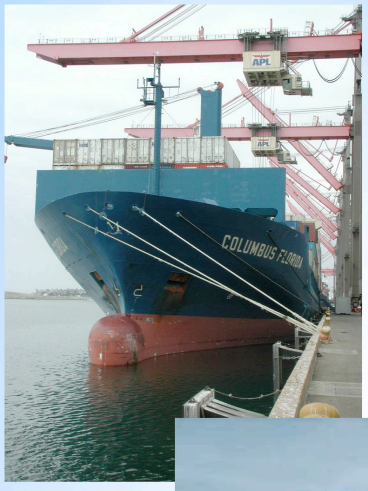
Report from the Second Workshop on High-Resolution Marine Meteorology



COAPS Report
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2nd Workshop on High-Resolution Marine Meteorology

15 and 16 April 2004
Silver Spring, MD, USA

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Acknowledgements

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Abstract

The report presents a summary of the recommendations, discussions, and implementation strategies from the 2nd Workshop on High-Resolution Marine Meteorology held in Silver Spring, Maryland, USA on 15 and 16 April 2004. Discussions covered data transfer paths, instrument accuracy and specifications, metadata standards, modeling of wind flow over ships, future training materials, and platform-to-platform comparisons. Also discussed were needs of the modeling and satellite communities, national and international partnerships, and future meetings and workshops. Abstracts of most invited talks and poster presentations are included. The report concludes with action items for the upcoming year.

The HRMM initiative seeks to improve access to high-quality, calibrated measurements from shipboard automated meteorological and oceanographic systems (SAMOS). Primary recommendations include (1) focusing the HRMM initiative on SAMOS observations from research and merchant ships, (2) starting data collection with the U.S. research vessel fleet, (3) expanding data collection to include any SAMOS equipped merchant vessels and those international research vessels that operate in the polar oceans. The panel also recommends that all SAMOS observations have free and open access to the research and operational communities.

Executive Summary

On 15 and 16 April 2004, the NOAA Office of Climate Observation hosted the *2nd High-Resolution Marine Meteorology (HRMM) Workshop* in Silver Spring, Maryland. The workshop focused on implementing the recommendations from the *Workshop on High-Resolution Marine Meteorology* held in Tallahassee, FL on 3-5 March 2003 (see http://www.coaps.fsu.edu/RVSMDC/marine_workshop/ Workshop.html). The HRMM community is working to improve access to calibrated, quality-controlled, climate-related data collected *in-situ* on ships and moored platforms. The meeting resolved that such data generated by vessels be identified as originating from Shipboard Automated Meteorological and Oceanographic Systems (SAMOS), to emphasize the key role of exchange processes between the two media, and to distinguish it from data obtained for purely weather forecast applications. New topics included soliciting user community input on the application of SAMOS data, and determining how to best interface HRMM activities with other national and international ocean observing programs.

The chairman, Shawn R. Smith, organized a workshop panel with representatives from the scientific and operational marine observational communities. Participants represented six NOAA facilities (ETL, OAR, NCDC, NODC, NWS/NCEP, and PMEL), the Brookhaven National Laboratory, and the U.S. Coast Guard. The university community was represented by the Woods Hole Oceanographic Institution, the Scripps Institution of Oceanography, the University of Miami, Columbia University, and the Florida State University. International representatives were present from CSIRO (Australia), JCOMM, WCRP, and GOOS. Program managers from NOAA/OGP/OCO and the National Science Foundation were also in attendance.

Topics of discussion included progress on implementing the first workshop recommendations, setting priorities for the HRMM program, developing requirements for SAMOS observations, setting goals for the coming year, assessing user community needs, and identifying opportunities for international collaboration. The workshop opened with a poster session highlighting achievements of the past year. Invited talks in each subsequent session focused on key topics and stimulated round-table discussions.

Progress in the last year includes (1) establishing a data assembly center for SAMOS observations from U.S. sponsored research and merchant ships, (2) securing funding to develop a surface flux standard instrument suite for onboard instrument comparison and for an online handbook for meteorological measurements at sea, (3) initiating communication with vessel operators (e.g., NOAA, UNOLS, USCG), and (4) soliciting support and input from the U.S. and international marine and climate science community. Several pilot projects were discussed to further these activities.

The panel recommended that the HRMM program focus first on improving access to SAMOS data collected by U.S. research vessels, then focus on data from SAMOS deployed on merchant ships and international research vessels operating in the polar oceans. Close collaboration with established mooring programs is anticipated. The panel identified a list of navigation, meteorology, and near surface ocean parameters required to meet the science objectives outlined at the first workshop. In addition, the panel intends to petition UNOLS and other cooperating vessel programs to agree to a new data policy whereby underway meteorology and thermosalinograph data would be freely available by default with the data being exempt from the traditional 2-year proprietary hold by chief

scientists. A chief scientist would have to specifically request any hold on these data. Free and open access will allow SAMOS observations to become part of a sustained ocean observing system, which will support their use by the modeling and remote sensing communities. The recommended focus of international collaboration is through the WMO VOSClim program, WCRP working group on surface fluxes, CLIVAR hydrographic program, International Ocean Carbon Coordination Project, and development of the marine handbook. Finally, the panel agreed that periodic HRMM workshops provide an important forum for the exchange of ideas and methods; they should be continued and expanded to include additional data users and developers of new SAMOS technology.

A summary of the 2nd HRMM Workshop will shortly appear in *EOS* to acquaint the AGU readership with this initiative and stimulate general discussion.

Meeting Summary (as submitted to *EOS* in July 2004)

On 15 and 16 April 2004, the NOAA Office of Climate Observation (OCO) hosted the *2nd High-Resolution Marine Meteorology (HRMM) Workshop* in Silver Spring, Maryland. The HRMM community is working to improve the quality of and access to surface marine meteorological and oceanographic data collected *in-situ* by automated instrumentation on ships and moored platforms. The purpose of the second workshop was to discuss implementation of the recommendations from the *Workshop on High-Resolution Marine Meteorology* held in Tallahassee, FL on 3-5 March 2003 (for details see http://www.coaps.fsu.edu/RVSMDC/marine_workshop/Workshop.html).

Shipboard automated meteorological and oceanographic systems (SAMOS) are an essential component of a sustained ocean observing system. SAMOS provide platform navigation, surface meteorology, and near-ocean surface data that are ideal benchmarks for new satellite sensors (e.g., WindSat, future NPOESS sensors) and global ocean-atmosphere models. SAMOS sampling is adequate to provide accurate estimates of the variability on scales (from sub-diurnal) needed for satellite calibration and validation. Sampling rates also are ideal for estimating turbulent air-sea heat, momentum, and moisture fluxes which are critical for climate research and can be used to help understand sources of bias and uncertainty in global model flux fields. SAMOS observations from oceanographic research vessels (R/Vs) are of particular importance since these vessels frequently operate in areas far outside the normal merchant shipping lanes.

The workshop panel recommended that the HRMM community focus first on improving access to SAMOS data collected by U.S. R/Vs. Improving access to data from SAMOS deployed on merchant ships and international R/Vs operating in the polar oceans will follow. Close collaboration with established mooring programs is anticipated. The panel identified a list of navigation, meteorology, and near surface ocean parameters required to meet the science objectives outlined at the first workshop. In addition, the panel outlined an effort to create a set of guidelines for metadata to be provided routinely SAMOS operators. The panel also intends to petition the University-National Oceanographic Laboratory System (UNOLS) council and other cooperating ship programs to agree to a new data policy whereby access to underway meteorology and thermosalinograph data would be free and open by default and the data would be exempt from the current practice of a 2-year proprietary hold by chief scientists. A chief scientist would have to specifically request any hold on these data. Free and open access will allow SAMOS observations to become part of a sustained ocean observing system, making these data readily available for use by the climate research, modeling, and remote sensing communities. The panel plans to seek international participation through the World Meteorological Organization Volunteer Observing Ship Climate (VOSClim) program, World Climate Research Program (WCRP) working group on surface fluxes, the WCRP Climate Variability and Predictability (CLIVAR) hydrographic program, and the International Ocean Carbon Coordination Project (IOCCP). Finally, the panel agreed that periodic HRMM workshops provide an important forum for the exchange of ideas and methods. Future workshops will include additional input from data users and developers of new SAMOS technology.

The panel, chaired by Shawn R. Smith, included representatives from the scientific and operational marine observational communities. Participants represented six

NOAA facilities (ETL, OAR, NCDC, NODC, NWS/NCEP, and PMEL), the Brookhaven National Laboratory, and the U.S. Coast Guard (USCG). The university community was represented by the Woods Hole Oceanographic Institution (WHOI), the Scripps Institution of Oceanography (SIO), the University of Miami, Columbia University, and the Florida State University. International representatives were present from CSIRO (Australia), the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology, WCRP, and the Global Ocean Observing System (GOOS). Program managers from NOAA OCO and the National Science Foundation were also present.

Progress and New Initiatives

The HRMM community is focusing on improving access to quality controlled SAMOS data for scientific and operational users, improving the accuracy of SAMOS measurements, and providing training for data collectors and improved metadata to users. The HRMM community has (1) established a data assembly center (DAC) for SAMOS observations from U.S. sponsored R/Vs and VOS, (2) begun developing a roving surface flux standard instrument suite for onboard instrument comparison, (3) outlined a "Handbook on Meteorological Measurements at Sea", (4) initiated communication with vessel operators (e.g., NOAA, UNOLS, USCG), and (5) solicited support and input from the U.S. and international marine and climate science communities. Several pilot projects were outlined by the 2nd HRMM panel which will be initiated in 2004-05.

The DAC was established specifically to coordinate the collection, quality control, distribution, and future archival of SAMOS data. The DAC, funded at FSU in 2004, will collaborate with WHOI and SIO to design a ship-to-shore-to-user data pathway for U.S. research vessel SAMOS data. In the past, the data flowed from ship to shore only in a delayed-mode with a 3 month to 2 year lag between collection and availability to the user community. The new vision will support data transmission from each ship to the DAC on a daily basis. A "quick-look" version of the SAMOS data will be available within a few days of receipt at the DAC. The quick-look data will have undergone common formatting and automated quality control. Visual inspection and further scientific quality control will result in a "research" quality SAMOS product. The DAC will provide distribution services for the quality controlled data in formats that meet user needs and will ensure that the original and quality controlled data are submitted to several national data archives.

Several improvements to the accuracy of SAMOS data are being investigated. Instrumentation developers at NOAA ETL and WHOI are designing a two part roving standard instrument suite that will be used for onboard validation and comparison with a research vessel's permanent SAMOS. The first component of the roving standard will be a state-of-the-art turbulent flux instrument suite that will be installed to provide the best possible measure of air-sea fluxes and surface meteorology. A second set of traditional marine weather instruments will be located near the R/V's SAMOS instruments to provide side-by-side comparison with the permanent shipboard sensors. A trained technician will travel with the roving standard and work with the R/V's technician (over the course of several weeks at sea) to identify discrepancies between the roving standard the R/V SAMOS measurements. A pilot project to compare the state-of-the-art flux sensors and an R/V SAMOS is planned for 2005.

Another initiative to improve data accuracy will provide for computational fluid dynamics (CFD) modeling of the airflow around vessels. Research at the Southampton Oceanography Center, WHOI, and other institutions revealed that modeled airflow can be used to determine optimal sensor locations. CFD results also can be used to adjust meteorological measurements to remove biases caused by the air flow around various ship structures. Discussions are underway to complete CFD modeling on new R/Vs during their design phase.

The focus of the training activities lies in the production of a handbook (or guide) to best procedures and practices for meteorological measurements at sea. This was first proposed by the WCRP/SCOR Working Group on Air-Sea Fluxes and adopted at the first HRMM Workshop at FSU in 2003. The handbook is aimed at the sea-going research community and ships' technical staff. Topics will include information on preferred sensor location, calibration, in-situ comparisons, documentation, metadata, bulk flux methodology, and measurement error. Plans are for a dynamic handbook which will be available on-line. Users will be able to download relevant computer code, specifications, and technical information whether on land or at sea.

Future Activities

At the second HRMM workshop, the panel decided to focus initially on U.S. research vessel SAMOS data. Clearly there is an opportunity to expand this initiative to the international marine community. The panel specifically noted the importance of vessels operating in the polar oceans and identified polar R/Vs and re-supply vessels as the first international vessels to integrate into the network of routine SAMOS measurements. The polar oceans play a key role in global ocean-atmosphere circulations and R/Vs provide platforms of opportunity to observe these regions. The panel discussed participation in the upcoming International Polar Year as a possible way to initiate inclusion of polar SAMOS observations into the network.

International collaboration is expected to continue and be expanded in the future. The goal of establishing a sustained global ocean observing system will involve contributions from many nations. The international fleet of R/Vs and SAMOS-equipped VOS will be a key component of that observing system, providing data for air-sea flux estimates and benchmark observations for global data assimilations and new satellite sensors. The HRMM community intends to expand its collaboration with ongoing international climate programs (e.g., CLIVAR, GOOS).

Improving the availability, accuracy, and quality of SAMOS measurements will require a wide range of technical and scientific expertise. For example, there is a need to develop more robust sensors for severe ocean environments, to expand broadband communication between ships and shore, and to provide education on best practices for SAMOS. User input also is critical to ensure that the HRMM community provides products that are useful to modelers, oceanographers, and meteorologists. User input has already resulted in improved data quality and the panel expects this process will continue. The HRMM community encourages members of the AGU to provide input towards the development of a sustained network of SAMOS on research vessels and VOS.

(End of submitted *EOS* article)

Discussion Topics

The meeting was organized around a limited number of invited talks. These talks opened each session and stimulated discussion on several key topics. Data discussions centered around parameter specification needed to meet science objectives, accuracy requirements, data transfer, and flow modeling around vessels. Interwoven through the data discussions were ideas to improve SAMOS metadata. Metadata issues and a number of training topics were included in the discussion of the "Handbook on Meteorological Measurements at Sea". Additional discussions focused on user needs, partnerships, pilot projects, and future meetings.

Data Specifications

Discussions focused on which navigational, meteorological, and oceanographic parameters are essential or desired to meet the objectives of the HRMM community (e.g., accurate flux estimation, climate quality observations for satellite and model validation). The list of parameters agreed to by the panel, Table 1, can all be measured routinely by a well designed SAMOS. Several of these parameters must be associated with documented instrument height/depth (e.g., winds, pressure, temperature, moisture, sea temperature, and salinity).

In addition to identifying parameters to measure routinely, the panel raised questions concerning data accuracy (see next section) and data sampling/averaging intervals. Although some satellite validation exercises could use data sampled at frequencies as high as one hertz, the consensus of the panel was that one-minute average values would be sufficient for most climate and flux applications. Additional discussion will be needed to outline best practices to produce one-minute averages (from values sampled at higher rates), with an emphasis on how to achieve the most accurate wind averages. The averaging methods may have to be a compromise between the "ideal" averaging method and the limitations of the instruments and data loggers onboard each vessel.

Data Accuracy

One of the major goals of the SAMOS initiative is to improve the accuracy of meteorological and oceanographic measurements. The first step in this process is to set accuracy targets and a draft set of target values for most meteorological values is included in Table 2. The target accuracies are based primarily on the those outlined by the TOGA/COARE and WOCE programs. Chris Fairall (NOAA/ETL) noted that the COARE targets can be achieved with existing instrument technology as long as the sensors are constantly monitored during a cruise. Whether they can be achieved by fully autonomous sensors is still an open question. One concern with most accuracy targets for climate applications is that the estimates tend to only include the accuracy of the mean. This may not be sufficient and it was suggested that accuracies should also include a target value for random error. Also it is necessary to "translate" these accuracy targets from the goals proposed for climate applications to accuracy targets that are of use to ship technicians and instrument developers.

Table 1: SAMOS parameters needed to meet HRMM science and operational objectives

Parameter	Comments
Navigation and Platform Motion	
Latitude and Longitude	
Heading	
Course and Speed over ground	
Speed over water (fore-aft and along beam components)	*Desired for surface current estimation in absence of ADCP data*
Pitch, Roll, Heave	*Desired, but not essential*
Surface Meteorology	
Platform-relative wind direction and speed	*Must be reported by all vessels*
Earth-relative (true) wind direction and speed	
Ocean-relative wind direction and speed	*Can be calculated provided surface currents are measured, not necessary to report*
Surface atmospheric pressure	
Air temperature	
Moisture (dewpoint, wet-bulb, or relative humidity)	
Precipitation	
Radiation	*Standard should include downwelling shortwave and longwave sensors (2 per vessel)*
Ocean surface	
Sea temperature	
Sea skin temperature	*Desired*
Salinity	
Conductivity	*Desired by salinity users*
Surface current	*Needed to obtain wind relative to ocean surface*
Swell and waves (sea state)	*Desired for future, current automated (radar) sensors are cost prohibitive*

Other issues related to accuracy were raised. First off, there was a desire to have accuracy targets for wind direction that vary with the wind speed; however, these varying accuracies for direction cannot be addressed until there is agreement on the overall target accuracies. Another extensive discussion focused on accuracies needed for GPS information (position, speed, course, and in some cases heading). GPS technology is improving much faster than meteorological sensors and can resolve positions to much higher accuracy that 1 km. The panel feels that knowing the ships position within a

kilometer will be sufficient for most satellite and flux applications, with coarser accuracy being adequate for modelers. Finally, the panel discussed the accuracy to which the instrument height/depth must be known. Changes in load can significantly alter the height of instruments on merchant vessels, but the consensus was that these changes are generally small (1-2 m) on research vessels. Several panelist suggested that placing height sensitive instruments as high as possible on a vessel will, to some extent, alleviate this problem on research vessels. Handling height changes on merchant vessels (sometimes up to 10 m, but more often 2-3 m [Elizabeth Kent, personal communication, 2004]) is still an open question.

Table 2: Draft accuracy, precision, and random error targets for SAMOS. Accuracy estimates are currently based on time scales for climate studies (i.e., 10 W/m^2 for Q_{net}). Several targets are still to be determined.

Parameter	Accuracy of Mean (bias)	Data Precision	Random Error (uncertainty)
Latitude and Longitude	0.001°	0.001°	
Heading	2°	0.1°	
Course over ground	2°	0.1°	
Speed over ground	Larger of 2% or 0.2 m/s	0.1 m/s	Greater of 10% or 0.5 m/s
Speed over water	Larger of 2% or 0.2 m/s	0.1 m/s	Greater of 10% or 0.5 m/s
Wind direction	2°	1°	
Wind speed	Larger of 2% or 0.2 m/s	0.1 m/s	Greater of 10% or 0.5 m/s
Atmospheric Pressure	0.5 hPa	0.01 hPa	
Air Temperature	0.1 °C	0.05 °C	
Dewpoint Temperature	1.5 °C	0.1 °C	
Wet-bulb Temperature	1.5 °C	0.1 °C	
Relative Humidity	1%	0.5 %	
Specific Humidity	0.15 g/kg	0.1 g/kg	
Precipitation	~0.4 mm/day	0.25 mm	
Radiation (SW in, LW in)	2-3 W/m2	1 W/m2	
Sea Temperature	0.1 °C	0.05 °C	
Salinity			
Surface current			

Computational Fluid Dynamics (CFD) Modeling

The topic of CFD modeling again received much attention during the second workshop. The need to understand the flow around vessels is clearly supported by the HRMM panel, who agreed that CFD modeling must be undertaken to improve SAMOS data accuracy. The primary issue is who will spearhead the CFD modeling effort. Panel

members from WHOI expressed a willingness to lead if funding can be secured. In addition, Phil McGillivary from the USCG has definite interest in the CFD topic and has been very helpful to the panel.

The panel raised some questions related to the CFD effort that need to be resolved. What does the HRMM community need to know from CFD modeling? What are the parameters of interest that CFD modeling can provide? How can they be used to improve SAMOS accuracy? Clearly improving sensor exposure is one positive result that can be derived from CFD modeling, but what are others? What are the current capabilities of CFD models? Can they meet our needs? Can the cost of CFD modeling be reduced to make it a routine procedure?

Finally, the panel discussed several avenues to try to achieve CFD modeling of new vessels. CFD modeling in the design phase would significantly improve data accuracy by allowing sensors to originally be placed in the "best" exposed location on the new vessel. Suggestions included contacting the Arctic/Antarctic RV planning group to discuss having CFD modeling completed for their new vessel. In addition, the panel should address their concerns to the UNOLS Fleet Improvement Committee to explore the possibility that CFD modeling can become part of new ship design.

Data Transfer

A brief discussion focused on data delivery schedules and methods for ship-to-shore data transfer. At present, the plan for daily transfer of data from ship-to-shore will suit most users' needs, with the exception of NWP efforts. Since the focus of SAMOS data is more on the validation aspect of NWP, at present daily transfers should be sufficient.

Methods for completing the data transfer stimulated more debate. Ideas include (1) simply adding a script onto the shipboard computing system to bundle the one-minute averages and ship them via email or (2) placing a "black box" piece of hardware onboard each vessel to handle data logging, averaging, and limited QC on the vessel. Central to this issue was the coming improvement in ship-to-shore communication. Sandy Shor stated that within 3 years all primary R/Vs will have "free" broadband communication capabilities. This led the panel to favor the approach of bundling the data with a script and completing all processing onshore at the RVSMDC. Details of data transfer methods will be worked out during a pilot project between the RVSMDC and its shipboard partners at WHOI and SIO.

Metadata

In addition to data specifications, there was a brief discussion of SAMOS metadata. Several groups (VOSClim, JCOMM, etc) are working at some level on metadata standards for marine observations. These standards need to be considered as the HRMM community develops a metadata standard for SAMOS. The bulk of the discussion centered around the need for a small group from the panel to develop a framework of a SAMOS metadata standard. The metadata group will include representatives from the RVSMDC, NODC, and SOC, with input from several ship operating institutions. One concern raised was making sure the standard included necessary components to easily produce FGDC metadata. Unresolved questions include how best to transfer metadata information from ship-to-shore and what system needs to

be in place to allow tracking and modification of metadata. The panel briefly discussed the dissemination of a vessel survey to collect initial metadata from participating vessels' home institutions.

Handbook

A synopsis of the proposed "Handbook on Meteorological Measurements at Sea" was presented by Frank Bradley (CSIRO). The concept of the handbook first arose as a recommendation of the WCRP/SCOR Working Group on Air-Sea Fluxes and a follow-up recommendation was made by the panel at the 1st Workshop on High-Resolution Marine Meteorology.

Discussion focused on broad concepts related to the development and structure of the handbook. The structure has always been envisioned to be an on-line reference aimed at the sea-going research community and ships' technical staff. The structure discussed would have "drill down" capacity, keeping the top level of the handbook fairly simple and allowing users to search for additional technical detail if desired. A suggestion was made for the handbook to include examples of common shipboard data problems, possibly using examples from past RVSMDC quality control experience. Another suggestion was that the handbook include a discussion of data errors in terms of mean bias and random error. Panel members were asked to review the proposed outline and suggest additions and changes to the content (see action items).

The handbook will provide a training and reference document for SAMOS data collectors and users. Once developed, the suggestion was made to seek additional resources to host one or more training workshops (short courses) to inform data collectors and users of the best procedures and practices related to SAMOS observations. UCAR was suggested as one possible avenue to support training activities.

The concept of a "best practices" handbook is being explored by other data programs. Maria Hood is helping develop a handbook for the IOCCP and CLIVAR is discussing updating the WOCE Hydrographic Program data handbook to support CLIVAR hydrographic data collection. The panel acknowledged that there is opportunity for collaboration and comparison with these other efforts, but that we should push forward at our own pace with the meteorological measurements handbook.

User Needs

The panel received input from members of the satellite and modeling communities regarding the use of SAMOS observations. Recent applications have shown SAMOS data to be useful for understanding the underlying physics of the ocean atmosphere interface. For example, Mark Bourassa showed how in-situ data can be used to help calculate orbital wave velocities, which can improve air-sea flux calculations. In addition, comparing SAMOS and satellite observations has revealed that natural variability is the largest source of differences between some satellite and in-situ measurements.

In general, the modeling community is interested in knowing how good are ship data. How far do the SAMOS data differ from "truth". Clearly a routine schedule of onboard sensor comparisons will be of great interest to the modeling community. These high-accuracy SAMOS data can provide key benchmarks for a wide range of modeling activities.

Glenn White provided the panel with an update on activities at NCEP and their current interest in SAMOS observations. First off, he noted that there is no primary ocean contact at NCEP through which the HRMM community can collaborate. The interest in the ocean seems to be scattered throughout various NCEP branches. For instance, the ETA group is very interested in ocean fluxes while the Global branch is starting to use MOM for ocean forecasting and is pushing the need for an ocean reanalysis. The atmospheric reanalysis groups are working to remove false trends caused by addition of new observing systems. CDC is also working on a "surface data only" reanalysis in which the HRMM community may wish to participate. Other modeling groups are interested in the impact that new observing systems can have on forecast products (e.g., where and at what density are observations needed?). The operational NWP community would need data delivery on a six hourly interval for the data to be useful for their products. This may be possible in the future. Finally, the HRMM community should note that there is great interest in cloud and shallow convection measurements. The community should seek possibly automated sensor solutions to measure cloud parameters.

Partnerships

From the beginning, the HRMM workshop panels have been interested in fostering collaboration at both the national and international level. Within the U.S. we continue to improve contacts and collaboration between the research, operations, and marine data collection communities. Lines of communication have been opened with several ship operators and with the UNOLS Council. We wish to strengthen these ties in the coming years. In addition we welcome our ongoing collaboration with NOAA OCO and NSF, and hope to improve contacts with the satellite and modeling communities.

On the international level, the panel discussed several partnership opportunities. Mike Johnson, representing JCOMM, suggested that the VOSClim program would be the best initial collaborator within JCOMM. VOSClim is focused on marine meteorological data and metadata, though not specifically new instrumentation systems. The HRMM community may also consider working with the Ship of Opportunity and Automated Aerological programs.

Chris Fairall provided an introduction to the newly established WCRP Working Group on Surface Fluxes (WGSF). This group will be working with several international programs (e.g., SOLAS, CLIVAR) to promote surface flux studies across the sea, air, and land interfaces. One focus of the HRMM community is improving air-sea flux accuracy, so several logical avenues for collaboration exist with the WGSF.

The panel also discussed plans to contact the Standing Committee on Antarctic Research (SCAR) to discuss possible collaboration on topics related to the Southern Ocean. Phil McGillivary noted that weather in the Antarctic has been atypical for the past three years. There still exists a severe deficit of surface meteorological observations in the Southern Ocean, which adversely affects modeling efforts. The panel discussed the need to focus data collection efforts at the international level on SAMOS deployed on polar research vessels and support ships. Finally, there was discussion of targeting the International Polar Year (2007-8) as a focal point for collaboration with SCAR.

Initial contact has been made with the Global Ocean Surface Underway Data (GOSUD) project to promote possible collaboration between the HRMM and the global

surface salinity communities. The chairman anticipates that a data exchange will be possible between the two groups. The HRMM community would routinely collect thermosalinograph data through the SAMOS and forward these data to the salinity data center in France for quality control. In turn, the salinity center would provide the RVSMDC with SAMOS observations from several international research vessels. Initial discussions with GOSUD are underway.

Finally, the HRMM community believes it is very important to continue close collaboration with both U.S. and international moored buoy programs. Although the panel recommends that the focus of the HRMM initiative be on ships, there is clear overlap in our activities and those within the buoy community. We need to continue to work together on sensor development, calibration, multi-platform comparisons, and integrating ship and buoy data into useful products.

Pilot Projects

The panel listed four primary pilot projects. The first will involve the design and testing of a ship-to-shore data transfer pathway and will involve the RVSMDC, SIO, and WHOI. The second project focuses on metadata collection and data archival and will involve the RVSMDC and NODC with input from the members of the panel regarding metadata standards and surveys. The third pilot project is a planned comparison between the ETL shipboard flux system and a SAMOS onboard a U.S. R/V. The final pilot project will entail having one or more vessel operators review and try to utilize the on-line handbook. The handbook evaluation is not envisioned to happen until later in 2005.

Future Meetings

Panel members are encouraged to disseminate plans of the HRMM community at any suitable meetings. Recommendations were made to send a representative to the SCAR Open Science Meeting in July 2004, the UNOLS RVTEC meeting in November 2004, and the JCOMM SOT-3 meeting in Spring 2005. The chair will continue to promote the HRMM activities within CLIVAR (as a CLIVAR data center) and at the upcoming American Meteorological Society annual meeting (Jan 2005).

Regarding future HRMM Workshops, the panel felt that they are an excellent forum to discuss issues related to SAMOS observations and generally supported continuing these meetings on an annual to 18 month time frame. Several suggestions were made to improve future meetings. First, invitations to future meetings should be expanded to include more people involved in the development of new SAMOS sensors and platforms. In addition the panel supported the idea of adding a short science session to the workshop. The session should focus on application and integration of SAMOS observations. Finally, there was support for making the HRMM meeting a stand alone workshop (especially if the workshop is expanded to include a science session), primarily due to the long week that is involved when the meeting is paired with the annual OCO system review. Plans for a 3rd HRMM Workshop will be revisited in October 2004.

Speaker and Poster Abstracts

Abstracts submitted by both speakers and poster presenters are included. Several of the speaker's PowerPoint slides are available from the workshop web page (http://www.coaps.fsu.edu/RVSMDC/marine_workshop2/Agenda.html).

Applications for Fine Resolution Marine Observations

Mark A. Bourassa and Shawn R. Smith
Center for Ocean-Atmospheric Prediction Studies

High quality fine temporal resolution observations are ideal for several applications. Discussion of these applications will include examples and explanations of the unique strengths of this type of data. The fine temporal resolution observations are ideal for calibration or validation of satellite instruments. Without fine temporal resolution, differences in co-located observations usually provide a better estimate of natural variability than instrument accuracy. Measurements of natural variability are also useful: they can be used to make realistic estimates of geophysical variability in the raw satellite observations, which is usually ignored in engineering estimates of accuracy (which assume all errors are due to the instrumentation or retrieval algorithms). In the case of the scatterometers flown to date, this geophysical noise appears to be a major contributor to the total noise in the observations. Non-satellite applications include the fine resolution modeling of surface turbulent fluxes (or radiation if it is measured), which can the integrated on the same temporal scale as numerical weather prediction or reanalysis products. These observed fluxes are excellent for comparisons to reanalysis fluxes. Coupled with observations of surface turbulent fluxes (or co-located satellite data) the data are useful for evaluating and improving models of surface turbulent fluxes. The research vessel observations can be found in many regions of the globe, sampling a very wide range of conditions, which is ideal for all the above applications.

Proposed Synopsis for a Handbook on Meteorological Measurements at Sea

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One recommendation from the 1st High-Resolution Marine Meteorology Workshop was to: "Produce a reference manual of best procedures and practices for the observation and documentation of meteorological parameters, including radiative and turbulent fluxes, in the marine environment. The manual will be maintained online and will be a resource for marine weather system standards." Progress thus far has been limited to occasional relevant thoughts, useful discussions, notes scribbled on the back of menus and firm resolve to make a start when the current crisis is past. On the basis of the above, we now present a synopsis of material to be included in the Handbook, as a topic for discussion.

The Global Ocean Surface Underway Data (GOSUD) Project

Thierry Carval – IFREMER
Bob Keely – MEDS
Thierry Delcroix – IRD
(presented by Steve Cook NOAA/OAR/GOOS Center)

The Global Ocean Surface Underway Data (GOSUD) Project is a project of the IODE programme of the IOC of UNESCO. Its objectives are:

- To build a comprehensive archive for surface data and associated meta-data.
- To add value to the archive by refining and standardizing the existing quality assessment procedure.
- To provide data and information to users in a timely fashion.
- To work with data collectors to improve the data acquisition systems.
- To work with scientific organizations to provide products to a broad community.

The Project was conceived in response to the need for surface salinity data and to manage the data produced from maturing instrumentation able to make reliable measurements of surface properties. Following other recommendations expressed by OOPC, IOC, JCOMM, the project proposes to deal with a broader issue of surface ocean data (pCO2, fluorescence.) rather than concentrating on surface salinity data only

The Project has a steering group responsible for its development and implementation. Co-chairs are Thierry Delcroix (IRD) and Bob Keeley (MEDS). There are approximately 10 countries that have expressed interest and contributed to developments so far. An ftp and web site has been put in place at IFREMER where information about the Project is available. The same site also has a data server with initial holdings of the Project. Interested parties can contact either of the co-chairs or visit the web site.

ftp://www.ifremer.fr/pub/coriolis/gosud

Introducing the NODC Archive Management System

Donald W. Collins, Steven Rutz, Eric Ogata, Francis Mitchell, Joseph Shirley,
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NOAA/NESDIS/NODC

The stewardship of the nation's oceanographic data archive is an essential responsibility of the U.S. National Oceanographic Data Center (NODC). At issue are the long-term preservation, integrity, and accessibility of irreplaceable observational data through multiple technological and scientific generations. Recognizing these challenges, the NODC implemented new processes to ensure that its data archive stewardship responsibilities are met, that online data discovery and retrieval services are expanded, and that adequate supporting metadata are available to guide use of the provided data. The NODC Archive Management System (AMS) enables datasets to be accessioned, archived, and disseminated in a Web-enabled, browser-based environment

(http://www.nodc.noaa.gov/Archive/Search/). Over 20,000 unique accessioned datasets, ranging from individual observations to large collections by major programs, are included in the system. The AMS enables the ocean community to search historic observation data in new ways, with links to related cruise reports and other gray literature. Now, ocean scientists can more easily fulfill contractual obligations for submitting federally funded observation data and verify the existence of previous data submissions. The NODC AMS consists of four primary components: (1) Accession Tracking Database (ATDB) - generates a unique accession (i.e., a tracking) number for each data submission, captures basic metadata and internal data management information; (2) Archive File Management System generates a uniform directory tree structure for each original dataset submission; creates message digests for file validation; performs virus checks; implements dataset versioning; and provides for automated backups; (3) NOAA Metadata Repository (NMR) - stores and manages FGDC CSDGM-compliant metadata for each accessioned dataset; and (4) NODC Ocean Archive System - allows for the search and dissemination of datasets archived at NODC via a web browser. The AMS enables NODC to comply with data archiving and access requirements described in the U.S. Integrated Ocean Observing System (IOOS) Plan for Data Management and Communications (DMAC).

Observations of Air-Sea Fluxes and the Surface of the Ocean Implementation of High-Density Line in the Tropical Atlantic

Robert Weller, David Hosom, and Frank Bahr
Woods Hole Oceanographic Institution

Voluntary Observing Ships (VOS) use IMET technology on long routes that span the ocean basins and are collecting high quality surface meteorological data and fluxes to get spatial variability in these fields and in the departures of these fields from other representations of the same fields (models, satellites). These observations are essential to:

- Identify errors in existing climatological flux fields.
- Provide motivation for improvements to algorithms.
- Provide data needed to correct existing climatologies.
- Validate new model codes and remote sensing methods.

Continue operation on the Horizon Enterprise and Columbus Florida with six-month turnarounds (Pacific ships). Install a new system on the SeaLand Express and continue six-month turnarounds (Atlantic Ship). Install a new system on a 4th ship early in 2005 and continue six-month turnarounds. Continue cooperation with Southampton Oceanography Centre on CFD (computer flow dynamics) for data improvement. Note that 3 new AutoIMET systems were fabricated and the 3 ASIMET modules sets were converted to AutoIMET systems. These systems interface with the real time SEAS 2000 (Shipboard Environmental (Data) Acquisition System) for automated VOS reports. These 6 systems support the 4 VOS currently planned and permit repairs and re-calibration on a 6 month cycle.

Intercomparison of Buoy-Mounted Anemometers

Michael McPhaden and H. Paul Freitag
NOAA/PMEL

Propeller-vane anemometers have been the standard sensor for decades on many marine wind measurement systems. ATLAS moorings deployed within the Tropical Atmosphere Ocean (TAO) and Pilot Research Moored Array in the Tropical Atlantic (PIRATA) Arrays have used the R. M. Young model 05103 anemometer since the mooring system was first designed in the early 1980's. In recent years several manufacturers have developed anemometers which use ultrasonic technology. These sensors have no moving parts which provide the advantage of no mechanical wear and reduced potential for fouling in an unattended marine environment. PMEL has deployed two of these newer sensors, the Vaisala Ultrasonic model WS425 and the Gill Wind Sonic collocated with a R. M. Young model 05103 on an ATLAS mooring in the tropical Pacific. Real-time daily mean wind components have been collected from this mooring for over 5 months. All three sensors have worked reasonably well. Preliminary analysis indicates daily mean differences between the R.M.Young and Gill sensors of < 0.1 m s-1 in speed and 1 degree in direction. Differences between the R. M. Young and Vaisala sensors are 0.4 m s-1 and 2 degrees, respectively.

ICOADS and High-Resolution Marine Meteorology

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[3] National Center for Atmospheric Research

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) is currently available at Release 2.1, spanning 1784 through 2002. The marine observations, data products, and supplemental data and metadata are freely distributed worldwide by the cooperating organizations: the NSF National Center for Atmospheric Research, and the Climate Diagnostics and National Climatic Data Centers of NOAA. Recent accomplishments include an update for 1998-2002 based on data from the Global Telecommunication System, and the introduction of a new ASCII-based International Maritime Meteorological Archive (IMMA) format, which is being developed under the auspices of the Joint WMO/IOC Commission on Oceanography and Marine Meteorology (JCOMM). In the future we plan to blend data extracted from the archive maintained by the Research Vessel Surface Meteorology Data Center (RVSMDC). These high-resolution data will be sub-sampled to maintain a reasonable measure of diurnal atmospheric variability, using the RVSMDC quality controls, and provided in IMMA format. Including the RVSMDC 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.

SWAP: Wireless Mesh Networking in the UNOLS Fleet

Val E. Schmidt, Toby Martin, Geoff Davis, and Eldridge McFadden
LDEO/Columbia

In the past two years, a few ships in the NSF University National Laboratory System (UNOLS) oceanographic research fleet have been experimenting informally with commercial 802.11 wireless systems for data transmission between ships. Previously, to send an email between vessels conducting collaborative research in a common area, has required transmission of the message to shore and back via low bandwidth, prohibitively expensive satellite services. Indeed, the most economical and expedient way to share large data files has been to put them on portable media (CD or tape), place the media in a plastic bag, and drop it over the side for the other vessel to retrieve. Large gain, omni-directional antennas combined with 802.11b wireless radios have provided line of sight links over several miles, greatly increasing the productivity of scientists and reducing their costs. This has lead to increased interest within the community for wireless networking between ships. When presented with the possibilities that wireless technologies might provide, the UNOLS Research Vehicle Technical Enhancement Committee (RVTEC) responded with a set of requirements in the form of "Story-Scenarios" for wireless networking between UNOLS ships. This paper describes those requirements and the prototype system we have created to meet them. The system consists of ship and shore nodes or "SWAP Devices" each consisting of a single board, Intel compatible PC running Pebble Linux, a high power 802.11b PCMCIA radio card, and a high gain omni-directional antennas. Point-to-point connections are created automatically between nodes within reception range creating complete routable wireless subnets. The nodes share routing information between them with OSPF daemons and this, in turn, creates a fully routable meshed network. A prototype system has been installed at the University of Hawaii, the R/V Kilomoana and recently the R/V Wecoma.

Recommendations from the Workshop on High-Resolution Marine Meteorology

Shawn R. Smith
Center for Ocean-Atmospheric Prediction Studies

An overview of the thirteen recommendations from the first "Workshop on High-Resolution Marine Meteorology" will be presented. The workshop was held from 3-5 March 2003 at the Center for Ocean-Atmospheric Prediction Studies (COAPS) in Tallahassee, Florida. The primary workshop goals were to identify scientific objectives that require high-resolution (sampling interval ≤ 1 hr.), high-accuracy marine meteorological observations and to discuss a sustained U.S. effort to obtain and disseminate these data in a manner consistent with the identified scientific goals. The workshop focused on *in-situ* marine meteorological observations from ships and buoys. Participants from U. S. government agencies, the university community, and two international marine institutes discussed data accuracy, calibration and inter-calibration, improved access to quality-assured, high-resolution observations, and a sustained observing system to meet short- and long-term science objectives. Participants noted that only a few ships and buoys can determine air-sea fluxes to the accuracy needed for

climate studies. Research vessels are capable of providing the highest quality data; however, this resource is not effectively utilized and data essential to climate studies are being lost.

Calibrating Shipboard Meteorological Instruments at the Scripps Institution of Oceanography

Woody Sutherland and Carl Mattson
Scripps Institution of Oceanography

Shipboard Technical Support (STS) and the earlier groups which evolved into STS have been operating a high-precision temperature calibration facility at Scripps Institution of Oceanography (SIO) for half a century. Initially the facility was focused on the calibration of Deep-Sea Reversing Thermometers (DSRTs), but shifted emphasis in the last 30 years with the increased use of electronic instrumentation (e.g. CTDs). Earlier temperature calibrations were performed at the 1 milli-Kelvin level but over the last 15 years, with the acquisition of very high precision automatic temperature bridges, 0.1 mK has been the target.

In 1985, STS acquired a Ruska Model 2400 piston gage for the generation of known pressures with an accuracy of 0.01% of the reading, and we started offering both high-precision pressure and temperature calibrations to the oceanographic community. Since that time we have expanded calibration services to include a suite of meteorological sensors. Our philosophy is that the best way to calibrate any sensor is to operate it the same way it operates during data collection, using where possible and practical the same digitizing system that will be used in the field with the sensor.

STS developed the capability to evaluate and calibrate meteorological sensors for several reasons, including a) to assure satisfactory performance on SIO ships, b) to achieve faster turn-around than is available from commercial suppliers of calibration services (at times essential during a short port stop), c) to verify whether sensors are operating correctly or need servicing, and d) to learn more about the true responses of the sensors.

As an example, after constructing a submersible pressure chamber with heat exchanger, fan, and internal platinum resistance thermometer, which can be pressurized over the range of 800 to 1100 millibars at any desired temperature obtainable in our water bath, we found that some of our barometers were out of specification at temperatures other than ambient room temperature. In some cases we have been able to modify manufacturer's algorithms to account for non-linear behavior as a function of temperature, thereby improving performance. With this equipment we have also found that the calibration sheets which accompany new instruments from the manufacturers do not always produce correct results (within specification) over all specified ranges of temperature and pressure.

We normally calibrate barometric pressure sensors over their full range of pressure, at 2 or more temperatures between -2 and 35 degrees Celcius, depending on the known temperature response characteristics. We would prefer to obtain colder temperatures, particularly for equipment going to high latitudes, and have submitted a proposal for an environmental chamber to do so. However, this temperature range is the

current capability of our constant temperature water baths. A Weston Solartron Digital Pressure Module is used as a substandard in the barometer calibrations. While our goal for overall accuracy is 0.5 millibars from shipboard data, our substandard accuracy is .05 millibars or better, with a precision of .02 millibars.

Humidity sensors are usually calibrated throughout a range of relative humidity, 10-98%, that is readily obtainable in a General Eastman C-1 Relative Humidity Generator, using a high precision General Eastman D-2 chilled-mirror dew-point sensor as a standard, but only at ambient laboratory temperature, typically 21-24 deg C. The proposed environmental chamber would permit us to check sensor behavior at lower temperatures.

Some air temperature sensors, such as those usually included in humidity sensor modules, are not designed for immersion in a water calibration bath, and must be calibrated in air. Other air temperature sensors, while immersible, may give slightly different results in water vs. air because of the radically different thermal conductivity of water; current passing through the sensor produces a small amount of heating which is dissipated faster in water than in air, heating the sensing element less, and producing a slightly lower reading. This effect, called self-heating, is generally negligible at the accuracy levels required of air temperature data, but is worth checking before a calibration method is finalized.

In the STS lab, those air temperature sensors which cannot be calibrated in water are calibrated in a small aluminum chamber which is almost entirely immersed in a water bath for temperature control. An opening at the top permits the insertion of a platinum standard thermometer. A small fan at the bottom of the chamber ensures that the air in the chamber is well mixed. The chamber is made of thin aluminum and exchanges heat readily with the bath, operating at a temperature slightly elevated over the bath because of the heat generated by the fan. The platinum standard is calibrated in a liquid medium; however, tests have shown that the self-heating effect in air is approximately 0.005 degrees Celsius, well below our accuracy goal (0.1 Deg C) for a shipboard air temperature sensor.

Standard practice for calibration of any sensor is to provide a complete record of the data taken, including data that might not be used in the calculation of new coefficients. This is the only way that one can really understand how sensors respond. Reports from commercial vendors sometimes include only the coefficients, which does not give an accurate picture of true sensor performance. Full instrument calibration and knowledge of sensor performance are the goals of an academic calibration lab. STS is interested in exactly how a sensor performs from a perspective that is quite different from a commercial lab. There is clearly a need for both types of calibration facilities.

Meteorological Measurements from the Observing Ship Explorer of the Seas

Elizabeth Williams, Edward Kearns, Bruce Albrecht, Peter Minnett,
Hal Maring, and Michael Reynolds
University of Miami

Meteorological Measurements on the Observing Ship Explorer of the Seas Dr. Edward Kearns, Dr. Bruce Albrecht, Dr. Peter Minnett, Dr. Hal Maring, Dr. Michael Reynolds, Elizabeth Williams The Explorer of the Seas contributes a unique opportunity to the research community to provide quality high-resolution meteorological measurements in the Inter-American Seas during weekly cruises. The program includes permanently installed instrumentation including: Wind Profiler, Ceilometer, Total Sky Imager, WeatherPak, Portable Radiation Package, M-AERI, Microwave Radiometer, and an Aerosol Laboratory. Measurements from these instruments have been taken since October 2000 and the long-term data set is available to any interested researcher. The ship is also an ideal test-bed platform that is presently underutilized. As part of the Southeast Coastal Observing System, a subset of the meteorological and oceanographic measurements are provided in near real-time to the online SEACOOS web interface. Technicians are onboard at all times to monitor data quality and to address instrument failure issues. Future program initiatives will be focused on the automation of the onboard systems utilizing an onboard QA/QC and product processing system, the development of technologies to provide near real-time two-way communications between the installed instrumentation and researchers which will allow updates to mission parameters, development of database technologies to handle the 3.5GB of weekly measurements and the development of technologies that will maintain equipment in the field without substantial intervention from technical personnel.. The ship also provides an outstanding opportunity for technician training in real-time through an internet interface between the laboratories and the onboard conference facilities. The program includes public outreach to 166,000 passengers annually and the education activities this year will include an implementation of the internationally recognized hands-on secondary school program GLOBE as part of the ship's youth program.

Action Items

1. Phil McGillivary will approach Alaska/Arctic RV planning group to discuss possibility of collaborating on CFD model for new ship. Possibly bring Shawn Smith and WHOI representative into conversation.

2. Don Collins will open communication on metadata standards between NCDC, SOC (Liz Kent), and FSU (Shawn Smith).

3. Panel members will provide feedback on outline of proposed handbook by 21 May 2004 to Chris Fairall (chris.fairall@noaa.gov) and Frank Bradley (frank.bradley@csiro.au)

4. Shawn Smith will email the attendees the Action Item review from the first workshop.

5. In June 2004, Shawn Smith will arrange a conference call between Val Schmidt, Woody Sutherland, Frank Bahr, and Barrie Walden. Topics will include a technical discussion of how best to average meteorological data, time and position stamps, data delivery for pilot projects, and how possibly data delivery methods will impact ships with and without onboard tech support.

6. Recommend sending representative to SOT-3 Meeting in Spring 2005. Possible representatives: Steve Cook, Liz Kent, or Shawn Smith.

7. Shawn Smith and Mark Bourassa will make contact with the Scientific Committee on Antarctic Research (SCAR) focusing on the importance of shipboard meteorological observations from polar research ships. Phil McGillivary will provide contact information for SCAR and the upcoming July 2004 meeting in Germany (www.scar28.org).

8. Michael Reynolds will write a paragraph explaining the scientific/observational reasoning for needing multiple radiation sensors onboard ships. In time, Chris Fairall will add this into the on-line handbook of best procedures and practices.

9. Mark Bourassa and Shawn Smith will create an accuracy list (unresolved biases) for essential observation parameter decided upon by the workshop attendees. The list will be sent out by 21 May 2004 for comment.

10. Shawn Smith will develop a status of automated surface meteorological observations on vessels operating in the polar regions prior to the 3rd HRMM workshop.

11. Don Collins will identify contacts at NCDC for discussion of whom should archive HRMM data

12. Shawn Smith will write an *EOS* article focusing on HRMM activities and draft the 2nd HRMM workshop report, with input as needed from other 2nd HRMM Workshop attendees.

13. Shawn Smith will provide update of action items in October 2004 and seek input on scheduling 3rd HRMM Workshop.

14. Phil McGillivary will prompt UNOLS RVTEC to put forth an official invitation for Shawn Smith to attend the fall 2004 RVTEC meeting.

15. Val Schmidt will help Shawn Smith outline observational requirements for HRMM data, prior to presenting them to UNOLS RVTEC in the fall of 2004. Val will help anticipate questions that may arise during the RVTEC meeting.

16. Phil McGillivary and Mark Bourassa will keep panel appraised of NPOESS risk reduction missions and possibility of interaction with NPOESS cal/val teams.

17. Woody Sutherland, Steve Cook, and Val Schmidt will provide feedback on vessel survey questions that will provide input for U.S. R/V AWS database at the FSU DAC. Draft survey will be created by Smith. (brought forward from 1st Workshop)

Appendix A: Acronyms

AGU	American Geophysical Union
AOML	Atlantic Oceanographic and Meteorological Laboratory
AWS	Automated Weather System
BNL	Brookhaven National Laboratory
CDC	Climate Diagnostic Center
CFD	Computational Fluid Dynamics
CLIVAR	Climate Variability and Predictability program
COAPS	Center for Ocean-Atmospheric Prediction Studies
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAC	Data Assembly Center
ETL	Environmental Technology Laboratory
FGDC	Federal Geographic Data Committee
FSU	Florida State University
GOOS	Global Ocean Observing System
GOSUD	Global Ocean Surface Underway Data project
GPS	Global Positioning System
HRMM	High-Resolution Marine Meteorology
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IMET	Improved Meteorology system
IOCCP	International Ocean Carbon Coordination Project
IOOS	Integrated Ocean Observing System
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NSF	National Science Foundation
NWP	Numerical Weather Prediction
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research (NOAA)
OCO	Office of Climate Observation (NOAA)
OGP	Office of Global Programs (NOAA)
PMEL	Pacific Marine Environmental Laboratory
QA	Quality Assurance
QC	Quality Control
RSMAS	Rosenstiel School of Marine and Atmospheric Science
RVSMDC	Research Vessel Surface Meteorology Data Center
R/V	Research Vessel
SAMOS	Shipboard Automated Meteorological and Oceanographic System
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SEAS	Shipboard Environmental data Acquisition System
SIO	Scripps Institution of Oceanography
SOC	Southampton Oceanography Centre

SOT	Ship Observations Team (of JCOMM)
SOLAS	Surface Ocean – Lower Atmosphere Study
TAO	Tropical Atmosphere Ocean project
TOGA/COARE	Tropical Ocean Global Atmosphere/Coupled Ocean-Atmosphere Response Experiment
UCAR	University Corporation for Atmospheric Research
UNOLS	University - National Oceanographic Laboratory System
USCG	United States Coast Guard
VOS	Volunteer Observing Ship
VOSClim	WMO VOS Climate project
WCRP	World Climate Research Program
WGSF	Working Group on Surface Fluxes
WHOI	Woods Hole Oceanographic Institution
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment

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