challenge continues to be the recruitment of additional vessels to participate in the SAMOS initiative. Many operators are interested, but starting new data flow continues to be a challenge. This is in part due to the heavy workload of the ship technicians and the need for individual vessel operators to develop scripts to push data to the DAC. The DAC was asked to develop a "how to participate" web page and include all necessary forms and recruitment documentation.

The challenge of technician workload brought about a discussion of human capital development and retention on vessels. The technicians are an essential component of SAMOS and GOSUD efforts to obtain high quality observations from research vessels (and in some cases for VOS with riders on board). As the level of technology increases on research vessels, the number of tasks for technicians also increases. Achieving routine meteorological and TSG collection on passage cruises, and other cruises where the primary science mission is not interested in these measurements, can be a challenge due to shifting priorities for the technicians. Additional responsibilities for ship-to-shore and intra-ship communication systems are ever growing. Turnover in technicians and training of new personnel continue to be a problem. SAMOS can help in the area of training by providing resources to ship technical groups related to making high-quality marine measurements (see handbook below). Additional activities may include contributing to the MATE program or developing training modules through the OceanTeacher initiative. To improve the quality of measurements and reap the most from the capital investment on underway measuring systems, SAMOS and GOSUD recommend that funding agencies increase their support for training and retention of marine technicians. Another important consideration is increasing the number of onboard technical staff to help carry the increasing workload for underway measurements, communications, and science party support.

Chris Fairall provided an update on the Portable Seagoing Air-sea Flux Standard (PSAFS). Conceptually the system would be in two parts, (1) a set of state-of-the-art instruments deployed for clean sampling of the air-sea fluxes of heat, momentum, fresh water, and radiation and (2) a suite of wireless instruments to make standard meteorological measurements side-by-side with the SAMOS that is permanently installed on a research vessel. The first part of the system, which NOAA/ESRL/PSD is developing, should be complete in a year and ready for deployment later in 2007. One unique aspect of the PSD system is the development of a tilt-stabilized platform for radiation measurements. The second part of the system, which WHOI is developing, is in preliminary design but will need additional support to purchase necessary instrumentation. Deployment of the PSAFS will be done in piggyback mode on previously scheduled science or transit cruises. Scheduling will be completed informally at present, but there was some discussion that, when possible, the deployments should coincide with cruises to regions of high scientific interest for fluxes, possibly including one or more IPY cruises. Deployments are not limited to NOAA vessels and should include NSF, NAVY, USCG, and international vessels. Standard deployment would include one or two technicians and current funding will support up to two deployments per year. PSAFS technicians will work with the research vessel technician to provide recommendations on how to improve data quality from the vessels' permanent instrumentation.

The potential deployment of the PSAFS opened a discussion of how to provide useful input to vessel operators on their current meteorological and oceanographic instrumentation. The potential improvements from a PSAFS deployment are high, but there was additional discussion that improvements in data quality could be made through personal visits to individual vessels. Visits could include reviews of practices in the marine handbook, evaluation of sensor locations on a vessel, etc. and should be completed by persons with a wide range of experience working with marine instrumentation (possibly through the PSAFS group at PSD). The question was raised as to whether these technical visits could be scheduled with the science inspections that happen through UNOLS.

The status of the marine handbook, officially titled "A Guide to Making Climate Quality Meteorological and Flux Measurements at Sea," was provided by Frank Bradley. The handbook is designed to reach a broad readership and will satisfy goals set out by the WCRP (WGASF, WGSF) and SAMOS. Frank raised a number of questions and issues related to the draft of the handbook. Table 1 of the handbook lists target accuracies for marine measurements and the question was whether the table provides sufficient guidance for vessel operators and scientists. The group agreed that a better description of the source of the accuracies in the table (e.g., from an original Peter Webster document) and their limitations was needed. These accuracies must be driven by the need to address science questions, and they likely fit that need for climate studies. As for satellite derived fluxes, more stringent accuracies may be needed. Liz Kent noted that instrument accuracy and measurement accuracy are not equal and some effort should be made to explain this for handbook readers. Mark Bourassa presented an overall assessment of the accuracy targets (see below) and he will add some discussion to the handbook to qualify the accuracies in the table. A need to cross-reference the handbook with standard manuals of practice for VOS was raised. The handbook was designed primarily with research vessels in mind, but a need to collaborate with WMO, JCOMM, and other VOS initiatives was discussed. The group agreed that the first version of the handbook would retain its focus on research vessels, but that future expansion and cross-referencing to VOS practices can be achieved through the handbook's dynamic on-line version. Other decisions included:

- Revisiting the descriptions of ship-relative, ocean-relative, and earth-relative (true) winds to make sure the distinction is clear. Included in this was the need to request routine inclusion of water-relative motion of a ship (via Doppler or EM log).

- Utilize the nomenclature SST_x for sea temperature, where x = dockside depth in meters of sensor or water intake. Also, include in bibliography reference to Donlan's manuscript on SST conventions.
- The catalog of bulk flux algorithms will not be published as part of the handbook, but a general description of bulk flux calculations would be included. Links to current algorithms will be available through handbook web pages.
- A sectionalized bibliography will be created for the first version of the handbook. It will likely not be comprehensive, but, as funds allow, an expandable bibliography can be created on-line. It should include some references to applications of marine data, WMO and other marine practices documents (e.g., NOAA handbook #1), sensor literature, etc.
- Focus the handbook introduction to state that it was developed primarily with automated instrumentation in mind, although practices are equally helpful for manual observations.
- When showing poor sensor locations (e.g., VOS instruments on Brown), choose wording carefully so it indicates that this is not representative of the majority of VOS installations.
- To help novice operators make sound judgments on sensor locations, a suggestion was made to collect a series of digital photos and schematics to represent good and poor installations (see action items). The ship names from which the photos were collected will not be used during any demonstrations or training sessions.

Publication of the handbook will include both printed and digital (e.g., CD) media (estimated 250 copies). Chris Fairall will contact NOAA concerning publication costs and the group targeted the INMARTECH 2006 meeting in October 2006 as the roll out date. The SAMOS DAC will develop an on-line presence for the handbook once the first version is completed. Cross-referencing the handbook to UNOLS (other) web pages will be a priority.

An expanded discussion of computational fluid dynamics (CFD) modeling of the airflow over research vessels was conducted in response to past workshop recommendations. Ben Moat provided his expertise to the discussion (see speaker program below). The first question was to determine the goals of a SAMOS CFD modeling program for research vessels. The panel put forth the following priorities for CFD modeling:

- Improving location and exposure of sensors;
- Determining bias corrections for measurements from individual sensors; and
- Determining the effective source height of air reaching individual sensors.

It was clear from the discussion that improving sensor locations on vessels could be achieved with lower grid resolution CFD models, which would result in dramatic improvement in measurements. Bias corrections for individual sensors can be achieved, but higher resolution ship geometry (possibly including instrument mast configuration) would be needed. Higher resolution generally implies higher cost (both in dollars and computer resources) to complete the flow calculations. In terms of costs, developing the ship geometry (mesh of the vessel shape) comprises a large fraction of the effort. This can be done by using static ship plans, digital plans derived from computer assisted design packages, and possibly through new techniques using digital stereographic photography (mentioned by P. McGillivary).

Discussion of CFD modeling at this point turned to potential proposals to fund research vessel modeling effort. The two primary approaches discussed were (1) to use off the shelf models (e.g., GERRIS) to conduct flow modeling and (2) to develop a "block" model approach that would consider different research vessel forms, but not individual vessels. The latter method is of interest in the UK and may be a focus of a UK proposal. Within the U.S., the proposal discussion focused on using the AARV (U. of Alaska) as a pilot vessel for a CFD modeling effort. In this case, we would be focusing on a vessel that is still in design but will be built soon. One goal of either CFD proposal should be to determine the minimum number of ship-relative wind angles that are necessary to find the "best" sensor location on a vessel. A recommendation was made for SAMOS to draft a letter outlining the importance of CFD modeling of new vessels during design to ensure proper exposure of their meteorological instrumentation (e.g. send to UNOLS Fleet Improvement Committee, NOAA OMAO, Navy).

Radiation measurements from vessels provide essential measurements that aid in the understanding of the surface radiative fluxes. Radiation measurements are needed by climate modelers and numerical weather prediction centers (for validating satellite radiation estimates and cloud studies) and are important to determine the bias adjustments and algorithm improvements necessary to derive satellite products. For the air-sea flux community, in-situ measurements help determine where large biases exist in derived radiation products prior to their use in deriving the global energy balance. In general, the SAMOS working group was in agreement with the assessment of Chris Fairall that by deploying low-cost sensors on a number of research vessels (and possibly VOS), we could derive better radiation estimates than those currently based on cloud and meteorological observations combined with models. The discussion of radiation measurements at sea focused on establishing standards for research vessels. At the first level, the standard would include each vessel having two sets of pyranometer and pyrgeometer (upward looking) pairs. The sensor pairs should be located far enough apart so that they are not both shadowed at the same time by any vessel structures. In addition, ventilated sensors are preferred to reduce dust buildup on the domes. The need for periodic cleaning of the domes makes this minimum standard only practical on research vessels and VOS with at-sea technicians or riders. A second level of more advanced radiation measurements may be undertaken by a select set of specially equipped research vessels. These vessels would have to be equipped with tilt-stabilized platforms for the radiation sensors and may be able to conduct solar tracking or shadowband radiation measurements. The second level radiation systems for ships would require further research and development and the panel agreed that there should be collaboration with the Baseline Surface Radiation Network's (BSRN) ocean working group. The future choice of vessels to equip with an advanced ocean radiation package would be determined in a manner that would best target the science drivers listed above.

The discussion next turned to the upcoming International Marine Technicians (INMARTECH) meeting to be held in Woods Hole, MA from 17-19 October 2006 (http://www.unols.org/meetings/2006/200610inm/inmartech06.html). There was agreement that the SAMOS initiative should have a presence at this meeting. Plans will include using INMARTECH 2006 as a rollout venue for the Marine Handbook. The suggestion was made by P. McGillivary to investigate having the handbook translated into additional languages. S. Smith will prepare a presentation on the SAMOS initiative that will include examples of good, adequate, and poor sensor exposures. To this end, everyone is requested to submit digital photography of sensor masts and instrument locations that can be used as illustrations in this talk. Finally, a proposal made to have the PSAFS deployed on one of the WHOI research vessels at the dock to showcase the calibration standards capabilities. C. Fairall, F. Bahr, and S. Smith will correspond with Barrie Walden and Bob Weller at WHOI to see if this demonstration will be possible.

The International Polar Year (IPY) is fast approaching and, at present, the SAMOS data center has no dedicated IPY funding. That said, discussions focused on recruiting vessels that will be participating in the IPY. B. Felix from Raytheon Polar Services felt it would be possible to get data transfers started from the *Gould* and *Nathaniel Palmer* in 2006. In addition, P. McGillivary will forward contact information to S. Smith for the research vessels he knows will participate in the IPY (including contacts in China). Our Japanese representatives were also requested to provide contact information for their polar research vessels.

The topic of technician training focused on a combination of on-line materials and personal interactions. The marine handbook will be the basis for an on-line resource for technicians. Suggestions included adding a frequently asked questions section, the possibility of having an email/chat list, and a list of content area experts for targeted questions. A vessel recruitment web page is needed to aid operators willing to participate in SAMOS. The page should include instructions and examples of how to fill out metadata forms, provide sample codes for data formatting on board each vessel, and contact experts for questions. A suggestion was made to encourage ship visits to improve one-on-one contact with vessel operators. Someone with experience in "best practices" for marine measurements should make the visits. The person should be at a level that fits between high-powered scientist and the technician, and they must be able to converse in the technician's language. The visits could be two fold: first including input on sensor deployment and exposure, and the second focusing on data collection, transfers to data center, and metadata. Combining the ship visits with the deployment of the PSAFS was suggested, but additional visits may be needed to reach more than two ships per year. Another possibility raised was to coordinate the ship visits with the UNOLS science inspections of vessels (contact John Freitag for possible support).

GOSUD working group report

Keeley and Delcroix opened the GOSUD session on Tuesday, 2 May at 1020: Keeley agreed to chair the session. Participants are listed in annex 1.

The first agenda item was to review the list of actions that have taken place since the last meeting in Southampton, UK in 2004. Results are listed after the action and recorded in annex 2.

The actions arising from the discussions at this meeting and follow on activities of those from the last meeting that were not fully completed can be found in Appendix A.

Status Reports

France began by describing their GOSUD-related program. This program acquires underway data from both: a) merchant ships (about 12) (see http://www.legos.obs-mip.fr/fr/observations/sss/), and b) French R/Vs (about six) (see http://www.coriolis.eu.org/). All data are transmitted to the GDAC via Inmarsat C. (Note that the merchant ship data are not inserted onto the GTS, unlike R/V data, for security reasons following requests from maritime companies.)

Canada noted that the TRACKOB reports from the first few months of 2006 are very few compared to other years. There is no obvious reason for this. Keeley offered to explore this noting that this is partly due to the security reasons noted above. Canada also noted that information received from Japan indicated that for most of the ships reporting TRACKOBS on the GTS, this is the sole source of data. France noted that underway data collected during servicing cruises for the TAO/ Triton array can be found on the TAO and/or JAMSTEC web pages. The GDAC should investigate this and take actions as appropriate to acquire the data.

France noted that the pCO2 data being collected through the IOCCP and CarbOcean programs all end up at the CDIAC in the U.S. For the moment, the participants still hold the data to a limited distribution until they have time to sort out comparison and calibration issues. Quality control is still a concern and continues to need attention as well. The CarbOcean is still committed to releasing the data by end of 2009. France also noted that associated observations such as XBTs and TSGs are employed during these cruises. Delcroix has contacted Spain to gain access to the data they have collected. Data collected by other nations or cruises are reported on the GTS. Petit de la Villéon noted that there might be some material at the GDAC site that is suitable for training purposes. He agreed to investigate this and notify Keeley.

The U.S. NODC (represented by S. Rutz) reported that they are now mirroring IFREMER's GDAC FTP site (ftp://ftp.nodc.noaa.gov/pub/data.nodc/iode/gosud). Each year, NODC archives a "snapshot" of the mirrored data. NODC archives each "snapshot" as a new version under accession number 0001715, which is discoverable through NODC's Ocean Archive System (http://www.nodc.noaa.gov/Archive/Search). In addition, the mirrored data are available through HTTP and an OPeNDAP server (http://data.nodc.noaa.gov/cgi-bin/nph-dods/iode/gosud), which NODC registered with OPeNDAP.org. NODC reported that some of these data may end up in the WOD (World Ocean Database), but perhaps not all (Rutz was asked to investigate). It was observed that U.S. holdings must be described by FGDC-compliant metadata records and IFREMER was not contemplating creating such records. It was noted in past meetings that much underway data existed at ICES. Rutz was requested to check that these data are archived at NODC.

SeaKeepers

Geoff Morrison of SeaKeepers reported that they have about 45 units installed and reporting both meteorological and oceanographic data (http://data.seakeepers.org/dps/DPSMain2.php). These were distributed on private yachts, cruise ships, C-MAN stations, and a French ferry among others. He also noted that they have opened up their patents so that others could build equivalent units for other installations. He also noted that they are encouraging other instrument manufacturers to plug units into the SeaKeepers housing. Some cruise ships are collecting water samples, but there is no comprehensive process yet to verify the operations of the TSGs. Morrison reported that they have recently received funding to set up a calibration facility and that this would begin soon. He noted that they were looking into distributing their data on the GTS in BUFR. Keeley noted that the data in TRACKOB form were still not getting out to the GTS. He and Steve Brodie from SeaKeepers had been able to track the data to the modelers in the U.S., but they were not yet leaving the U.S. Keeley will work with SeaKeepers to fix this. At the same time, Morrison noted there was some eight years of historical data and that he would work with the GDAC to move the data to the GOSUD archives. Finally, he noted that he was trying to encourage the U.S. Regional Associations to make use of the SeaKeepers' hardware for installation in coastal situations.

There was some question whether the appropriate metadata for GOSUD instruments was, or could be, held in the ODAS database or perhaps in the WMO Pub47. Keeley agreed to look into this.

Aquarius

John Gunn reported on progress of NASA's planned Aquarius mission. The launch is scheduled for March 2009. Argentina is building the main instrument. Goddard is building the "sea surface salinity" sensor. The satellite will measure brightness temperature and, after a number of corrections, will report sea surface salinity (SSS). The objective is to report SSS on a global scale at 100-km resolution monthly to a precision of 0.2 PSU. NASA is intending to work with as much real-time (weekly) SSS data as possible to validate the satellite measurements. To assist in surface validation, there is a pilot project to install and deploy salinity sensors on surface drifters from the Global Drifter Center in Miami. The operational part of the processing will be set up over the next two years in preparation for the launch. The processing part of the mission is funded for three years and it is intended that all data will be released to the public six months after collection. There is also a plan to do a re-analysis using higher quality in-situ data. Data will be available using FTP and netCDF.

SMOS

The Soil Moisture and Ocean Salinity (SMOS) satellite is planned for launch by ESA in September 2007. The development of the data processing is underway. The cal/val announcement of opportunity was issued in 2006; the scientific AO will be issued soon. Sensor spatial resolution will be typically 40 km. The orbit will repeat every three days and it is expected that the salinity precision on individual retrieval will be on the order of 1 PSU. Data will be made available through ESA (high-resolution level 2 data) and IFREMER (level 3, average maps). Precision is expected to be 0.1-0.2 PSU on average maps at typical GODAE scales. The satellite is planned to last three years with follow-on missions intended using smaller SMOS-type satellites.

OceanSITES

The OceanSITES program is in its initial stages. The Global Data Assembly Centre (GDAC) is being set up at Coriolis with perhaps a mirror site in NOAA. The data will be distributed in netCDF and it is intended that they become available as soon as possible after collection. The data will be collected at research moorings and the TOGA/TAO and TRITON moorings. OceanSITES is collecting appropriate information about the moorings and at this stage expects to be managing this metadata themselves. There has been some work done to standardize quality control procedures. The program is well connected into the U.S. QARTOD project. Data at the GDAC will include information collected by vessels transiting to moorings and so it is expected that there will be overlaps with GOSUD and SAMOS underway measurements. Those interested in more information should visit http://www.oceansites.org.

Interaction with SAMOS

The participants spent time discussing possible modes of interaction between GOSUD and the SAMOS project. Questions such as the following were raised.

- How to share data collected together?
- Do we need common access to the data and if so, how to do this?
- Do we need common quality control procedures, or how do we ensure consistency in managing the same variables?
- Would it be possible for the GOSUD mirror site at the U.S. NODC to be a contact point in common for both programs?
- What would be the linkages to the VOS program?
- If two archives are maintained, one for ocean data, one for meteorological data, then the data originating together will be split. How do we ensure that they can be readily reassembled?
- Both programs currently use netCDF to deliver data. To ease the reassembly of the data, do we want an identical or a similar netCDF file structure?
- Can we agree on a common naming convention, units, etc., within the netCDF files?
- What can GOSUD do to encourage more meteorological data to flow to SAMOS and what can SAMOS do to encourage more ocean data to flow to GOSUD?
- Can we get clarification from the scientific and operational communities on the goals for number of ships and regions that need to be covered?
- How can we maintain coordination between Argo and GOSUD?
- Can we advance the transmission of SeaKeepers data to Coriolis?
- Is there a need to encourage cooperation with SMOS and Aquarius mission?

At the end of the day, a number of possible solutions were agreed to. These will be reported in the results of the joint meeting.

The session ended with the suggestion that the next meeting be held in conjunction with an upcoming SOT meeting scheduled for Rome in the first quarter of 2007. This was agreed to be a good target for the next meeting.

Annex 1: List of Participants

Jacqueline Boutin – CNRS, France
Patrice Cousineau – Integrated Science Data Management (formerly MEDS), Canada
Thierry Delcroix – IRD, France
Gustavo Goni – NOAA/AOML, U.S.A.
John Gunn –ESR, U.S.A.
Bob Keeley - Integrated Science Data Management (formerly MEDS), Canada
Geoffrey Morrison – Sea Keepers, U.S.A
Loïc Petit de la Villéon – IFREMER, France
Steven Rutz – NOAA/NODC, U.S.A.
Benoit Tranchant – Mercator, France
David Varillon – IRD, New Caledonia
Scott Woodruff – NOAA/ESRL, U.S.A.
Huiqin Yang, U. of Miami, U.S.A

Annex 2: Review of actions from the meeting at Southampton, UK in 2004

Item	Action	Who	When
1.	MEDS and Coriolis to decide and implement how real-time data from GTS contribute to GOSUD **Done**: GTS data received at MEDS, passed through auto QC, and transferred daily to Coriolis. Some delays in including the data from MEDS were encountered due to needing to preserve surface current data. This is now resolved.	Keeley and Carval	next meeting
2.	Need to get Japanese and other data into GOSUD **Done**: Japanese data from VOS will only appear on GTS. Data collected from TRITON service cruises available on TAO web site.	co-chairs, Rickards	next meeting
3.	Australia agreed to document data flow from their ships and provide to co-chairs **Not done:** Keeley to contact Australia to inquire about this.	Butler	1 Jan 2005
4.	AOML to notify MEDS when data first go out to the GTS and MEDS to verify that they received the data from the GTS (to check the distribution on the GTS). **Not done:** This is still intended. See report of meeting.	Goni, Keeley	next meeting
5.	AOML to document delayed QC procedures and provide to GDAC for inclusion on web site. **Partial**: This should be done in summer 2006.	Chong, Carval	next meeting
6.	Suggested AOML contact SAMOS in US to determine level of cooperation / duplication and to take appropriate actions and report to next meeting. **Unknown**: Keeley to follow up.	Yeun-Ho, Cook	next meeting
7.	Need to compare underway data available from WOCE DR V3 to what have been made available at GDAC and in WOD. **Partial**: WOCE data now in GDAC archive. Still a question of resolving ship names for IRD ships. Also needs some QC carried out.	Petit de la Villéon, Rutz	next meeting
8.	NODC to implement a long-term archive and mirror service of the GOSUD GDAC. **Done**: NODC pulling data daily. Data available through FTP, HTTP, and OPeNDAP servers.	Rutz	next meeting
9.	Coriolis to provide a description of statistical tests performed on RT data prior to feeding data to modelers. **Partial**: Description is done. Ouellet at MEDS has included TRACKOB into OI. There is a possible collaboration with Coriolis on this work.	Carval, Delcroix	next meeting

10.	Identify the duplicates problem(s) needing solution, propose solution(s), and to begin implementation as possible. **Done**: There is no problem with duplications between GTS and directly received data. No other issues identified.	Keeley, Vladimir, Rutz, Petit de la Villéon	next meeting
11.	Products or documents of interest to GOSUD should be linked to/from the GOSUD web pages **Partial**: IRD documents are referenced, but getting references is difficult. The best way seems to be to scout published documents.	all, Loïc Petit de la Villéon	on-going
12.	Set up a subscription service **Not done:** This action will be suspended until it is clear there is a strong need. With Argo, there has been a poor experience with subscription service. so,	Carval	next meeting
13.	Define how to distinguish data of RT or DM quality and resolution and how to indicate this easily to users. **Partial**: netCDF format records original and corrected data in same structure. Corrected is inferred as delayed.	Rickards, Carval, Delcroix, Keeley	next meeting
14.	GDAC to prepare a document or help page that describes the various ways data can be accessed from the GDAC. **Done**	Carval	next meeting
15.	Keep under review how GOSUD data can be used by modelers. **Partial**: Experience being gained at least through Mercator and Canadian efforts.	co-chairs	next meeting
16.	Draft a reply to specific questions raised by metadata requirements proposed by SAMOS. **Partial**: Response was drafted. Need to re-examine to be sure necessary information is present.	Keeley, Delcroix, Rickards	31 Oct, 2004
17.	Develop details of how SAMOS and GOSUD will cooperate. **Done**: The subject of this meeting.	Keeley, Delcroix, SAMOS	next meeting
18.	Keep GOSUD informed of developments in the FerryBox program. **Partial**: IFREMER will be working with data collected by ferries. Keeley to ask Rickards for update. See also Oceanology International 2006 meeting.	Rickards	next meeting
19.	Complete 2003 Annual Report. **Done**: Reports for 2003, 2004 completed. Report for 2005 to be started mid 2006. Target completion by SOT 2007 meeting.	Keeley	Dec, 2004
20.	Provide information to Keeley on who is using GOSUD data, and statistics on data downloads. **Done**: Will be part of 2005 annual report.	all, Carval	30 Nov, 2004
21.	Provide comments on the proposed BUFR template for underway data **Done**: Keeley provided comments. More work will take place in context of JCOMM. The proposed template reproduces TRACKOB. JCOMM will be pursuing this more vigorously.	Keeley	31 Oct, 2004
22.	Prepare poster for IODE meeting and if possible for GODAE meeting **Done.** International Marine Technology (Inmartech) meeting is opportunity to promote GOSUD this summer. Can we combine with SAMOS presence? Keeley to pursue.	Rickards, Keeley, Petit de la Villéon, Delcroix	Nov, 2004, Apr, 2005

Speaker program

Gary Wick kicked off the Wednesday speaker program with a discussion of in-situ data needs to improve and validate satellite-derived sea surface temperature products. A complex pattern of spatial differences exist between infrared and microwave SST products. In some regions (e.g., off the west coast of Africa in the tropical Atlantic, Arabian Sea) aerosols can adversely affect satellite retrievals of SST. In terms of in-situ comparisons, most are completed using moored buoys and drifters. Moored buoys have good calibrations and high data quality, but have lower spatial sampling. Drifters have better sampling, but poorer calibrations. Automated shipboard measurements are primarily from intakes, for which intake heating can be a concern, and more recently from radiometric sea temperature sensors. In general, shipboard data were found to play a more significant role in the delayed mode reprocessing of SST products (to remove biases, etc.) while buoy observations are more commonly used in real time. Recently, a National Oceanographic Partnership Program project has been implemented to expand the number of radiometric SST sensors on ships. One interesting preliminary result presented was the accuracy for SST retrievals was generally better when using bulk SST versus radiometric SST observations. This may be related to the higher variability of skin temperature observations from radiometric sensors. The needs expressed by Gary for in-situ observations from ships to validate SST products include independent observations (withheld from NWP), sufficient accuracy, and adequate sampling of all representative environmental conditions (e.g., high wind cases, sharp SST gradients, in regions of high aerosols, etc.).

The role that in-situ measurements can play in the upcoming SMOS and Aquarius satellite salinity missions was presented by Jacqueline Boutin and John Gunn, respectively. SMOS is scheduled for a 2007 launch and will be capable of providing complete sea surface salinity (SSS) coverage every three days. Aquarius is planned for a 2009 launch and will produce complete global coverage every seven days. For SMOS cal/val, Jacqueline emphasized a need for high quality wind data because wind waves have a significant impact on SMOS SSS retrievals. In addition, high quality in-situ SSS, SST, atmospheric pressure, and air temperature data are desired for validation efforts. Jacqueline provided a preliminary analysis of the impact of wind speed and SST bias on retrieved SSS along with an assessment of the number of in-situ samples needed in a ten-day window to achieve a 0.1 PSU accuracy from SMOS. This analysis resulted in a summary table of requirements for in-situ measurements for SMOS cal/val (Table 1). The Aquarius Validation Data Segment (AVDS) will coordinate in-situ data for cal/val of Aquarius (and SMOS). Although the primary Aquarius validation plans focus on drifters for SSS and SST, additional high-quality meteorological data (if available in a desired seven-day window) would be useful. To aid satellite validation efforts, John noted that current research vessel and VOS data archives need to allow easier extraction of data by location, time, and parameter. John expressed the opinion that SMOS will perform better for SSS, as Aquarius was designed to measure soil moisture over land in addition to making ocean measurements. Overall, with some improvements in data search capabilities, both SAMOS and GOSUD appear to be well positioned to provide cal/val data for satellite SSS missions. According to Jacqueline, with respect to moorings, GOSUD and SAMOS measurements can provide global ocean coverage across a wide range of oceanic and atmospheric conditions. With respect to Argo data, GOSUD and SAMOS can provide complementary observations necessary to interpret differences between in-situ and satellite-retrieved SSS (from SMOS and Aquarius).

Table 1: Requirements on in-situ measurements for SMOS Calibration and Validation (extracted from presentation by J. Boutin).

	Sampling	Accuracy	Precision	Remarks
Parameters needed to compute Tb with present forward models (resolution ~40km):				
SSS	Nmeas = 16 in 40x40km pixel (optimal)	0.05PSU	0.1PSU	Depth: Upper layer (same as SST)
SST	Similar to SSS	0.3°C	0.5°C	Depth: Upper layer (diurnal cycle) (L-band signal coming from 1cm depth)
Wind speed (direction)	hourly	0.2m/s	1m/s	Computed at 10m height (equivalent neutral)

Benoit Tranchant provided an overview of the assimilation of SSS data into the Mercator ocean model. The assimilation methods have been steadily improving since 2001 and their model has been expanded to global coverage, from Atlantic only, in 2005. Benoit is working on experiments to assimilate SMOS and Aquarius data into the model. A larger reduction in root mean square (RMS) error has been achieved by assimilating the simulated SMOS level-3 data (10-day maps) versus using the individual swath data. In addition, the assimilation of SSS from two satellites results in better model products, although the improvement is small. In terms of using in-situ observations from SAMOS and GOSUD, the pathway to improving the model assimilations is through improvements to the satellite SSS fields. There is no direct assimilation of in-situ observations in the Mercator model.

The southern ocean is an area of special scientific interest for the air-sea flux and climate communities. Janet Sprintall introduced two primary science applications that rely on in-situ ocean and atmospheric measurements in the Southern Ocean. Variability in the Antarctic Polar Front can now be assessed using infrared and microwave satellite sensors, although a necessary first step is to validate the Polar Front position using shipboard sea temperature observations (e.g., from TSG and XBT). Variability in the polar front location responds to meridional shifts in the wind fields. Wind fields can also be determined from satellite, but need to be validated with in-situ observations at these high latitudes. The upper ocean heat budget in the Southern Ocean is another topic that can be addressed using shipboard measurements. Well-understood surface heat flux products (known biases and uncertainties) are essential for the upper ocean heat budget. In-situ validation data are needed to assess the quality of existing flux products and to reduce the large uncertainties in all terms of the upper ocean heat balance for the Southern Ocean. In addition, the complex upper ocean processes near strong gradients are not well-resolved using existing measurements (either satellite or in-situ). The Southern Ocean provides a challenge for in-situ measurements. Currently the region is data poor, has very few over water wintertime observations, and all products for the region have large uncertainties. Routine shipboard sampling is limited to eight main XBT lines, while the available research and re-supply vessel meteorological and oceanographic observations do not routinely enter the SAMOS or other data systems, and hence are rarely used to validate heat flux products or for general scientific analysis. Additional sampling is needed in both shipboard meteorology (especially winds) and newer sampling efforts (e.g., pCO2). Measurements during the winter months are needed, including SSS which plays an important role in the upper ocean heat balance in the Southern Ocean.

The role of in-situ data for improving satellite flux products was presented by Hiroyuki Tomita. In general, satellite-derived air-sea fluxes are calculated using bulk flux algorithms. The focus is to produce daily fields. Parameters for the bulk flux calculations are derived from microwave radiometers (wind speed, specific humidity, SST), scatterometers (wind speed), and infrared radiometers (SST). Large differences are noted when satellite products (e.g., J-OFURO, HOAPS) are compared to in-situ only (e.g., NOC) or reanalysis flux products. Zonal averaged latent heat fluxes (Fig. 1) show the extent to which many of the current air-sea flux products differ. Hiroyuki provided some examples of comparisons of the flux products to in-situ observations. At present, these are limited to using moored buoys (TAO, JMA, NDBC) with the resulting latent heat flux bias ~8.5 W/m2 and an RMS of ~49 W/m2. Point comparisons to the Kuroshio extension mooring showed large differences between in-situ and satellite-derived specific humidity. This exercise showed the value of in-situ measurements (from buoys and ships) to help determine the parameters (Tair, Qair, SST, winds) that have the largest impact on the resulting flux fields. Finally, he noted that great care must be taken when blending in-situ data into gridded air-sea flux products. An example provided showed the clear signal of the TAO mooring chains in the specific humidity fields from ERA40.

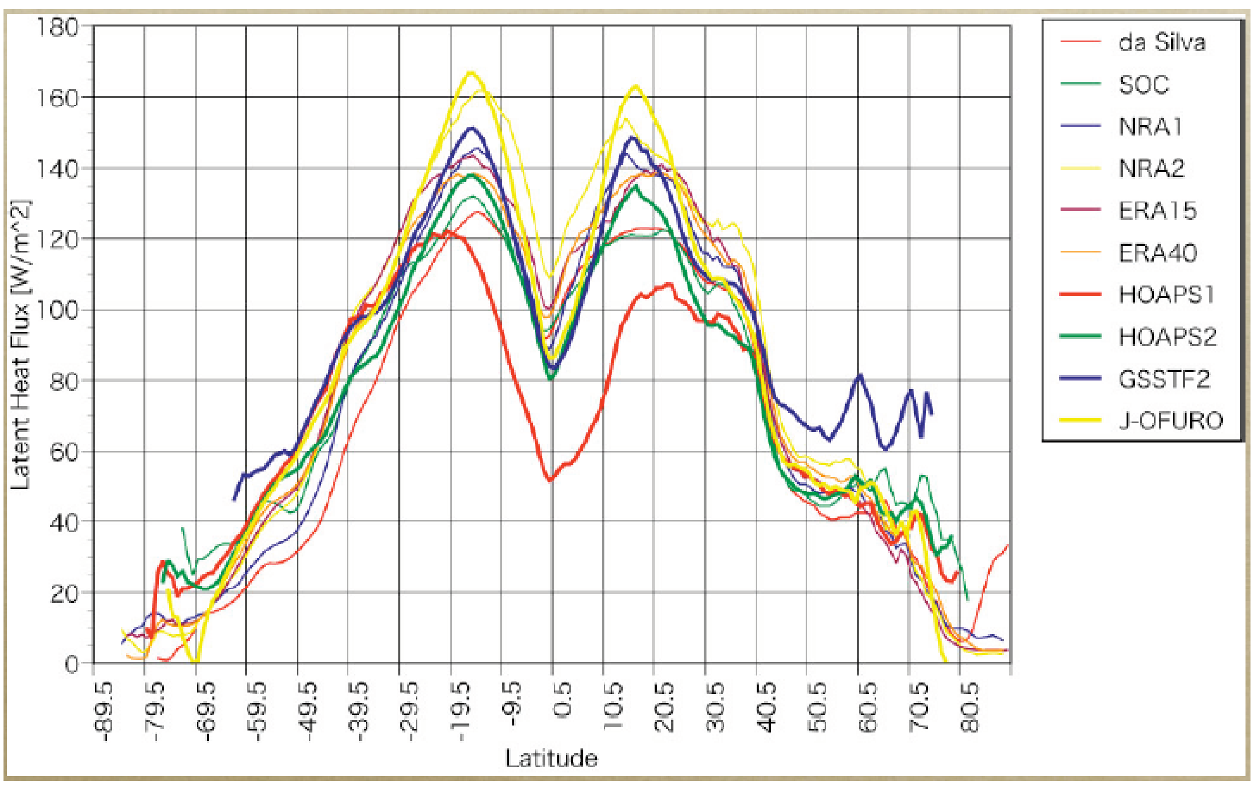

Figure 1. A comparison of zonally averaged latent heat flux for the period 1992-1993. Extracted from H. Tomita's talk.

Frank Bradley presented a talk on the complex problem of collecting rainfall measurements on a ship. One motivation for collecting high quality in-situ rainfall observations at sea is to validate the satellite-derived precipitation measurements that are heavily relied on by GEWEX and other climate programs. Rainfall estimates are essential for understanding the cycle of evaporation, precipitation, and cloud formation and are a priority for predicting climate change. Rainfall also plays a key role in the net energy and freshwater balance at the air-sea interface, especially when trying to resolve sub-daily temporal scales. There are two primary in-situ sensors used for rainfall on ships: Optical and Siphon rain gauges. Siphon rain gauges are volumetric and easy to calibrate, but they distort the wind flow over the funnel (resulting in under catch), are affected by ship motion, can be plugged by debris, miss catch when siphoning, and can be prone to evaporation loss. Optical gauges are sensitive to low rain rates and have less problems with flow distortion, but are more difficult to calibrate and have an uncertain response to wind direction. Challenges of measuring precipitation in the marine environment include bird guano, capture of sea spray in heavy seas, and the ever-present distortion of the airflow over a vessel. Frank also noted that corrections for rainfall could be derived when nearby wind measurements (relative to the ship) are available. In summary, Frank provided the following recommendations for making rainfall measurements at sea:

- Use a single location, if possible elevated to avoid severe updrafts
- Deploy both a siphon and an optical rain gauge
- Have an anemometer at the same location for correction
- Pre-cruise, operate the gauges at a land site, preferably alongside a tipping bucket instrument
- Continue to collect rain data in dock to compare the optical rain and siphon gauges under more favorable conditions
- The new Hasse gauge shows promise, but is not yet an operational instrument

Wave measurements, as presented by Val Swail, have been addressed as an important measurement for a wide array of applications (e.g., loads on structures and ships, ship and platform operations, coastal impacts, bottom scour, weather and climate) at several past meetings and workshops. That said, there has not been much action to improve the number of high quality wave measurements. The problem is in part due to the lack of a low-cost automated wave measuring system. Most existing systems are high cost due to limited commercial demand. In addition, VOS ship routing tends to minimize the number of good wave data sets. Commercial ships generally want to avoid high wave environments. At present improving automation of wave sampling on VOS may not be possible; however, research vessels with their onboard technicians should be further exploited as wave measurement platforms. Several new technology solutions are being explored, including radar systems (very high cost), Tucker instruments, downward looking lasers, and ADCP. At issue is the fact that waves are hard to measure. You must first define what you want to measure (has this been done for climate and fluxes?) and then you must understand the varying responses of ships (or buoys) to the waves. Where to place shipboard sensors is a concern (holes in ship often discouraged, sensors can be too exposed and subject to failure) and you have the usual problems of power consumption, onboard data processing, and data transmission. Clearly, there is much work to be done to move forward with improved wave observations. To that end, Val wrapped up with a series of recommended actions including:

- More measured wave data and significant wave height (from 2-D spectra), no preference on location or whether data are real time or delayed;
- More open-ocean wave measurements in the Southern Ocean and tropics;
- More high-quality automated wind measurements (which can be used to model waves);
- More high-quality research vessel wave data (see Rockall Trough results in Val's talk);
- More development of (automated) ship wave measurement system;
- More development of other (e.g., buoy) wave measurement systems;
- Development of JCOMM extreme measured wave data base (proposed);
- Inclusion of more wave measurements in existing marine data bases (e.g., ICOADS);
- Development of wave products in ICOADS – coordinate with JCOMM TT OPD;
- Better linkages of JCOMM Expert Team-Waves and Surges, Expert Team-Marine Climatology, Ocean Coordination Group (Data Buoy Cooperation Panel, SOT); Ocean Observation Panel for Climate; SAMOS; GOSUD.

Atmospheric radiation is another challenging measurement on marine platforms. Ellsworth Dutton, chairman of the Baseline Surface Radiation Network (BSRN), was invited to provide his perspective on this challenge. The BSRN program currently has measurement sites in more than 18 countries focusing on the goal of providing the highest possible quality, climatically-diverse, surface-based radiation measurements for climate and remote sensing applications. They have a standard suite of measurements, data specifications, and a central archive. BSRN requires adherence to its specifications, but has no central funding. It is a cooperative project of WCRP and GEWEX and relies on volunteers working for individual countries with independent funding sources. Ellsworth showed some nice slides showing how the efforts of BSRN partners has resulted in improved measurement accuracy and how land-based measurements compare with new satellite-derived radiation products. Although the BSRN program is currently focused on radiation over land, they recognize the need for more high-quality ocean surface radiation measurements. BSRN has a small ocean radiation working group that may be of interest to SAMOS. This working group is charged with revisiting the BSRN land specifications to consider modifications for an ocean standard. A potential BSRN-like suite of shipboard measurements could include downwelling solar and longwave irradiances, direct and diffuse solar, Aerosol optical depth, cloud imagery, and surface meteorology.

Elizabeth Kent provided an overview of the sources of bias and methods of correcting for these biases in meteorological observations collected on ships. Wind observations can be biased due to airflow distortion, improper height adjustment, anemometer calibrations, and inhomogeneities between visual and anemometer observations. Sea surface temperatures are subject to bias from variations in measurement depth, sensor calibration or drift, heating (cooling) of the local environment, or by mixing of the surface ocean layer by the observing platform. Radiative heating, improper height adjustment, sensor drift, and sensor ventilation all affect air temperature and humidity measurements. In addition, humidity sensors can be biased by drying of the wet bulb wick and salt contamination. Pressure observations can also be biased due to sensor calibration/drift, wind effects on the pressure port, or having barometers located in a sealed bridge or lab. Biases can be identified directly by comparison to high quality data from ocean weather ships or research vessels. One can even determine biases using "biased" observations, but one must understand the error structure of the data. Another approach compares model output (e.g., from NWP) to in-situ ship observations. This approach assumes that the model has a consistent spatial bias structure. This method was used to determine that hull SST sensors have a lower bias and stay fairly constant during the diurnal cycle as compared to bucket SST. Airflow modeling can also be used to assess bias magnitude (see next paragraph). Other techniques to identify bias include laboratory tests and triple co-location given three independent estimates of the same quantity. Elizabeth again emphasized the importance of metadata to do bias corrections. One must know the sensor heights, exposures, and calibration information. Metadata collection continues to be a challenge (ask for too much and get nothing), but one can sometimes work with proxy metadata (e.g., look at the skewness of data distribution by observing country). As a final thought, Elizabeth noted that bias correction could be applied to rehabilitate data for a wide range of applications.

Airflow modeling of vessels has been used to identify regions of acceleration/deceleration of the flow over several research vessels. Ben Moat provided a review of these past efforts, outlined some characteristics of airflow over a vessel, and described some options for a computational fluid dynamics (CFD) modeling program for SAMOS. The problems that can be addressed using CFD modeling include identifying acceleration (and deceleration) of the airflow at a given instrument location, determining the effective measurement height (vertical displacement of the air), and defining bias corrections for measured values. The overall goal for SAMOS is to achieve an effective CFD tool that can be used both during vessel design and for existing vessels to determine optimal sensor locations on each vessel. The challenge is to find a balance between the time and financial cost of the modeling effort. Ben noted that although flow distortion is not very sensitive to ship-relative wind speed, the distortion is very sensitive to changes in ship-relative wind angle. In a general sense, there are four steps to the CFD modeling process:

1. Creating the ship geometry;
2. Generating the 3-dimensional mesh;
3. Computing the solution; and
4. Post-processing (to estimate wind speed bias and vertical displacement).

Creating the ship geometry can be achieved using ship plans (digitization) or by obtaining a model from the naval architects. Both methods require substantial man-hours to implement. Creating the mesh has historically been the most difficult part of CFD modeling, whereas, computing the solution is mostly dependent upon the speed and memory capabilities of the computer hardware. Ideally, the CFD is employed during the vessel design phase. Recent work on the RSS *James Cook* revealed that a streamlined superstructure and an uncluttered foremast placed far forward reduced the flow biases. Ben's talk outlines a number of available CFD codes along with their strengths and weaknesses. He also introduced a parametric method being explored in the UK. In summary, Ben noted that the existing CFD codes (GERRIS, VECTIS, FLUENT) might be a good approach for a small number of vessels, but that the potential for modeling a large number of vessels is better with the parametric approach. The latter is not operational and would require an initial investment in research and development.

Mark Bourassa presented an analysis of the sensitivity of fluxes to the individual measurement accuracy. The analysis was undertaken, in part, to assess the accuracy requirements for the SAMOS initiative and to aid some decisions on accuracy needed for CFD modeling. One challenge is that accuracy targets are dependent on the downstream data application. Overall, his results showed that the proposed SAMOS accuracy table is pretty good for climate applications and needs some added discussion and qualification of the conditions under which they apply. For example, these flux accuracy targets could not be achieved within a strong marine cyclone or other areas of strong winds. Mark noted that one could use the ratio of sensitivities between parameters to see where we get more bang for our buck (in terms of focusing on sensor technology improvements). Heat fluxes are fairly sensitive to higher wind speeds and to large air/sea temperature difference. Mark recommended tightening the SAMOS accuracy requirements for mean wind speed and SST. Tighter requirements are also preferred for satellite calibration efforts. Finally, he noted that surface current and wave data are needed to further improve flux accuracies (the absence of these observations could dominate speed-related errors), but a technology solution is needed to automate these measurements.

The Wednesday speaker program concluded with four talks focusing on potential collaborations between SAMOS, GOSUD, and other marine observing programs. This session began with a presentation on the Coriolis project by Loïc Petit de la Villéon. The Coriolis project was introduced as a French contribution to a global structure for operational oceanography. The in-situ observing component of Coriolis is comprised of real time data for model assimilation, delayed-mode data for validation of models and satellites products, and the generation of products. Coriolis envisions a one-stop shop for in-situ ocean data. Coriolis is a partnership between seven French institutions and collaborates with a number of international programs. The core of Coriolis activities is the data center. The center uses a relational database to store information from a wide array of observing platforms (including ships, mooring, floats, etc.). They employ a wide array of automated and visual quality control and create products for the ocean community. As the home of the GOSUD data center, Coriolis evaluates the underway TSG observations received via the GTS. The data center is also the repository for meteorological, TSG, XBT, CTD, and other ocean measurements. Most research vessels are operated by France, but the effort is expanding out into other European countries. As opposed to the VOS data received through GOSUD, most of the research vessel data are delayed. The potential for collaboration between Coriolis (GOSUD) and SAMOS is great. Loïc suggested starting with a pilot data exchange using the R/V *Atalante* and one of the U.S. vessels (possibly the *Knorr*). The exchange would push French meteorological data to SAMOS and SAMOS TSG data to Coriolis. Coriolis would gain valuable insight into meteorological data quality evaluation through this exchange, while SAMOS would gain regular quality evaluation of TSG data through the experience of Coriolis. Another potential area of collaboration is the OceanSites project for which Coriolis serves as the global data assembly center. The OceanSites moorings require routine maintenance from ships and these vessels could provide additional data to GOSUD and SAMOS. Several issues related to data tagging, shared data distribution, and possible distribution on the GTS were raised. Several action items have been crafted to address our collaborative activities (see Appendix A).

Phil McGillivary gave an interesting talk on the future use of autonomous surface vessels (ASV) for in-situ air-sea measurements. The first option discussed was a self-positioning buoy. This buoy has the potential to be launched from a land site, will travel to its "station," remain for a period, and return for service as needed. They could be redeployed or re-tasked via satellite communication and do not necessarily require the use of large service vessels. They could also be deployed simply as arrays. Several technical challenges (e.g., stability, performance in extreme environments) need to be addressed, but the future looks bright. An alternative is the expanding number of ASVs that are coming to market. These range from aluminum multi-hulls to Robo-kayaks. Current battery life limits these vessels' speed and range, but advancements in battery technology will improve capability in the future. Another obstacle to overcome is the addition of instrument masts to the ASVs. One example he showed was the NASA Adaptive Sensor Fleet Ocean Atmosphere Sensor Integrated System. This platform is intended for use in satellite calibration and validation exercises. Some of the ASVs are being equipped with CTDs and winches with capability for measurements on the order of 100-m depth. As a final glimpse into the low-cost future, Phil described an effort to launch PICOSATs for use in data transmission and communications. These mini polar-orbiting satellites can provide low cost communications over their 1-3 year life span. To be viable for an ocean observing network, one would envision a constellation of PICOSATs.

For several years, the data center at FSU has been evaluating the quality of marine meteorological observations from two NOAA research vessels. Douglas Perry presented an overview of the shipboard data program at NOAA and discussed the potential to include data from 18 to 19 vessels to the SAMOS data center. NOAA is currently undertaking a fleet standardization, which will result in two ship classes comprising 10 of the 19 vessels by 2009. This vessel form standardization should ease future CFD modeling efforts for NOAA vessels. In addition, all vessels will soon have the updated Scientific Computer System software (SCS version 4.0). NOAA is also moving towards standard instrument suites and communications systems (ten ships will have 24/7 broadband communication by the end of 2006). Doug mentioned that they need to improve upon capturing metadata early in their processing. They could also collaborate with SAMOS and GOSUD to improve their on-board data quality control. Currently, at the end of a cruise, a separate data set is created for the ship, PI, and the national archive at NODC. Areas of potential collaboration include developing a joint SAMOS-GOSUD-NOAA (OMAO, NODC, AOML, etc.) data management plan, improving bridge observations via automated data capture, and improving transfer of data to the national archives. Doug welcomed participants from SAMOS and GOSUD to a NOAA OMAO data workshop (to occur summer 2006). In addition, he plans to initiate a SAMOS and GOSUD pilot project using the new FSV *Henry Bigelow*.

The final presentation of the speaker program summarized the activities of the JCOMM SOT. Elizabeth Kent, stepping in for Graeme Ball, provided an overview of SOT and discussed some potential for collaboration with SAMOS and GOSUD. SOT is comprised of three successful data collection programs:

- Voluntary Observing Ship (VOS) Scheme;
- Ship of Opportunity Programme (SOOP); and
- Automated Shipboard Aerological Programme (ASAP).

VOS globally has ~5400 vessels providing data in real-time via the GTS and in delayed mode. Of these, about 140 have automated observing systems and the number of automated systems is growing. Automated systems allow for hourly reporting, but also provide a challenge for metadata collection and storage. The VOS Climate Project is a subset of about 150 VOS that comprise a high-quality reference subset for climate research, modeling applications, and benchmarking. SOOP is comprised of about 70 merchant and research ships globally. This program focuses on upper ocean observations via XBT, TSG, etc. The ASAP program is collecting upper atmospheric profiles (radiosonde) observations from a limited number of vessels. SOT seeks to improve communication and collaboration between groups that utilize VOS and SOOP as observing platforms. They are active in training Port Meteorological Officers and using these PMOs as primary contacts between the observing programs and the vessel masters. Elizabeth wrapped up by summarizing two primary areas of potential collaboration between SOT and SAMOS/GOSUD – promoting standards and metadata. Collaborative efforts within these areas could include:

- Promoting standards:
  - Instrument/sensor accuracy and resolution;
  - Ship or platform inspection regime;

  - Instrument/sensor performance checks
  - Sensor traceability to national/international standards;
  - Observing methods;
  - Observer/operator training;
  - Real-time data delivery;
  - Quality monitoring of real time data and strategies to expediently resolve problems or errors;
  - Quality control procedures for delayed-mode data;
  - Data submission to GDAC or GCC;
- Metadata:
  - Ship or platform particulars;
  - Instrument types and make;
  - Instrument exposure;
  - Observing program; and
  - Instrument/sensor calibration.

Poster Session

The speaker program was followed by an evening poster session. Topics of the posters included automation of marine measurements, air-sea flux studies, comparisons between marine data collection systems, and data stewardship.

Several initiatives continue to advance the automation of both near surface oceanographic and meteorological measurements from vessels. WHOI (F. Bahr) provided an update on the Air-Sea Interaction Meteorology sensors that have been deployed on VOS for the past five years. The systems interface with the SEAS 2000 system to provide hourly reports via satellite, while the raw observations are retrieved when the sensors are periodically retrieved and serviced. Patrick French provided some hands-on hardware, displaying a low cost micro weather station developed by ADA technologies. These small systems can provide wireless data transmission to a central collection point on a vessel and measure both meteorological and vessel position/motion data. The system is now undergoing testing on a NOAA vessel. Phil McGillivary introduced plans to use autonomous surface and subsurface vessels to make meteorological and ocean measurements during the IPY. A combination of autonomous vessels, PICOSATs, and traditional research vessels will allow more measurements to be collected at a reduced cost. Geoff Morrison presented a poster describing the Ferrybox Sensor Interface Standard (FSIS) and its relationship to the automated SeaKeepers' sensor suite. The idea behind the FSIS is to encourage manufacturers of flow through sensors to adopt a standard architecture, which will free them from having to acquire navigation data or to log/telemeter the observations. The latter would be handled by the SeaKeepers' system or other systems that adopt the FSIS. As part of the European CARBO-OCEAN program, the French have developed an automated system to measure the fugacity of CO2. The plans are to deploy this system on select VOS and two PIRATA moorings. The goal is to better understand the time variability of CO2 sources and sinks at the air-sea interface. In an effort related to improved automation, Chris Fairall provided an update on the progress of the NOAA portable seagoing air-sea flux standard. This system (see SAMOS working group report above) will be deployed to assess the accuracy of SAMOS onboard NOAA and UNOLS research vessels.

The air-sea flux community provided examples of the application of in-situ data to assess the quality of flux products. Masahisa Kubota presented a comparison of observations from the Kuroshio Extension Observatory mooring and the NCEP reanalysis products. The second NCEP reanalysis was shown to have smaller differences than the first reanalysis when compared to the KEO mooring. Some of the large biases were expected due to the high degree of variability in the Kuroshio Extension. Other portions of the bias were attributed to differences in flux algorithms and differences in the state variables from the reanalysis and the mooring. The poster reinforced the need for independent validation data over the oceans. Since SST plays a critical role in developing flux products, Shinsuke Iwasaki presented a comparison of two SST products: the Center for Atmosphere and Oceanic Studies (CAOS) and the Reynolds SST. Both products were compared to mooring observations. Differences between the CAOS and Reynolds products were largest in regions of strong gradients (e.g., Kuroshio, Gulf Stream, and Antarctic Circumpolar Current). Comparison to mooring data showed that accuracy of both products is good, but it is worth noting that the mooring data are assimilated into Reynolds, but not CAOS. The impact of the differences between the SST products can be upwards of 30 to 50 W/m^2 in latent heat flux in the regions of strong SST gradients. The final flux poster, presented by Mark Bourassa, examined the spatial variability in the random error and biases in the new FSU3 flux product. Biases in the Atlantic and Indian Ocean winds are generally small, with larger biases occurring in poorly sampled regions. When compared to satellite winds, the objective technique for in-situ data is producing error estimates with reasonable spatial patterns and magnitudes.

Data comparisons were presented in three posters. Frank Bahr presented comparisons between automated measurements made on two VOS and data collected by the Northwest Tropical Atlantic Station mooring. The goal of this comparison was to assess the spatial coherence scales for barometric pressure, air and sea temperature, relative humidity, and winds. Elizabeth Kent and Shawn Smith both presented comparisons of research vessel observations to VOS reports. The former used optimal interpolation (OI) to derive daily fields of SST, air temperature, surface humidity, and winds using the ICOADS and then co-located these daily values with independent hourly research vessel meteorological data provided by FSU. For the RSS Discovery, comparisons for sea and air temperature were good with most of the variability being captured. Pressure differences shown by the RSS Discovery data are not well represented by the OI pressure fields. The OI also cannot capture the sub-daily variations (especially in wind speed) revealed by the RSS Discovery data. Shawn Smith completed preliminary comparisons between the science quality meteorological data from R/Vs compared to the ICOADS (standard bridge) reports for the identical vessels. One problem illustrated by this comparison was the critical need for improved metadata for both ICOADS and from the science systems deployed on R/Vs. The most critical information is sensor exposure and height, as these are needed to adjust the ICOADS and science observations to a common reference height for comparison. For example, pressure differences of up to 6 hPa were revealed on some vessels. Part of this difference can be attributed to the ICOADS reports being at sea level versus the science reports being at the instrument height; however, in some cases the difference is still too large.

Data stewardship has always been a focus of the SAMOS and GOSUD projects. Shawn Smith provided an overview of the SAMOS data stewardship practices as part of a poster summarizing the SAMOS Initiative. Steve Rutz showed two examples of how NODC archives surface marine data. For GOSUD, data are pulled daily from the GDAC server and are archived once per year in the NODC's Archive Management System. Technicians send underway data from NOAA vessels to NODC at the end of a cruise and NODC archives each submission. A near future activity is to ensure that the SAMOS data are suitably archived at NODC. Scott Woodruff provided an overview and update on the ICOADS project. Recent releases include version 2.2 (updated through 2004) and version 2.3 which includes GTS data for 2005. Scott also presented a new supplement to the ICOADS that was created by FSU and contains high-quality research vessel reports from over 90 research cruises from 1990-1998. Stewardship of surface ocean data was described by Gustavo Goni and Thierry Delcroix. Gustavo's poster provided insight into the TSG transects maintained by NOAA/AOML. Currently, three transects are maintained and all observations undergo quality control to remove SSS drift, compare the observations to climatology, and test for spikes, gradients, and expected ranges. Buddy checks are completed using XBT, CTD, thermistor chain, and float data when possible. AOML is working to establish an archive of these quality processed observations. Thierry's poster focused on the French SSS Observation Service (http://www.legos.obs-mip.fr/observations/sss/). The service contributes observations to the GOSUD GDAC. All data undergo quality control and are used to derive products and climate indices.

Joint discussion

The joint discussion session centered around the three desired outcomes of the workshop (1) establishing a framework for collaboration between GOSUD and SAMOS, (2) defining near- and long-term scientific applications of SAMOS and GOSUD observations, and (3) providing practical guidance to vessel operators on the front line of data collection. The result of the day-long discussions was several recommendations and action items (Appendix A).

The workshop panel agreed that there are several avenues for collaboration between SAMOS and GOSUD and for expansion of the collaboration between the two programs through other activities focused on marine data collection. Both SAMOS and GOSUD are encouraged to continue and expand collaborations with the IOCCP and CLIVAR in the areas of ocean and atmospheric carbon measurements. There has been some initial dialog between SAMOS and IOCCP. The carbon community has a need for high quality meteorological and underway water measurements to compliment the automated pCO2 sensors. In addition, the participation of Ellsworth Dutton from BSRN at the workshop opened a new dialog focused on underway radiation measurements. He noted that BSRN has an ocean working group that could be a focus of collaborative activities with SAMOS.

Another area for expanded collaboration is within the community of polar vessels (including research, re-supply, and tourist). Initial contact has been made with COMNAP to design a strategy for improving routine meteorological and TSG measurements from National Antarctic Program vessels. A discussion brief provided by Antoine Guichard (COMNAP Executive Secretary) was circulated and comments were received via email after the workshop. To achieve the needs of National Antarctic Program vessels, any data strategy must focus on improved marine forecasts and safety at sea. The International Association of Antarctic Tour Operators also expressed interest in providing platforms of opportunity for ocean and atmospheric measurements. The panel noted that this might be an opportunity for the International SeaKeepers program to expand to the Southern Ocean. Finally, the group noted that there are several climate panels and programs (e.g., CLIVAR, IPY) that could benefit from the expertise and data collected by the GOSUD and SAMOS programs.

The discussion group noted that there are several avenues to be explored for collaboration with the VOS programs. In addition to the JCOMM SOT, within the U.S. the NDBC is focused on the U.S. VOS program while AOML is responsible for the SOOP vessels. As possible, these groups should collaborate in areas of real-time data distribution (GTS), metadata standards, and providing vessels with clear instructions of what data are needed by the science community. Several panelists noted that, while most research vessels are equipped with separate bridge and science instrument systems, it is not always clear which system is being used for standard bridge weather reports (logs or GTS). In some cases, the bridge crew may pull data from the science system instead of using manual or bridge sensors. The problem is that the source of the data is rarely reported and the loss of this metadata can cause problems during data analysis. There is a need for a clear message to be sent to vessel operators concerning recording the source of the reported observations and it was suggested that a handful of people from the panel work with SOT to develop this message for data collectors. In addition, the guidelines should be provided to bridge crews (especially on research vessels) to clarify the minimum information desired by the science community. An effort should also be made to collect and archive the bridge observations (logs) from research vessels participating in the SAMOS and GOSUD programs (coordinate as possible with SOT and VOS).

The question of whether or not to distribute meteorological observations from SAMOS via the GTS continues to be difficult to answer. On the one hand, withholding these observations for validation purposes is desirable (although with adequate metadata in the GTS reports to discriminate between different classes of data, users may selectively withhold data as desired). At present, only a very few SAMOS observations (those collected around 0000 UTC) could be made available via the GTS in a time frame needed by NWP. That said, there are a number of users (including private forecasters and marine data archive such as ICOADS) that desire data on the GTS well beyond the NWP cut-off times. Also, due to the question noted above about science observations being used in bridge weather reports, it is not at all clear if the SAMOS data are fully independent of the GTS. This dialog needs to continue, but in the meantime, SAMOS will explore options to place data on the GTS in a delayed mode through collaboration with the Coriolis data center.

A framework for a data exchange between the SAMOS and GOSUD data centers was discussed. As proposed, the exchange would send meteorological (TSG, other underway ocean) data collected by GOSUD (SAMOS) to the SAMOS (GOSUD) data center for quality evaluation. These data would then be recombined through some form of joint distribution system. A wide range of details will need to be worked out between these two centers and NODC (which has volunteered to serve as a joint archive). First off, the two centers will identify sample data sets to exchange so that each group can become familiar with the observations collected by the other center. In addition, plans were put forth to use the NOAA FSV *Bigelow* as a pilot vessel for data exchange from SAMOS to GOSUD. The *Bigelow* is scheduled to begin data collection around September 2006. GOSUD was requested to formulate a wish list of ocean variables of interest to the ocean community, which can then be provided to NOAA for the *Bigelow* pilot project. The SAMOS and GOSUD data centers will establish a method of versioning and uniquely identifying data sets that will allow for the separated ocean and atmospheric data to be recombined at the archive center. A dialog will be undertaken with NODC to explore the options for mirroring or other forms of distributed data access and archiving. Another topic raised was the need for a comparison of SAMOS and GOSUD metadata specifications to identify gaps in information and the need for some exchange of quality control techniques.

One topic central to the SAMOS and GOSUD collaboration and a main issue that arose in the SAMOS working group meeting, was the need for additional procedures for the collection of TSG data on vessels. SAMOS receives TSG observations from participating vessels; however, we need input from GOSUD to ensure that we are collecting all the necessary observations and metadata. We need to state what are ideal versus acceptable calibration practices for TSG and other water measurements (e.g., fluorescence, oxygen). The protocol should outline whether or not once-a-year factory calibration of the TSG is adequate (a common practice now). We also need to understand how water samples collected on a vessel are processed and whether there is a protocol to store and use this information.

Both GOSUD and SAMOS observations can be utilized to achieve a wide array of research and operational science objectives. The focus of the speaker program was to bring to light current and future applications for these observations. A series of applications were discussed during the joint session.

Validation of existing and new satellite sensors and products continues to be a focus for both the SAMOS and GOSUD programs. Several attendees working with the satellite community noted that there is a great need for more validation observations at the extremes of the observational distributions. For example, meteorological data during periods of high (> 20 ms^{-1}) and low (< 3 ms^{-1}) wind are needed to validate scatterometer data and other satellite wind products. These extreme wind cases are also useful for wave modeling studies. Generally, VOS try to avoid storms and much of the mooring data come from the tropics. As a result, high wind speed data are rare. Research vessels provide the best opportunity to obtain observations during extreme wind conditions.

In a few years, two new satellites will be launched to measure SSS. The requirements of SSS for calibration and validation will start with high quality SSS and related meteorological data (winds, air and sea temperatures) in regions where ocean salinity is relatively stable spatially. Later on, both satellite groups noted that there would be a need for SSS data in gradient regions (e.g., river mouths) and locations that experience high SSS variability. These in-situ SSS observations should be collected within the surface-mixed zone to ensure that observations are representative of surface conditions that will be measured by satellites (e.g., ~1 cm depth for Aquarius). During the SSS satellite discussion, the question was raised as to how well the vertical structure of SSS near the surface is known (upper 10 m). Argo float data indicate that the variations in near-surface SSS are smaller than expected satellite accuracy. Another study mentioned, which used surface drifters in the Bay of Biscay with T and S sensors at 50 cm below the surface, did not show salinity variations that could be unraveled from T variations. During TOGA-COARE, high-resolution surface observations revealed that surface fresh water lenses (e.g., resulting from precipitation) do not persist for very long. The panel agreed that the SSS community could benefit from a summary or review paper on the current state of knowledge of near-surface SSS variability.

The development of satellite-based air-sea flux products would benefit from an increase in high-quality specific humidity data. Humidity, at present, can only be estimated from satellites (no direct measurements) making any in-situ humidity data very valuable. In addition to humidity, vessels are encouraged to re-emphasize the recording of the vessel's motion relative to the water mass (via a speed log). The water-relative motion of the vessel is necessary to create ocean-relative (vs. true) winds, which are the best wind measurements to use when calculating turbulent fluxes. It turns out that most vessels report ship-relative and true (earth-relative) winds, which are not ideal for flux calculations. True winds can be adjusted to ocean-relative if the current is measured from the vessel (via ADCP or other technology). The panel noted that recording ship motion relative to the water is still required by the International Maritime Organization and that there is information available in the search and rescue manual about positioning a ship with respect to the winds and currents.

Beyond fluxes, the discussion again turned to the need for more/better wave measurements. As noted in Val's talk, many users could benefit from better wave data. The development of innovative, low cost, automated wave recording systems is needed before wide deployment on vessels will be possible. Several possible technologies were discussed including wave radars, stereoscopic digital imagery, ADCP, or laser range finders. Of these, the use of ADCP would seem a good choice to at least explore in depth, as many research vessels are already equipped with ADCP. Laser range finders and acoustic systems mounted on the bow may be possible, but they are very exposed and would be at risk in heavy seas. Other technologies to explore would be using the tri-axis ship motion sensors, but the hull characteristics of each vessel would need to be known.

Additional user requirements were raised. The ocean data assimilation community is interested in high quality sea surface height, winds, and surface currents in addition to the need for SSS. The altimeter community is looking at steric or mass changes, with an emphasis on the North Atlantic due to its importance for variations in the meridional overturning circulation. Another potential user group is the coastal science community. The point was raised that there are a lot of resources going into coastal science and they are an important client to consider. We should contact the Ocean.US Director, Mary Altalo (http://www.ocean.us/), for advice and possibly the IOOS subcomponent, the National Federation of Regional Associations (http://www.usnfra.org/), and seek collaborations with their observing programs that gather underway meteorological and near-surface ocean data. The NFRA is growing rapidly and will give full coverage of all U.S. coastal waters. These interactions would make SAMOS and GOSUD participants in the IOOS efforts and insure integrations of the data to a broad spectrum of users.

For the user community, there was as discussion that the SAMOS and GOSUD data centers should explore new methods to distribute their observations. One-minute values stored by cruise are not ideal for all users. Some would prefer hourly subsets of the available data. One example of this is the hourly subset of one-minute WOCE meteorological data developed by the SAMOS data center for ICOADS (http://dss.ucar.edu/datasets/ds530.1/). Additional lower resolution data sets, possibly sorted by synoptic time, should be developed.

A final discussion related to the science users focused on the possibility of placing instruments on select research vessels to achieve maximum data return on the sensor investment. For example, are there research vessels that conduct routine cruises in regions desired for wave, cloud, or radiative measurements? Since some emerging technologies (e.g., wave radars, tilt-stabilized radiation sensors, etc) will require a large capital investment, funding agencies would see maximum return on their investment if these instruments were deployed on select vessels. Another example is the need for more and better measurements in the Southern Ocean. Deploying sensors on vessels that routinely cross the Antarctic Circumpolar Current or circumnavigate the Antarctic would be desirable. The question raised is how do we influence where observations are made. First off, we should approach JCOMM-OPA for coordination help (also possibly something that COMNAP could help with in the Southern Ocean). We need to know which research vessels tend to operate on regular routes (e.g., the *Polarstern* yearly Atlantic transect to the Arctic and Antarctic).

The focus of the discussion to provide practical guidance to operators was on creating and/or publishing additional training and reference materials. Primary of these will be the fall 2006 publication of the "Guide to making climate quality meteorological and flux measurements at sea." Soon after hardcopy and possible CD publication, the SAMOS data center will design an on-line presence for the guide. One example of how the handbook will provide guidance is related to improving precipitation measurements by using a combination of a siphon and an optical rain gauge collocated with a wind sensor. This simple approach could greatly improve ocean precipitation estimates. An effort should be made to link the marine handbook to the technical manuals created for TSG by GOSUD. It would be helpful to have one or more of the marine techs review the GOSUD TSG installation manual and make comments. One example of input that manuals can provide is that TSG water flow rates should be monitored and provided as part of the standard data transmission packages. Another suggestion was to contact the OceanTeacher program to see if they would develop training materials for GOSUD and SAMOS.

The technicians at the workshop encouraged SAMOS and GOSUD to consider establishing ship visits. Visits should be conducted by persons well versed in the technology, able to explain the motivation for making the measurements, and able to communicate at the technical level.

Discussions noted that visits would build a human connection with the vessels and provide a quick opportunity to review instrument exposures and locations. There is the possibility in the U.S. of coordinating these visits with the UNOLS science inspections. In addition, visits could become part of the mobile reference standard evaluations of vessels. How to coordinate this with international research vessels is unclear, but the topic could be raised with the JCOMM SOT.

Another area of improvement (though not simply through practical guidance) was to motivate the ship operators to make high quality measurements. There is a need for additional outreach activities. SAMOS and GOSUD need to make operators and the public aware why these measurements are important. One suggestion was to send an article to the Mariner's Weather Log. Others include providing some token that signifies a vessel as participating in GOSUD or SAMOS.

For most vessel operators, their role in the long term archival of meteorological and oceanic observations needs to be readdressed. The current system of providing the data to the scientists so that they will forward the data to a national archive has never worked well. SAMOS, GOSUD, and NODC should open a dialog on this topic. We should consider what data are actually making it to the national archives and in what form (e.g., good or poor documentation). We need to consider the role of vessels in retaining copies of their original data and what to do with these data. Most large centers (WHOI, Scripps) have data libraries, while others keep the data on disk informally for months or years. A new policy for these data is needed to improve the chances the data will be available for users in 10, 20, or 50 years.

Several additional topics were addressed concerning practical guidance. The science community was encouraged to advise data collectors as to the "best" type of instrumentation to meet SAMOS and GOSUD objectives. Although SAMOS refrains from recommending specific sensor manufacturers, would it be prudent to offer advice on classes of sensors (e.g., optical rain gauges, sonic anemometers) for use at sea? In addition, the issue of biofouling of ocean sensors was raised. Some resources on techniques to reduce biofouling could be made available (new technology or possible links to information available from NOAA, UNOLS). Finally, the marine community was encouraged to explore future applications of ASV to achieve additional sampling at a reduced cost.

The workshop concluded with a brief discussion of future meetings. It was agreed that SAMOS and GOSUD should be represented at the INMARTECH meeting at WHOI (17-19 October 2006). Smith and others from SAMOS have tentative plans to attend. In addition, Smith plans to attend the 2007 SOT meeting to address collaboration between SAMOS and the VOS and SOOP communities. It is expected that there will be GOSUD working group meeting along with the 2007 SOT meeting. The panel agreed that another Joint GOSUD and SAMOS meeting should be held in two years time (~spring 2008). Efforts should be made to expand invitations to other shipboard data collection programs and user communities (e.g., fisheries and coastal).

Appendix A: Action items

Collaborative Actions:

Item	Action	Who	When
1	SAMOS to receive data from NOAA FSV *Bigelow* and will use this as the pilot for sending ocean data to Coriolis	Smith, Perry	Summer 2006
2	Coriolis to select a French R/V as pilot for meteorological data and metadata transfer to SAMOS	Petit de la Villéon	July 2006
3	SAMOS and GOSUD to agree on the data exchange format	Petit de la Villéon, Smith	July 2006
4	Investigate if ODAS database can store SAMOS metadata	Keeley	As possible
5	Review metadata information desired by GOSUD from ships providing ocean data	Petit de la Villéon, Keeley, Delcroix	July 2006
6	Investigate an appropriate template for combined SAMOS & GOSUD data (IMMA and/or BUFR)	Smith, Keeley, Worley, Woodruff, Rutz	Early 2007
7	SeaKeepers to push sample data to Coriolis	Morrison	July 2006
8	GOSUD & SAMOS to compare QC on SST	Smith, Keeley, Petit de la Villéon	Summer/Fall 2006
9	NODC to explore value of a common data structure to combine GOSUD & SAMOS data (possibly through OPeNDAP to extract met data from SAMOS and ocean data from GOSUD and combine in output). GOSUD/SAMOS to provide test data.	Rutz, Petit de la Villéon, Smith	Test Fall 2006
10	Work out a unique data identifier to link met and ocean data	Smith, Petit de la Villéon, cc Keeley	Fall 2006
11	Determine interest of SAMOS to be recognized as a pilot for JCOMM OPA	Smith	May 2006
12	GOSUD to seek assistance from SOOP, VOS to identify ships collecting ocean underway data and to get necessary metadata	Ball, Kent, others	Spring 2007
13	Cross linking of web pages (SAMOS, GOSUD, ICOADS, WGSF, others)	Petit de la Villéon, Smith, Fairall, Woodruff	As possible
14	Explore possibility of developing training materials through use of OceanTeacher for SAMOS and GOSUD	Keeley to initiate	As possible
15	Please send catalog of historical holdings of meteorology and TSG data from R/Vs to Shawn – Include time ranges, data volume, media type	all	As possible
16	Contact other vessel operators for catalog of meteorological and TSG data	Smith, Woodruff	as possible
17	Test netCDF formats for GOSUD and SAMOS to ensure that they are CF compliant, conform to a single netCDF convention (e.g., COARDS), and compliment Argo and OceanSITES plans	Smith	As possible
18	Create a mutual catalogue to discover SAMOS and GOSUD data and metadata (THREDDS, others). Explore possible linkage to proposed NCAR IPY data portal	Worley, Smith, Rutz, cc Keeley	As possible
19	Develop combined list of recommended measurements (and sensors) of interest to SAMOS, GOSUD	SAMOS, GOSUD	Fall 2006

20	Consider compiling a review article of underway marine sensors (approach Sea Technology staff about this effort).	McGillivary	As possible
21	Find U.S. docs that talk about sampling and accuracies needed from IOOS, Coastal, and GCOS efforts. Send to Smith, Keeley, and Delcroix.	Worley, Morrison	June 2006
22	Report to SAMOS/GOSUD the results of the CLIVAR salinity workshop as they relate to in-situ observing efforts (a few paragraphs would suffice)	Gunn	June 2006
23	Approach JCOMM ETWS concerning need for better technology to measure waves at sea from ships, develop a list of available and potential wave sensors.	Swail, Boutin	As possible

GOSUD Actions:

Note: Items 1-20 resulted from the GOSUD working group meeting, while items 21 and 22 arose during the joint discussion session.

1	TSG data from AOML started to be QCed and these will be made available to Coriolis	Goni	summer 2006
2	AOML to explore retrieving and QCing NOAA ship TSG data that are archived at NODC. Jun 2006: Goni reports this is underway	Goni, Rutz	1 Jan, 2007
3	AOML to consider doing QC in real-time for NOAA ships Jun 2006: expect this to begin by mid-year	Goni	TBD
4	Contact Australia to inquire about documentation of the data flow from their ships and provide to co-chairs	Keeley	next meeting
5	AOML to document delayed QC procedures and provide to GDAC for inclusion on web site	Goni	3rd quarter, 2006
6	AOML to contact SAMOS to determine level of cooperation / duplication and to take appropriate actions and report to co-chair	Keeley, Goni, Smith	3rd quarter, 2006
7	NODC to reference GDAC on their mirror site.	Rutz	next meeting
8	Coriolis to provide a description of statistical tests on both real-time and delayed mode data prior to feeding data to modelers	Carval, Delcroix	next meeting
9	Products or documents of interest to GOSUD should be linked to/from the GOSUD web pages	all, Petit de la Villéon	on-going
10	Keep under review how GOSUD data can be used by modelers.	co-chairs	on-going
11	Keep GOSUD informed of developments in the FerryBox program.	Rickards, Keeley	next meeting
12	Investigate reasons why the number of TRACKOB reports circulating on the GTS are lower in early 2006	Keeley	immediately
13	GDAC to investigate presence of underway data on the TAO/Triton web site collected during U.S./Japan servicing cruises.	Petit de la Villéon	next meeting
14	NODC to check if ICES data are present at NODC	Rutz	next meeting
15	Investigate if all of the GOSUD data are reaching the WOD.	Rutz	next meeting
16	Ensure that SeaKeepers' data in TRACKOB get worldwide distribution on the GTS.	Keeley, Morrison	immediate
17	Move the eight year backlog of historical data to the GDAC.	Morrison, Petit de la Villéon	next meeting

18	Investigate if appropriate GOSUD metadata exist in, or could reside in, ODAS or Pub47.	Keeley	next meeting
19	Investigate what information about GOSUD would be suitable for training and notify Keeley. This will then be passed to IODE for consideration in their OceanTeacher project	Petit de la Villéon	next meeting.
20	Review literature on salinity vs. depth at near surface for variations and possibly draft a review article - are there lessons to learn from GHRSST-PP?	Sprintall	Spring 2007
21	Ask marine technicians to review GOSUD TSG manual to provide comments and suggestions	Petit de la Villéon, Smith to provide contacts	As possible

SAMOS Actions:

Item	Comments	Who	When
1	Compare contents of NODC archive of R/V data received to holdings at RVSMDC (FSU)	Rutz	January 2007
2	To launch handbook in October 2006, need all comments on topics for bibliography, references, to Frank (Frank.Bradley@csiro.au).	all	ASAP, by 20 May
3	Write wave impact on flux measurements and comments on accuracy table for the handbook	Bourassa	ASAP, by 20 May
4	Provide copy of handbook to Graeme Ball	Smith	June 2006
5	SAMOS and NODC to talk about mirroring data	Rutz, Smith	Summer 2006
6	Evaluate sampling interval (i.e., hourly values) for TSG and meteorology data to be released by SAMOS and GOSUD and establish some common intervals to simplify data application.	Smith, Petit de la Villéon, Keeley	Fall 2006
7	Develop parallel proposals (NSF, UK) for block model CFD. Consider AARV as pilot vessel for NSF.	Moat, Fairall, Hartz, McGillivary, cc. Smith	Summer 2006
8	Decide the objectives and priorities of CFD	Smith to make first draft	June 2006
9	Examine archiving of full resolution underway data, perhaps in conjunction with SAMOS pilot with FSV *Bigelow*	Rutz, Smith, Perry	Summer 2006
10	Marine technicians are requested to provide input on handbook. Does it provide useful information in appropriate form? Send comments to Frank (Frank.Bradley@csiro.au).	Hartz, Felix, O'Gorman	ASAP, by 25 May
11	Revised handbook to be circulated for final review after workshop comments are incorporated. Final comments to be returned within 2 weeks of circulation.	Bradley	June 2006
12	Provide digital photography of instrument towers and sites on existing vessels (both science and bridge sensors) and commentary on the sensor exposures (good, bad, ugly) to Shawn so he can begin compiling training visuals for INMARTECH 2006.	All with access to photos or vessels	August 2006
13	Draft a letter of recommendation from SAMOS emphasizing the importance of CFD for new ship design (to whom to circulate? UNOLS FIC, others?)	Smith, with input from Moat, Fairall, Hartz, McGillivary	September 2006

14	Provide list of minimum (essential) parameters to include in a SAMOS record to ensure quality of pyranometer and pyrgeometer measurements (send to Smith)	Fairall, Dutton	June 2006
15	Contact Barrie Walden at WHOI concerning setting up ESRL portable standard on Oceanus during INMARTECH 2006	Fairall, cc Smith	June 2006
16	Provide contact information for Japanese research vessel operators to Smith for SAMOS program	Kubota, Tomita	As possible
17	Provide contact for Chinese polar vessel operators and 8 primary IPY research vessels to Smith for SAMOS	McGillivary	As possible
18	Develop on-line documentation for vessels interested in contributing to SAMOS (including forms, possible examples of formatting scripts)	SAMOS data center	July 2006
19	Approach BSRN ocean radiation expert team about collaboration with SAMOS	Dutton	May 2006
20	SAMOS requests speed (velocity) through water (both axes) be routinely provided from R/Vs participating in SAMOS data exchange	All participating vessels	As possible
21	Extract set of high wind speed (>20 m/s) marine reports from R/V holdings at FSU, make available to satellite community	Smith, Bourassa	Summer 2006
22	Contact JCOMM task team on instrumentation to make them aware of SAMOS efforts. Open dialog to compare our activities to other WMO efforts.	Smith	As possible

Appendix B: Abstracts

INVITED SPEAKERS

Application of in situ Observations to Current Satellite-Derived Sea Surface Temperature Products

Presenting Author: Gary A. Wick
gary.a.wick@noaa.gov
NOAA Earth System Research Laboratory

While growing numbers of satellite products provide global retrievals of sea surface temperature (SST), in situ measurements remain critical for maintaining the absolute accuracy of the SST products. Pre-launch and on-orbit characterization of the satellite sensors and knowledge of atmospheric attenuation are generally insufficient to ascribe definitive uncertainties to satellite observations. Virtually all satellite SST products are either derived with or validated against in situ observations in some manner. Various examples illustrate the dependence of satellite products on sufficient numbers of in situ temperature measurements. Operational infrared SST algorithms are derived through regression of the satellite brightness temperatures against in situ observations from drifting and moored buoys and studies have been performed to determine the minimum number of observations required to preserve adequate product accuracy. Independent in situ observations are then used to validate the product and provide error estimates. Validation of alternative radiative-transfer based SST products with in situ observations has been central in illustrating problems with cloud detection procedures and assumed water vapor continuum absorption rates. Common analyzed SST products utilize in situ measurements to remove biases in the satellite inputs and directly the analysis. For new multi-sensor satellite SST products, buoy measurements provide the common source of uncertainty estimates for all sensors. Though most historical work has utilized ship and buoy temperature measurements at depths of 1-5 m, current projects are further exploring the feasibility of deriving skin temperature products using in situ radiometric measurements of the ocean surface. Specific details of the need for and impact of the in situ observations for each of these applications will be described in the presentation.

SMOS mission: a new way for monitoring SSS?

Presenting Author: Jacqueline Boutin
jb@lodyc.jussieu.fr
LOCEAN/CNRS
Other Authors: SMOS team

The ESA/SMOS satellite mission (launch foreseen in 2007) aims at monitoring Sea Surface Salinity (SSS) using L-band (1.4GHz) radiometry. It uses a new concept which allows a spatial resolution at ground level of about 40km and global earth coverage in 3 days. SMOS individual measurements (Tb) are expected to be very noisy (1-3K) resulting in a noise of 0.7-3 on SMOS instantaneous SSS at 40km; however owing to the very good spatial and temporal SMOS

sampling, SSS precision should be improved by averaging SSS towards about 0.2 over 200x200km and 10days. This goal is very challenging because the sensitivity of L-band Tb to SSS is small, on the order of 0.5K PSU-1, and requires very well controlled stability of the radiometer and very good corrections for geophysical effects other than SSS, like sea surface roughness, which affect L-band radiometer measurements by a few kelvins. Given these stringent requirements, intensive calibration/validation phases will be necessary 1) to check and eventually correct instrument calibration, 2) to optimize geophysical description of L-band emissivity and ultimately 3) to validate retrieved SSS. With that respect, numerous in situ measurements of SSS, SST, wind speed and eventually rain could be very useful.

In this paper, I will comment on the usefulness of oceanic and atmospheric ship measurements and on their suitable accuracy and sampling for SMOS Cal/Val.

Aquarius Sea Surface Salinity satellite mission validation using near real-time, in-situ oceanographic data

Presenting Author: John Gunn
gunn@esr.org
Earth & Space Research
Other Author: Gary S.E. Lagerloef

The Aquarius satellite mission, scheduled to launch in 2009, will provide global sea surface salinity (SSS) maps at monthly intervals. Near real-time data consisting of near surface in-situ salinity measurements will be used as a validation tool for performance evaluation of the satellite measurements. Data from surface ships, field surveys, fixed moored instrumentation, drifting surface buoys and profiling floats (ARGO) will be contributors. The rapid acquisition, quality control and distribution of such data will be critical in the application of the data to this validation role. The Aquarius Validation Data Segment (AVDS) will collect and process surface measurements as a means of delivering surface calibration data to the Aquarius data processing center. Liaisons maintained with various observation programs will acquire near surface data on a daily basis. The GOSUD/SAMOS data stream will be a key contributor of measurements to this system.

Interest of assimilating SSS data in an operational oceanographical context: The MERCATOR OCEAN experience

Presenting Author: Benoit Tranchant
benoit.tranchant@mercator-ocean.fr
MERCATOR OCEAN
Other Authors: Lionel Renault, Charles-Emmanuel Testut, Pierre Brasseur, and Florence Birol

In the context of a study undertaken by a consortium of European research centers, an OSSE (Observing System Simulation Experiment) has been realized to contribute to the development of the ground segment of the ESA SMOS (Soil Moisture and Ocean Salinity) mission.

This study has been performed in an operational context within the French MERCATOR project which is developing several operational ocean forecasting systems to take part in the Global Ocean Data Assimilation Experiment (GODAE).

The OSSE used the new generation of fully multivariate assimilation system referred to as SAM2v1 which is being developed from the SEEK (Singular Evolutive Extended Kalman) algorithm. This scheme is a Reduced Order Kalman Filter using a 3D multivariate modal decomposition of the forecast error covariance as well as an adaptive scheme to specify parameters of the forecast error.

Assimilation experiments of SSS (Sea Surface Salinity) with the SAM2v1 scheme using various data covers (SMOS Level 3, SMOS Level 2, Aquarius Level 2) and combinations (SMOS L2 + Aquarius L2) have been performed and inter-compared. In all the assimilation experiments, the operational observation baseline (along track sea level anomalies, SST, temperature and salinity in situ profiles and T/S climatology field in under 2000 meter depth) has been taken up.

The OSSE enabled to show the positive impact of SSS assimilation on the MERCATOR operational forecasting system with a North Atlantic configuration at 1/3°, even when all other data sets (altimetry, sea surface temperature, and in situ vertical profiles of temperature and salinity) are assimilated. Conclusions of these SSS data assimilation experiments in an operational context will be presented and discussed.

Southern Ocean Surface Measurements and the Upper Ocean Heat Budget

Presenting Author: Janet Sprintall
jsprintall@ucsd.edu
Scripps Institution of Oceanography
Other Authors: Sarah Gille and Shenfu Dong

High-resolution XBT observations sample upper ocean temperatures at 6 to 15 km intervals along two repeat lines in the Southern Ocean, one spanning Drake Passage and the second extending between Hobart, Australia and the French Antarctic base at Dumont d'Urville. The Drake Passage transect has been operating since 1996, with 6-8 surveys at bimonthly intervals, while south of Australia 6-8 summer surveys have been conducted since 1992. Both ships have a hull-mounted thermosalinograph, and the Drake Passage vessel also has shipboard meteorological and pCO2 sensors, and an ADCP has been measuring upper ocean velocities since 1999. Additional upper ocean measurements in the Southern Ocean are available from surface drifters and ARGO floats, along with satellite measurements of SST (all weather measurements from AMSR-E), sea surface height and surface winds from scatterometers. All these measurements have been combined in a recent study to examine the upper ocean heat balance in the Southern Ocean. While zonally-averaged terms of heat advection, entrainment, diffusion and air-sea flux are largely consistent with the evolution of the upper ocean heat content, substantial imbalances exist in the regional heat budgets. On this local level, small scale coupling between the wind and SST in the vicinity of the SST fronts may result in a complex system of feedback effects on the upper ocean processes that are not well resolved by the existing measurements. The biggest contributor to the surface heat budget error are the air-sea heat fluxes, as only limited Southern Hemisphere data are available for the reanalysis products and hence these fluxes have large uncertainties. In particular, the lack of in situ measurements during winter is of fundamental concern. The presentation will discuss the limitations of the existing data sets, and the desired spatial and temporal resolution that may lead to improvement in their application to scientific analysis.

Estimation of satellite-derived turbulent heat flux and use of in situ observation

Presenting Author: Hiroyuki Tomita
tomitah@jamstec.go.jp
JAMSTEC/IORGC
Other Author: Masahisa Kubota

Since turbulent heat flux plays an important role in the global climate system, the monitoring of global turbulent heat flux is a key issue for understanding the mechanism of global climate. There are several global data sets for satellite-derived turbulent heat flux, e.g. Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) data (Chou et al, 2003), Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite (HOAPS) data (Shulz et al. 1997) and Japanese Ocean Flux data sets with Use of Remote Sensing Observations (J-OFURO) data (Kubota et al., 2002). However, it is not so easy for us to obtain globally accurate turbulent heat flux. In the present study we investigate about several issues related to estimate accurate global turbulent heat flux derived from satellite data. High-quality in situ observations are required and quite valuable for validating satellite-derived meteorological parameters and turbulent heat fluxes. In addition, the in-situ observations allow us simulation of multi-satellite and sensors. High frequency observation using multi-satellite and sensor is one of key features for producing more accurate global turbulent heat flux product. Results form multi-satellite simulation using in situ buoy data suggest that the maximum difference between multi-satellite and single-satellite turbulent heat flux products is quite large, about 30 W/m^2. The simulation results also show that the accuracy of multi-satellite product is dependent on how combine multi-satellite data and local variability, and tell us most appropriate combination of multi-satellite for more accurate global turbulent heat flux data.

Rainfall measurements aboard ships

Presenting Author: Frank Bradley
Frank.Bradley@csiro.au
CSIRO Land and Water

The global hydrological cycle is a critical element of global climate models. Over the earth,s land masses, the modeling is supported by precipitation data obtained from a vast, and in places quite dense, array of surface rain gauges, and by satellite observations. These two sources of data are complementary, the in situ observations serving as spot validation for the superior spatial coverage of the satellite. Over the remaining 4/5 of the globe, i.e. the ocean basins, in situ precipitation sampling is sparse. The satellite observations are supported only by validation sites on islands and coastal locations, and by a few rain-gauge equipped surface moorings. Ships would appear to offer ideal platforms for rain measurement across the open oceans, but numerous studies have shown that shipboard rainfall data can be subject to large errors, mainly associated with wind flow distortion around the ship and/or poor location of the rain-gauge. Justifiably, the satellite community regards ship-based rainfall data as unreliable and does not routinely use it for validation.

The situation is further complicated by the fact that different types of rain detector respond differently to the wind effect, to ship motion and to other challenges of the marine environment. Recent experiments have attempted to quantify and correct for the errors, and to determine ways of improving the accuracy of rainfall measurements from ships. This would enable rain data from research vessels and VOS to contribute to the validation of satellite observations, and to global precipitation data sets. Furthermore, since the freshwater input plays an important role in the stability of the upper ocean, better accuracy and spatial sampling of rainfall will lead to improved modeling of the ocean surface layer and hence of the coupled ocean-atmosphere system. This paper will illustrate some of the problems, and indicate ways in which the measurement of rainfall from ships can be improved.

Requirements for surface marine observations in support of wind and wave forecasting and hindcasting

Presenting Author: Val Swail
Val.Swail@ec.gc.ca
Environment Canada

High quality surface marine observations, particularly of winds and waves, covering all ocean basins, particularly away from the coastal margins, are a vital component to both real time and non-real time applications. Such high quality observations may be used in several different ways at different stages in the life cycle of a data point. Initially, such observations provide valuable input to real-time wind and wave forecasting operations, which feeds back immediately to the marine user community in terms of marine warnings and ship routing services. If properly archived, such as in ICOADS, these data continue to be useful over time, in climatological summaries, in operational forecast verification, in wind wave model validation studies, in calibration and validation of satellite estimates of winds and waves, in development and validation of wave hindcast models and reanalyses which form the basis for most offshore design and operating criteria. The continuing decline in the number of ship observations is a serious concern for all wind and wave activities.

Progress in surface radiation measurements

Presenting Author: Ellsworth Dutton
ells.dutton@noaa.gov
NOAA

This presentation will focus on recent advances in measurements of the individual broadband components of the surface radiation budget. Of all the basic meteorological variables, accurate radiation observations have remained difficult to achieve in a continuous unattended modes of operation. This is due to a range of reasons from limited or non-existent references standards, to imprecise and or spectrally challenged instrumentation, to operational considerations relating to sensor orientation and optical surface cleanliness. These problems have been addressed on an international basis under the conditions of continuous operations at land-based sites with periodic inspection and maintenance. Improvements and advances have been made in commercially available instrumentation, consensus measurement references, and operational practices. Much of the work to be discussed has been done under the auspices of activities of the World Climate Research Program/Global Energy and Water Experiment/Baseline Surface Radiation Network.

Bias correction of in situ observations

Presenting Author: Elizabeth Kent
eck@noc.soton.ac.uk
National Oceanography Centre, Southampton
Other Authors: David Berry, Peter K. Taylor, Ben Moat, and Margaret Yelland

Marine meteorological observations from in situ platforms may contain biases from a range of sources. Most well known are the biases in the routine weather reports from Voluntary Observing Ships (VOS) but measurements from research vessels, moored buoys and drifting buoys may also contain biases.

Some biases are easy to correct if observing metadata is available, for example height adjustment of winds and temperatures. The availability of metadata is however patchy and not always easy to access. Collection of metadata for ODAS (Offshore Data Acquisition Systems) has only recently been organized internationally and resources are required to make historical ODAS metadata available and easy to use. Other biases may vary with the measurement method, with environmental conditions and from platform to platform. Biases are not always easy to identify and correct. Methods of identification include comparison with co-located higher quality data sources, intercomparison of a number of data sources each containing biases with different characteristics or using model output or satellite retrievals as a comparison standard. Examples of each method of bias identification will be shown.

This talk will review recent research into bias in marine meteorological observations with a focus on VOS but addressing other types of observation as well. The need for metadata and for an understanding of the random uncertainty in the observations is common to all platforms.

Airflow modeling for research vessels

Presenting Author: Ben Moat
bim@noc.soton.ac.uk
National Oceanography Centre, Southampton, UK
Other Authors: Margaret J Yelland, Robin W Pascal, Stephen R Turnock, and Stephane Popinet

Three-dimensional computational fluid dynamics (CFD) models are used to simulate the airflow over individual research ships and derive corrections of the mean wind speed measurements for the effects of flow distortion. Previous CFD model results for bow-on flows at very well-exposed anemometer sites show wind speed biases of order 5 %. Recent results show these biases vary by up to about 20 % for a 30 degree change in wind direction relative to the ship.

The CFD codes FLUENT, VECTIS and GERRIS are available to simulate the airflow over research ships. In comparison with experimental data all three codes are accurate to about 4 % in predicting the mean wind speed at well-exposed anemometer locations for flows within ±30 degrees of the bow. However, there are a number of factors to take into account when choosing a CFD code to study this problem. These include: financial cost, ease of use, computing power available and validation of the code for these types of problems. The advantages and drawbacks of applying each CFD code to the flow distortion problem will be presented.

Creating the ship geometry can be the most time consuming phase of the CFD process, therefore existing numerical representations of the RV Knorr, RV Ron Brown, and FS Polarstern research ship geometries will be made available to the SAMOS project for further CFD study. A full list of ships modeled using VECTIS is available from http://www.noc.soton.ac.uk/JRD/MET/cfd_shipflow.php.

Sensitivity of Surface Turbulent Fluxes to Observational Errors

Presenting Author: Mark A. Bourassa
bourassa@coaps.fsu.edu
Center for Ocean-Atmospheric Prediction Studies
Other Authors: Paul J. Hughes

The influences of errors (random and systematic) on turbulent fluxes of momentum, sensible heat, and latent heat are modeled. The sensitivity can be thought of as a gain, or a multiplying factor, showing how errors in parameters used to calculate fluxes result in errors in fluxes.

Potential collaboration between the Coriolis - a French project for Operational Oceanography- and the SAMOS initiative

Presenting Author: Loïc Petit de la Villéon
petit@ifremer.fr
IFREMER
Other Author: Thierry Carval

Seven French agencies (CNES, CNRS, IFRTP, IRD, METEO-FRANCE, SHOM and IFREMER) involved in ocean research are developing together a strong capability in operational oceanography based on a triad including satellite altimetry (JASON), numerical modeling with assimilation (MERCATOR) and in-situ data (CORIOLIS).

The CORIOLIS pilot project aims to build a pre-operational structure to collect, validate and distribute ocean in situ data (mainly temperature, salinity and currents) to the scientific community and modelers.

The CORIOLIS project is organized in four sub-projects with a strong scientific support:

1. Development of the CORIOLIS data centre,
2. French contribution to ARGO ,
3. Development of profiling floats,
4. Integration of national activities related to in situ measurements (mostly routine measurements performed on French research and hydrographic vessels). Both ocean and meteorological data are concerned.

Moreover within the EU funded project Mersea, a great effort is done to enlarge the CORIOLIS area of work to a larger European scale. CORIOLIS is also involved as a Global Data Centre in the GOSUD project which aims to collect and distribute near surface data collected by en route vessels.

As the SAMOS initiative objective is to provide routine access to accurate, high-quality marine meteorological and near-surface ocean data from both research vessels and selected voluntary observing ships, there are obviously strong possibilities of partnership between SAMOS and CORIOLIS.

The main possibilities of collaboration between SAMOS and CORIOLIS could be:

1. Data exchange between the 2 projects. CORIOLIS collects routinely meteorological data but don't process them and could supply them to SAMOS. CORIOLIS receive routinely ocean data from European research vessels; SAMOS could share the ocean data it processes with CORIOLIS;
2. Methods on data qualification could be shared;
3. As a GOSUD GDAC (with US-NODC) CORIOLIS could provide a larger visibility to the SAMOS data

As a first step of collaboration, CORIOLIS and SAMOS could identify one research vessel from each side (e.g. ATLANTIS and ATALANTE) and share the data between the 2 projects

NOAA Shipboard Data Acquisition and Data Management

Presenting Author: Douglas Perry
douglas.a.perry@noaa.gov
NOAA

The NOAA Office of Marine and Aviation Operations (OMAO) operates a wide variety of specialized aircraft and ships in order to complete NOAA's environmental and scientific missions. The presentation will provide an overview of NOAA shipboard data acquisition capabilities, describe OMAO initiatives to improve our data management process, and discuss opportunities for collaborative, data-related pilot projects.

The JCOMM Ship Observations Team

Presenting Author: Elizabeth Kent (for Graeme Ball)
g.ball@bom.gov.au
Chair of SOT, Bureau of Meteorology, Melbourne, Australia
Other Author: Elizabeth Kent

The Ship Observations Team (SOT, www.jcommops.org/sot/) consists of three successful data collection programs: the Voluntary Observing Ships, (VOS) Scheme measuring surface meteorology; the Ship of Opportunity Programme (SOOP) sampling the upper ocean; and the Automated Shipboard Aerological Programme (ASAP) making upper air observations. The role of the SOT is to manage and integrate these programs to support a range of well defined operational and research applications. The data from all three programmes also form a vital component of the Global Climate Observing System (GCOS).

The activities of VOS and SOOP are directly relevant to GOSUD and SAMOS. With increasing automation, VOS and SAMOS are becoming more similar and some research vessels participate in both program. Sampling the thermal structure of the upper oceans with expendable bathythermographs on repeat XBT sampling lines is the most visible sub-program in SOOP, and is a major contributor to our knowledge of the upper ocean and to seasonal and ocean forecasting. The importance of multidisciplinary underway sampling, currently limited to some research-based agencies in the SOOP community, will only increase as the complex role of the oceans and the air-sea interface becomes even more critical to the performance of atmospheric models. The SOT recognized this and established a Task Team to draft specifications to ship builders to accommodate a range of current and future atmospheric and oceanographic sampling requirements.

Key SOT activities that are pertinent to GOSUD/SAMOS are the promotion of standards for instrumentation, inspection, observing methods and data quality across the three programs; the collection of adequate metadata about the observing platform and the observation; and the integration of data from ships participating in both SOT programs and in GOSUD/SAMOS

POSTER PRESENTATIONS

Surface meteorology from Volunteer Observing Ships

Presenting Author: Frank Bahr
fbahr@whoi.edu
Woods Hole Oceanographic Institution
Other Authors: David Hosom, Albert Plueddemann, and Robert Weller

At present, over much of the globe, quantitative maps of air-sea fluxes, derived either from ship reports, numerical model analyses or satellites, have errors that are large compared to the size of climatically significant signals. To address the need for accurate in-situ observations on broad spatial scales, the Upper Ocean Processes Group at WHOI has undertaken a program of observations using a suite of Air-Sea Interaction Meteorology (ASIMET, AutoIMET) sensors adapted for installation on Volunteer Observing Ships (VOS). These systems have been installed on 5 different VOS over the last 4 years, providing a wealth of data along repeated (or nearly repeated) tracks in the Atlantic and Pacific basins. The AutoIMET system allowed an interface to NOAA SEAS 2000 (Shipboard Environmental (Data) Acquisition System), providing automated one hour satellite reports via Inmarsat C. Further details about the WHOI VOS program are available at http://uop.whoi.edu/vos/.

Some VOS installations were chosen because the nominal ship tracks not only passed through regions of interest for evaluating global flux products, but also passed near Ocean Reference Station (ORS) buoys operated by WHOI. The ORS buoys offer high-quality surface meteorology at fixed points, and can be used to identify biases and other errors in model and remote-sensing products. However, determining the spatial structure of the meteorological fields and associated errors requires spatial sampling as achieved by the VOS. In this presentation, we will focus on results from VOS tracks passing near the Northwest Tropical Atlantic Station (NTAS) buoy at 15 N, 51 W. Tracks from two different ships over a two-year period resulted in ten „encounters‰ where the ship passed within a 500 km radius of the buoy location. The duration of a typical encounter was about one day. Shipboard records of barometric pressure, air temperature, sea surface temperature, relative humidity and wind are compared to buoy data for each encounter. The statistics of the differences between like variables are presented along with auto- and cross-correlation analyses. Based on an understanding of the expected temporal correlation scales for each variable from the buoy time series, the goal is to assess the spatial coherence scales for the meteorology indicated by the VOS encounters.

Uncertainty in Monthly Surface Wind Fields from In Situ Observations

Presenting Author: Mark A. Bourassa
bourassa@coaps.fsu.edu
Center for Ocean-Atmospheric Prediction Studies

Random errors in objectively derived fields of Surface winds are determined and verified through comparison to satellite observations. The large spatial variability in error characteristics is shown.

Monitoring Sea Surface Salinity in the Global Ocean from Ships of Opportunity: the French Observation Service

Presenting Author: Thierry Delcroix
Thierry.Delcroix@legos.obs-mip.fr
IRD / LEGOS
Other Authors: D. Diverres, C. Maes, G. Reverdin, P. T'chine, and D. Varillon

Sea Surface Salinity (SSS) observations are needed to improve our knowledge of the earth's water cycle and climate, and as such is one of the fundamental variables for which global sustained measurements are needed in the context of CLIVAR (CLImate VARiability and predictability) and of GOOS (Global Ocean Observing System) programs. SSS has proven to be valuable for improving estimates of evaporation minus precipitation (E-P) budgets, describing and understanding climate variability at seasonal to decadal time scales, testing physical processes, assessing numerical model performances, improving mixed layer representation by assimilation techniques used in operational oceanography, quantifying the role of salinity on sea level change, and improving El Nino prediction lead time.

The importance of SSS in the climate system has motivated the development by European and USA/Argentina space agencies of dedicated satellite missions (SMOS and Aquarius) to enhance global observations.

This presentation will mainly focus on the French Sea Surface Salinity Observation Service (see http://www.legos.obs-mip.fr/observations/sss/), its strength and potential improvements. This service aims at collecting, validating, archiving and distributing in situ SSS measurements derived from Voluntary Observing Ship programs, both for climate research and operational oceanography. It represents the French contribution to the international Global Ocean Surface Underway Data program (GOSUD; see http://www.gosud.org). Details will be given about instruments and software used, the management of real time data transmission, the validation processes for real time and delayed mode data, as well as the derived products and climatic indices.

Progress on the NOAA Portable Seagoing Air-Sea Flux Standard

Presenting Author: C. W. Fairall
chris.fairall@noaa.gov
NOAA ESR: PSD3
Other Authors: D. E. Wolfe and S. Pezoa

The air-sea interaction group at PSD (formerly ETL) is constructing a 3rd generation flux measurement system to use as a portable standard to promote the quality assurance of NOAA and UNOLS R/V's and other components of the OOS (principally buoys). This poster will provide an update on progress with the design, a summary of the present architecture, and results of recent field tests.

Development of a low-cost autonomous micro-weather station module for use in open and coastal marine environments

Presenting Author: Patrick D. French
patf@adatech.com
ADA Technologies, Inc.
Other Authors: Jeff Jenner, Blase Yamona

NOAA collects meteorological measurements in open ocean and coastal marine environments from research vessels, data buoys and commercial ships for use in numerical weather prediction, global climate change research, and severe storm identification. The current system costs for robust marine automated meteorological stations along with the necessary long-haul satellite communications systems is too high to allow ubiquitous use on the available platforms.

Through an SBIR Phase II project, funded through NOAA's Office of Global Programs, ADA Technologies is developing a cost effective, modular micro-weather station network (sensors, local wireless communications, and satellite communications) for use in marine environments. ADA is leveraging an existing miniature self-networking sensor pod developed for military applications. The final modular system will 1) weigh a few pounds, 2) measure meteorological parameters, 3) measure GPS location and spatial orientation to correct for platform motions, 4) contain integral communications to wirelessly transfer data on a routine basis to the aggregation point on the ship then through the Iridium satellite system back to NOAA, 5) use a plug-and-play port for additional sensors, and 6) be extremely simple to install. In Phase II, the system is being rigorously tested on a VOS ship. Also in Phase II, the system is being integrated with the existing manual collection methods so that both manual observations and automated measurements are collected through the system.

Thermosalinograph (TSG) transects maintained by NOAA/AOML

Presenting Author: Gustavo Jorge Goni
gustavo.goni@noaa.gov
NOAA/AOML
Other Author: Huiqin Yang

NOAA/AOML maintains several components of the observing system, including three thermosalinograph (TSG) transects, two in the North Atlantic (New York to Bermudas and New York to Iceland) and one in the Pacific Ocean, in support of a NOAA project to quantify air-pCO2 fluxes from VOS. Sea surface salinity (SSS) is a key parameter that needs to be investigated to meet climate research goals. XBTs in low density mode are deployed along each transect to monitor the mixed layer depth. TSG data have been collected from 2001 and are being routinely quality controlled with a procedure similar to that used with Argo temperature and salinity profile data, but for surface observations only. Additionally, drift in the salinity data are removed in between calibrations (approximately 6 months) using climatology, profiling float, XBT and drifter data. Real-time TSG data transmission will be implemented this year using a modification to the SEAS2000 unit being developed by AOML, which is currently used to transmit surface meteorological and expendable bathythermograph data from research and commercial vessels. Real and delayed time data will be posted and distributed through an AOML web site.

Comparison of two global sea surface temperature data sets

Presenting Author: Shinsuke Iwasaki
iwasaki@mercury.oi.u-tokai.ac.jp
Tokai university
Other Authors: Makahisa Kubota and Hiroyuki Tomita

Sea Surface Temperature (SST) is essential for turbulent heat flux estimation. In the present study , We have compared two kinds of global SST data, Center for Atmospheric and Oceanis Studies (CAOS) and Reynolds SST data. In addition, we investigated difference of turbulent heat flux by using two different global SST data.

Exploiting the synergies of VOS and research vessel marine meteorology

Presenting Author: Elizabeth Kent
eck@noc.soton.ac.uk
National Oceanography Centre, Southampton
Other Authors: David Berry and Scott Woodruff

Research vessels (RV) and Voluntary Observing Ships (VOS) provide complementary marine meteorological information over the ocean. RVs provide high-resolution and usually high-quality data for a limited number of locations and periods. VOS typically provide low-resolution observations and the data quality can be variable. VOS data have a wide spatial distribution and can provide time series going back over many years. Further RVs sometimes carry sophisticated instrumentation, for example for radiation measurement, which can be used to develop parameterizations for use with VOS measurements.

Comparisons of VOS and RV data have in the past been difficult due to the differences in sampling from the two data sources. Typically VOS data have been used to construct monthly mean datasets. Comparison with RV data, where a particular cruise takes only a month or two of observations, required the assembling of many cruises-worth of data and were not often made. However new VOS datasets are being developed which contain daily fields in well sampled regions (typically Northern mid-latitudes, major shipping lanes and some coastal areas and inland waters). It should be possible to use these datasets together to give added value. The VOS datasets can provide a wider-scale context for the RV data, the RV measurements provide information about diurnal cycles and at shorter timescales. With careful analysis and characterization with uncertainty estimates it should be possible to use the VOS-derived data fields to compare data from different RVs and help to identify any problems which may arise with a particular RV.

The poster will show examples of the quality of fields that can be generated using VOS observations and illustrate their use with RV observations.

Measuring surface seawater fugacity of CO2 on board ships of opportunity and moorings

Presenting Author: Jacqueline Boutin (for Nathalie Lefevre)
nathalie.lefevre@lodyc.jussieu.fr
IRD LOCEAN
Other Authors: Denis Diverrs, Laurence Beaumont, Tho Danguy, and Antoine Guillot

The ocean is a sink of CO2 for the atmosphere, absorbing about 2 GtC/y. The distribution of sources and sinks of CO2 is well identified but there is little information about the time variability of these sources and sinks and how they will evolve under increasing atmospheric CO2 levels. The development of autonomous fCO2 (fugacity of CO2) systems has allowed programmes of long-term monitoring of fCO2 on board ships of opportunity. As part of the European programme CARBO-OCEAN, we will assess the variability of the air-sea CO2 flux in the Atlantic. For sampling the tropical Atlantic, we plan to equip 2 merchant ships with an autonomous fCO2 system. One ship sails from France to French Guiana and the other sails from France to Brazil. We also plan to equip 2 PIRATA moorings (6S, 10W; 8N, 38W) with a CO2 sensor and an oxygen optode to have a time series of the fCO2 and O2 variability in the South Equatorial Current (SEC) and the North Equatorial Counter Current (NECC). We will present the system we have recently installed on board a merchant ship and the CARIOCA CO2 sensors designed to be installed on buoys.

Surface heat fluxes from the NCEP/NCAR reanalysis at the KEO buoy site

Presenting Author: Masahisa Kubota
kubota@mercury.oi.u-tokai.ac.jp
Tokai University
Other Authors: Noriyasu Iwabe and Meghan F. Cronin

Surface heat fluxes from the Kuroshio Extension Observatory (KEO) buoy are compared with National Centers for Environmental Prediction/National Center for Atmospheric Research reanalysis-1 (NRA1) surface heat fluxes. KEO turbulent heat fluxes are estimated by applying the Coupled Ocean-Atmosphere Response Experiment (COARE) version 3.0 bulk algorithm to state variables observed by the KEO buoy. If we can assume KEO fluxes to be true, then there exist larger errors in NRA1. In particular the NRA1 latent heat flux has both a large bias caused primarily by the difference of a bulk algorithm, and a large Rms error caused by differences in the state variables. The biases are such that NRA1 heat transfer from the ocean to the atmosphere are larger than observed by KEO. The present results point out the importance of maintaining in situ observations that are independent of reanalysis data, and the importance of monitoring surface heat fluxes in the Kuroshio/Kuroshio Extension regions.

Autonomous Surface Vessels For Air-Sea Flux and Satellite Calibration/Validation Studies

Presenting Author: Philip A. McGillivary
philip.a.mcgillivary@uscg.mil
US Coast Guard Icebreakers
Other Authors: Joseph A. Curcio, Kevin Fall, and Bob Twiggs

We discuss use of relatively inexpensive autonomous surface vessels (ASVs) to provide measurements of thermohaline structure in the upper water column as well as wind speed and direction data with height above the sea surface as a basis for air-sea flux studies. ASVs have advantages over ship-derived measurements: wind field distortion from hull freeboard is minimal; position-holding is easily specified in real time, including in relation to ships or other ASVs; data can be collected for months; and, ASVs can be deployed in locations and conditions ship operators avoid. ASVs require a marine meteorological mast and mini-winch for lowerable CTD measurements. Submarine sensor masts have also been developed. Additional sensors for marine chemical measurements permit air-sea gas flux data collection. As with ship and buoy data, measurements must be corrected for pitch/roll/yaw. Data may be transmitted in near-real time via wireless protocols to moored buoys, ships, or satellites. Improved wireless Delay Tolerant Networking (DTN) protocols increase distance, bandwidth and reliability of transmissions in noisy or interruption-prone environments. Typically twice daily communications permit operations for months. An existing PICOSAT can be used for cost-effective data transmission, but new protocols could take advantage of additional PICOSATs. Coordination of multiple PICOSATs, with the ability to transmit data to each other and then to a downlink station, could reduce the need for on-satellite storage, and increase the area over which data can be transmitted in near-real time. Finally, we review current and planned satellites which could benefit from ASV measurements of near-surface air and ocean measurements.

Ferrybox Sensor Interface Standard (FSIS)

Presenting Author: Geoffrey Morrison
morrison@SeaKeepers.org
The International SeaKeepers Society

To facilitate the development of economical flow through sensors to monitor a variety of sea surface oceanographic parameters, SeaKeepers has developed and encouraged ocean sensor manufacturers to adopt a standardized architecture for flow through sensing of near surface parameters.

Each SeaKeeper 1000(TM) provides a clean seawater stream for up to 5 different sensor suites, surface meteorological data, platform position, speed and course over ground, UTC time, power, data logging, data telemetry and system antifouling by means of electrically generated chlorine at the system inlet.

The centralization of these important parameters permits each individual sensor to be stripped to perform only their unique measurement(s) without carrying unnecessary, duplicated overhead. The adoption of this standard by program managers and individual scientists will permit manufacturers to build standardized flow-through sensor packages in significant quantities enabling them to price sensors as standard products rather than expensive one-of-a-kind units.

A different configuration is available for low-power systems on buoys or in remote locations and different pumping systems are available depending upon the lift requirements (e.g. piers vs. vessels of opportunity).

Currently, eight manufacturers have built sensors that conform to this architecture. Many others are in the process of repackaging sensors. This technology is being actively promoted to the eleven U.S. regional associations responsible for instrumenting and maintaining a U.S. coastal observing system (COOS). Internationally, the system is being promoted to the Ferrybox and Global Ocean Observing System (GOOS) communities.

Following the flow of two underway data streams within the U.S. National Oceanographic Data Center

Presenting Author: Steven Rutz
Steven.Rutz@noaa.gov
NOAA National Oceanographic Data Center

The U.S. National Oceanographic Data Center (NODC) is acquiring, archiving, and disseminating two streams of underway data. NODC acquires these data streams from (1) the Global Data Assembly Center (GDAC) of the International Oceanographic Data and Information Exchange's Global Ocean Surface Underway Data Project (GOSUD), and (2) NOAA's Office of Marine and Aviation Operations (NOMAO), which maintains the underway data collection systems aboard NOAA's vessels. The following describes the flow of these two data streams within the NODC, and NODC's Archive Management System (AMS) and the underway data archived within it.

The primary features of the GOSUD GDAC data stream are:

1. Acquiring - Once a day, NODC pulls data updates from the FTP server for the GOSUD GDAC;
2. Archiving - About once a year, NODC archives a snapshot of these data in the AMS;
3. Disseminating - NODC disseminates these data via the AMS and OPeNDAP

The primary features of the NOAA underway data stream are:

1. Acquiring - Technicians aboard NOAA vessels that have the NOMAO's Scientific Computer System installed are directed to deliver data once a month to NODC;
2. Archiving - NODC archives each data submission in the AMS;
3. Disseminating - NODC disseminates the data via the AMS and the web-enabled Shipboard Sensor Database.

The AMS consists of three major components:

1. Accession Tracking Database;
2. File management; and
3. Ocean Archive System - The public interface to NODC's archive.

A Comparison of SAMOS and Bridge Observations on Research Vessels

Presenting Author: Shawn R. Smith
smith@coaps.fsu.edu
Center for Ocean-Atmospheric Prediction Studies

The author will present a comparison between marine meteorological observations that currently are available in the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) and those collected by automated science instrument systems on a dozen research vessels (R/Vs). Research vessels participating in the Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative are typically equipped with both an automated science instrument system and a set of independent sensors used by the bridge crew for routine weather reports. The routine bridge reports are the typical source of observations in ICOADS and tend to be reported at one, three, or six hourly intervals. Hourly observations, derived from one-minute interval science system data, are used to evaluate the ICOADS reports from each R/V.

For this experiment, comparison data come from a dozen R/Vs that participated in the World Ocean Circulation Experiment. The comparison reveals large differences in temporal coverage provided by the bridge and science reporting systems on R/Vs. For the vessels examined, a large fraction of the bridge observation do not routinely appear in ICOADS. Using standard statistical techniques the author examines differences in atmospheric pressure, sea and air temperature, humidity, and true wind direction and speed. In some cases, large differences exist between bridge and science observations on individual vessels. Using available metadata (e.g., instrument heights, varying data sources in ICOADS, etc.) the author will consider possible causes for observed differences between the bridge and science observations. In addition, the author will evaluate the impact that these differences would have on turbulent air-sea fluxes calculated with the bridge and science observations.

ICOADS and High-Resolution Marine Meteorology and Oceanography

Presenting Author: Scott D. Woodruff
scott.d.woodruff@noaa.gov
NOAA Earth System Research Laboratory
Other Authors: Steven J. Worley and Richard W. Reynolds

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) is the world's largest archive of marine data, currently spanning 1784-2005 at Release 2.3. The basic observational archive (213 million records) is augmented with simple derived monthly summary data products, metadata, and documentation—with centralized access provided via the project web portal (icoads.noaa.gov). Recent accomplishments include an update for 2005, and the introduction of an ASCII-based International Maritime Meteorological Archive (IMMA) format, being developed under the Joint WMO/IOC Technical Commission on Oceanography and Marine Meteorology (JCOMM).

Synoptic marine meteorological observations from Voluntary Observing Ships (VOS), now managed under JCOMM, form a relatively consistent data foundation over the complete period of record. For recent decades we have augmented the VOS observations with measurements, some at high temporal sampling rates, from moored and drifting buoys, and with near-surface (i.e., from a depth of three meters or less) oceanographic profile temperatures from the Levitus World Ocean Atlas/Database (1874-1996).

We plan to blend high-resolution data extracted from the archive maintained by the Research Vessel Surface Meteorology Data Center, which are being sub-sampled to maintain a reasonable measure of diurnal atmospheric variability, and provided in IMMA format. Including these data will enhance ICOADS coverage outside of the normal shipping lanes, and the increased data frequency will help resolve the diurnal and semi-diurnal cycles over the ocean. We suggest additional ways ICOADS might evolve to include more automated high-resolution marine and near-surface ocean data (e.g., sea surface salinity), in keeping with JCOMM goals to further operationalize and integrate the marine and ocean data domains.

Appendix C: Participants

Ed Andreas
Army Cold Regions Lab
72 Lyme Road
Hanover, NH 03755
USA
Tel: (1) 603-646-4436
Fax: (1) 603-646-4644
E-mail: eandreas@crrel.usace.army. mil

Frank Bahr
Woods Hole Oceanographic Institution
266 Woods Hole Road
Woods Hole, MA 02543
USA
Tel: (1) 508-289-2910
Fax: (1) 508-457-2165
E-mail: fbahr@woi.edu

Ludovic Bariteau
Physical Sciences Division
NOAA/OAR/Earth System Research Laboratory
325 Broadway, R/PSD3
Boulder, CO 80305-3337
USA
Tel: (1) 303-497-4482
Fax: (1) 303-497-6181
E-mail: ludovic.bariteau@noaa.gov

Mark A. Bourassa
COAPS
Florida State University
2035 E. Dirac Drive
R.M. Johnson Bldg., Suite 200
Tallahassee, FL 32306-2840
USA
Tel: (1) 850-644-6923
Fax: (1) 850-644-4841
E-mail: bourassa@coaps.fsu.edu

Jacqueline Boutin
CNRS
LOCEAN-UPMC
Case 100
4, place Jussieu
75252 Paris Cedex 05
FRANCE
Tel: (33) 1-44-274-765
Fax: (33) 1-44-273-805
E-mail: jb@lodyc.jussieu.fr

E. Frank Bradley
CSIRO Land and Water
G.P.O. Box 1666
Canberra, ACT 2601
AUSTRALIA
Tel: (61) 2-62-46-5575
Fax: (61) 2-62-46-5965
E-mail: frank.bradley@csiro.au

Patrice Cousineau
DFO-MEDS
200 Kent Street
Ottawa, Ontario
CANADA
Tel: (1) 613-990-0236
Fax: (1) 613-993-4658
E-mail: cousineau@meds-sdmm.dfo-mpo.gc.ca

Thierry Delcroix
IRD/LEGOS
14, avenue Edouard
Belin, Toulouse, 31400
FRANCE
Tel: (33) 561-333001
Fax: (33) 561-253205
E-mail: thierry.delcroix@legos.cnes.fr

Ellsworth G. Dutton
NOAA Earth System Research Laboratory
325 Broadway, GMD-1
Boulder, CO 80305-3328
USA
Tel: (1) 303-497-6660
Fax: (1) 303-497-6290
E-mail: ellsworth.g.dutton@noaa.gov

Christopher W. Fairall
NOAA Earth System Research Laboratory
R/PSD
325 Broadway
Boulder, CO 80305
USA
Tel: (1) 303-497-3253
Fax: (1) 303-497-6181
E-mail: chris.fairall@noaa.gov

Bruce Felix
Raytheon Polar Services Company
7400 S. Tucson Way
Centennial, CO 80112-3839
USA
Tel: (1) 720-568-2348
Fax: (1) 303-792-9006
E-mail: ethq@usap.gov

Patrick French
ADA Technologies
8100 Shaffer Parkway
Suite 130
Littleton, CO 80128
USA
Tel: (1) 303-973-8344
Fax: (1) 303-792-5615
E-mail: patf@adatech.com

Gustavo Goni
NOAA/AOML
4301 Rickenbacker Causeway
Miami, FL 33149 USA
Tel: (1) 305-361-4339
Fax: (1) 305-361-4412
E-mail: gustavo.goni@noaa.gov

John Gunn
Earth & Space Research
1910 Fairview Ave. E.
Suite 210
Seattle, WA 98102
USA
Tel: (1) 206-726-0501
Fax: (1) 206-724-0524
E-mail: gunn@esr.org

Steven Hartz
University of Alaska
PO Box 730
201 Railway Ave
Fairbanks, AK USA
Tel: (1) 907-224-5261
E-mail: fnsjh@uaf.edu

Shinsuke Iwasaki
Tokai University
3-20, 1-chome, orido, Shimizu-ku
Shizouka-si, Shizouka 242-0901
JAPAN
Tel: (090) 8035-5253
E-mail: iwasaki@mercury.oi.u-tokai.ac.jp

David Jansen
ADA Technologies, Inc.
8100 Shaffer Parkway, Suite 130
Littleton, CO 80127-4107
USA
Tel: (1) 303-792-5615
Fax: (1) 303-792-5633

Jeff Jenner
NOAA National Data Buoy Center
Building 1100, Room 359D
Stennis space Center, MS 39529
USA
Tel: (1) 228-688-2784
Fax: (1) 228-688-3153
E-mail: jeff.jenner@noaa.gov

Robert (Bob) Keeley
Department of Fisheries and Oceans
Marine Environmental Data Service
1202-200 Kent Street
Ottawa, Ontario K1A OE6
CANADA
Tel: (1) 613-990-0246
Fax: (1) 613-993-4658
E-mail: keeley@meds-sdmm.dfo-mpo.gc.ca

Elizabeth Kent
National Oceanography Centre, Southampton
Room 254/26 James Rennell Division
European Way
Southampton SO14 3ZH
UNITED KINGDOM
Tel: (44) 23 8059 6646
Fax: (44) 23 8059 6400
E-mail: eck@noc.soton.ac.uk

Masahisa Kubota
School of Marine Science & Technology
Tokai University
3-20-1 Orido
Shimizu, Shizouka 424-8610
JAPAN
Tel: (81) 543-37-0916
Fax: (81) 543-34-9983
E-mail: kubota@mercury.oi.u-tokai.ac.jp

Phil McGillivary
USCG Icebreaker Science Liaison
PO Box 5082
Alameda, CA 94501-8582
USA
Tel: (1) 510-437-5355
Fax: (1) 510-437-2961
E-mail: philip.a.mcgillivary@uscg.mil

Ben Moat
National Oceanography Centre, Southampton
European Way
Southampton, SO14 3ZH
UNITED KINGDOM
Tel: (44) 23 8059 7739
Fax: (44) 23 8059 6204
E-mail: bim@noc.soton.ac.uk

Geoffrey Morrison
International Sea Keepers Society
4101 Ravenswood Road, #128
Ft Lauderdale, FL 33312
USA
Tel: (1) 786-325-3733
Fax: (1) 305-675-0256
E-mail: morrison@seakeepers.org

David O'Gorman
Oregon State University
130 Burt Hall
Corvalis, OR 97331
USA
Tel: (1) 616-406-7460
E-mail: dave@coas.oregonstate.edu

Douglas Perry
NOAA Marine & Aviation Operations
8403 Colesville Road, Suite 500
Silver Spring, MD 20910
USA
Tel: (1) 301-713-7673
Fax: (1) 301-713-1578
E-mail: douglas.a.perry@noaa.gov

Loïc Petit de la Villéon
IFREMER
BP 70
29280 Plouzane
FRANCE
Tel: (33) 0 2982-24913
Fax: (33) 0 2982-24644
E-mail: petit@ifremer.fr

Steven Rutz
NOAA NODC
E/OC1
1315 East West Highway
Silver Spring, MD 20910
USA
Tel: (1) 301-713-3272
E-mail: steven.rutz@noaa.gov

Shawn R. Smith
Center for Ocean Atmospheric Prediction Studies
Florida State University
2035 E. Dirac Drive
R.M. Johnson Building, Suite 236
Tallahassee, FL 32306-2840
USA
Tel: (1) 850-644-6918
Fax: (1) 850-644-4841
E-mail: smith@coaps.fsu.edu

Janet Sprintall
Scripps Institution of Oceanography
University of California at San Diego
9500 Gilman Dr.
La Jolla, CA 92093
USA
Tel: (1) 858-822-0589
Fax: (1) 858-534-9820
E-mail: jsprintall@ucsd.edu

Val Swail
Environment Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4
CANADA
Tel: (1) 416-739-4347
Fax: (1) 416-739-5700
E-mail: val.swail@ec.gc.ca

Hiroyuki Tomita
JAMSTEC/IORGC
2-15, Natsushima
Yokosuka, Kanagawa
JAPAN
Tel: (81) 46 867 9836
Fax: (81) 46 867 9455
E-mail: tomitah@jamstec.go.jp

Benoit Tranchant
Mercator Ocean
8/10, rue Hermes
Parc Technologique du Canal
31520 Ramonville St. Agne
FRANCE
Tel: (33) 561-393-828
Fax: (33) 561-393-899
E-mail: benoit.tranchant@mercator-ocean.fr

David Varillon
IRD
BP A5
Noumeau Cedex
NEW CALEDONIA
Tel: 687-260711
E-mail: varillon@noumea.ird.nc

Gary Wick
NOAA/ESRL
325 Broadway
R/PSD3
Boulder, CO 80302
USA
Tel: (1) 303-497-6322
Fax: (1) 303-497-6181
E-mail: gary.a.wick@noaa.gov

Scott D. Woodruff
NOAA Earth System Research Laboratory
R/PSD1
325 Broadway
Boulder, CO 80305-3328
USA
Tel: (1) 303-497-6747
Fax: (1) 303-497-6449
E-mail: scott.d.woodruff@noaa.gov

Steven Worley
Scientific Computing Division
NCAR
P.O. Box 3000
Boulder, CO 80307
USA
Tel: (1) 303-497-1248
Fax: (1) 303-497-1291
E-mail: worley@ucar.edu

Huiqin Yang
CIMAS
4600 Rickenbacker Causeway
University of Miami-RSMAS
Miami, FL 33149
USA
Tel: (1) 305-361-4435
E-mail: huiqin.yang@noaa.gov

Appendix D: Acronyms

AARV	Alaska Region Research Vessel
ADCP	Acoustic Doppler Current Profiler
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA)
ASAP	Automated Shipboard Aerological Programme
ASV	Autonomous Surface Vessels
BSRN	Baseline Surface Radiation Network
BUFR	Binary Universal Form for the Representation of meteorological data
CFD	Computational Fluid Dynamics
CLIVAR	Climate Variability and Predictability program
CNRS	Centre national de la recherche scientifique (France)
COAPS	Center for Ocean-Atmospheric Prediction Studies
COMNAP	Council of Managers of National Antarctic Programs
COOS	Coastal Ocean Observing System
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CTD	Conductivity-Temperature-Depth recorder
DAC	Data Assembly Center
DM	Delayed Mode
ESRL	Earth System Research Laboratory (NOAA)
ETL	Environmental Technology Laboratory (now PSD)
ESA	European Space Agency
FGDC	Federal Geographic Data Committee
FSU	Florida State University
GDAC	Global Data Assembly Centre
GEWEX	Global Energy and Water Cycle Experiment
GMD	Global Monitoring Division (NOAA/ESRL)
GOOS	Global Ocean Observing System
GOSUD	Global Ocean Surface Underway Data project
GPS	Global Positioning System
GTS	Global Telecommunication System
HOAPS	Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IFREMER	Institut français de recherche pour l'exploitation de la mer
IMET	Improved Meteorology system
IOCCP	International Ocean Carbon Coordination Project
IOOS	Integrated Ocean Observing System
IPY	International Polar Year
IRD	L'Institut de recherche pour le développement (France)
JAMSTEC	Japan Agency for Marine-Earth Science and Technology (Japan)
JCOMM	WMO/IOC Joint Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
J-OFURO	Japanese Ocean Flux data sets with Use of Remote Sensing Observations
MEDS	Marine Environmental Data Services (Canada)

NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction (NOAA)
NDBC	National Data Buoy Center (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NOC	National Oceanography Centre, Southampton (UK)
NODC	National Oceanographic Data Center (NOAA)
NSF	National Science Foundation
NWP	Numerical Weather Prediction
OAR	Office of Oceanic and Atmospheric Research (NOAA)
OCO	Office of Climate Observation (NOAA)
ODAS	Offshore Data Acquisition Systems
OMAO	Office of Marine and Aviation Operations (NOAA)
PSAFS	Portable Seagoing Air-sea Flux Standard
PSD	Physical Sciences Division (NOAA/ESRL)
QARTOD	Quality Assurance of Real-Time Oceanographic Data
QC	Quality Control
RSMAS	Rosenstiel School of Marine and Atmospheric Science
RT	Real Time
RVSMDC	Research Vessel Surface Meteorology Data Center
R/V	Research Vessel
SAMOS	Shipboard Automated Meteorological and Oceanographic System
SEAS	Shipboard Environmental data Acquisition System
SMOS	Soil Moisture and Ocean Salinity
SOOP	Ship of Opportunity Programme
SOT	Ship Observations Team (of JCOMM)
SSS	Sea-Surface Salinity
TAO	Tropical Atmosphere Ocean project
TOGA-COARE	Tropical Ocean Global Atmosphere - Coupled Ocean-Atmosphere Response Experiment
TSG	Thermosalinograph
UCAR	University Corporation for Atmospheric Research
UNOLS	University - National Oceanographic Laboratory System
USCG	United States Coast Guard
VOS	Voluntary Observing Ship
VOSClim	WMO VOS Climate project
WCRP	World Climate Research Program
WGASF	Working Group on Air-Sea Fluxes
WGSF	Working Group on Surface Fluxes
WHOI	Woods Hole Oceanographic Institution
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
XBT	Expendable Bathythermograph