U.S. Research Vessel Surface Meteorology Data Assembly Center

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1. Abstract

The U.S. Research Vessel Surface Meteorology Data Assembly Center at the Florida State University retrieves, quality evaluates, distributes, and ensures permanent archival of underway meteorological and oceanographic data from select research vessels. The central activity is the development and implementation of the Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative (http://samos.coaps.fsu.edu/). To date, 21 U. S. operated research vessels and 1 Australian research vessel are routinely contributing 1-minute averaged meteorology and surface oceanographic data to the data center. The data handled by the data center address programmatic deliverables related to sea surface temperature, surface currents (via the wind), and air sea exchanges of heat, momentum, and fresh water. Users include satellite algorithms developers, operational meteorologists, atmospheric and oceanic modelers, and researchers studying air-sea exchange and conducting process studies. In addition, data center personnel are active contributors to the international marine climate and marine technical communities.

2. Project Summary

The central activity of the U.S. Research Vessel Surface Meteorology Data Assembly Center (DAC) is the development and implementation of the Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative (http://samos.coaps.fsu.edu/). The SAMOS initiative focuses on improving the quality of and access to surface marine meteorological and oceanographic data collected *in-situ* by automated instrumentation on research vessels and ships of opportunity. The DAC activities focus primarily on NOAA Strategic Plan Goals 2 and 3 by providing high quality weather and near surface ocean data for use in validating complementary satellite observations, global analyses of the ocean-atmosphere exchange of heat, moisture, and momentum, and computer model-derived analyses of climate, weather, and ocean parameters. The data distributed by the DAC address the Office of Climate Observation program deliverables related to sea surface temperature, surface currents (via the wind), and air sea exchanges of heat, momentum, and fresh water.

Research vessels are mobile observing platforms that are an essential component of the global ocean observing system. They are equipped with computerized data systems that continuously record navigation (ship position, course, speed, and heading), meteorological (winds, air temperature, pressure, moisture, rainfall, and radiation), and near ocean surface (sea temperature and salinity) parameters while a vessel is underway. Research vessels travel to remote and hard to observe ocean locations that are far from normal shipping lanes sampled by merchant vessels. The mobility of research vessels provide essential observations between the fixed locations of surface moorings, and in turn allow side-by-side comparison to mooring data when moorings are deployed or serviced.

The rationale for DAC activities includes comprehending the physical and thermodynamic processes that govern the interaction between the ocean and atmosphere. This interaction is key to our understanding of how marine weather systems evolve, how these systems impact the ocean, and how the oceans impact the weather. On longer time scales, understanding the interaction between the ocean and atmosphere is necessary to assess our changing global climate system. The role of the DAC is providing the high quality marine meteorological and surface ocean measurements to the research and operational community so that they can address these ocean-atmospheric interactions.

Our user community includes scientists developing algorithms to retrieve marine observations from space, those working to constrain the range of air-sea exchanges in extreme environments (e.g., the Southern Ocean), and operational meteorologists verifying marine forecasts. For many applications, our users require observations in the extremes of the marine environment (e.g., very high or low winds) and need frequent sampling in space and/or time to identify local marine features (e.g., weather and ocean fronts). The research vessels providing observations to the DAC meet these needs and the DAC quality evaluation ensures the users receive fully documented observations to complete their analyses.

The DAC was established at the Florida State University to implement a ship-to-shore-to-user data pathway for research vessel meteorological and near-surface ocean data. Through the SAMOS initiative, participating vessels send daily emails containing one-minute interval data to

the DAC. Broadband satellite communication facilitates this transfer as near as possible to 0000 UTC daily. A preliminary version of the data is made available via web services within five minutes of receipt. The preliminary data undergo common formatting, metadata enhancement, and automated quality control (QC). Visual inspection and further scientific QC result in intermediate and research-quality products that are nominally distributed with a 10-day delay from the original data collection date. All data and metadata (e.g., instrument height, type, units) are version controlled and tracked using structured query language (SQL) databases. All data are distributed free of charge and proprietary holds via http://www.coaps.fsu.edu/RVSMDC/html/data.shtml and long-term archiving occurs at the U.S. National Oceanographic Data Center (NODC).

3. Scientific Accomplishments

Over the past year, our efforts have concentrated on additional vessel recruitment, the full implementation of the data quality evaluation (from collection to archival), and enhancing the data quality control system. We also expended a large effort on international collaboration, including extensive contributions to the OceanObs'09 conference (Fairall et al. 2010, Gille et al. 2010, Gulev et al. 2010, Hood et al. 2010, Rieneiker et al. 2010, Roemmich et al. 2010, Smith et al. 2010a, Smith et al. 2010b, Worley et al. 2010). In collaboration with partners at NOAA's Office of Marine and Aviation Operations (OMAO), Raytheon Polar Services (RPS), the United States Coast Guard (USCG), the Woods Hole Oceanographic Institution, and the Australian Bureau of Meteorology (our first international participant), the number of vessels participating in SAMOS has increased from 17 to 22. Data from all vessels are routinely pushed through our automated (preliminary) data quality evaluation (DQE). Starting in January 2009, we have been able to conduct routine visual (research) QC on most vessels. Due to flat funding and increasing demand, we no longer actively recruit new vessels; however, the success of SAMOS has resulted in vessels contacting the DAC with interest in participating. These vessels are not turned away, but we must limit the quality evaluation to the automated processes only (visual analyst time is limited).

Deliverables for FY 2009 included:

1. Recruit additional research vessels to the SAMOS initiative
2. Continue routine quality evaluation of meteorological data for 17 SAMOS vessels currently contributing to the DAC
3. Improve and enhance metadata collection from participating research vessels
4. Implement new data quality evaluation techniques to reduce analyst workload.
5. Continue liaison activities with U.S. and international government agencies, archives, climate programs, and throughout the marine community
    - Subtask 1: Establish data exchange with GOSUD
    - Subtask 2: Produce subset of SAMOS observations for ICOADS
6. Respond to actions and recommendations of the 2nd Joint GOSUD/SAMOS workshop
    - Subtask 1: Develop data and quality reporting mechanisms for vessel operators
    - Subtask 2: Develop educational and training materials
7. Expand user options on the SAMOS web site to ease user access to observations and metadata

- Subtask 1: Implement Google Earth maps displaying physical variables along track lines

8. Create and distribute turbulent air-sea fluxes for vessels contributing to SAMOS
    - Subtask1: Compare SAMOS fluxes with available NWP products

3.1 Vessel Recruitment [Deliverable 1]

Recruitment of additional vessels to participate in the SAMOS Initiative continued in FY 2009, with five new vessels recruited (Table 1). These vessels now routinely contribute SAMOS observations when they are at sea. Collaboration with NOAA OMAO resulted in three new recruitments and the *Polar Sea* is a new addition from the U. S. Coast Guard. In FY2009, we began receiving SAMOS data from the *Southern Surveyor* operated as part of the Integrated Marine Observing System (IMOS) by the Australian Bureau of Meteorology (ABoM). The *Southern Surveyor* is our first international vessel and we are pleased to have a strong working agreement with Eric Schulz at ABoM. These data included historical SAMOS reports from FY2008, which were processed in FY2009 (Table 1).

The success of the SAMOS initiative has raised interest among additional U.S. and international RV operators. At OceanObs'09, presentations related to the role of mobile platforms in the ocean observing system (Roemmich et al. 2010) and the status of air-sea exchange (Gulev et al. 2010) both recommended that SAMOS be expanded to include more international vessel. Additional community white papers address the needs for expanding the role of RVs in the ocean observing system (Bourassa et al. 2010, Kent et al. 2010[1], Hood et al. 2010, Fairall et al. 2010, Gille et al. 2010, Rienecker et al. 2010, Worley et al. 2010, Smith et al. 2010a). Although operator interest is expanding and the scientific need for observations is growing, flat funding at the SAMOS DAC has limited our ability to further increase the number of vessels contributing data to the DAC. As noted above, we do not actively recruit new vessels at present, but we will accept new vessels when approached. QC on these new recruits is limited (see below).

Table 1: Ships transmitting observations to SAMOS DAC during FY 2008 and FY 2009.

		Number of ship days with data	
Vessel	Operator	1/10/2007 – 30/9/2008	1/10/2008 – 30/9/2009
Atlantis	WHOI	296	299
David Star Jordan	NOAA	88	76
Delaware II	NOAA	-	84
Fairweather	NOAA	83	38
Gordon Gunter	NOAA	44	219
Healy	USCG	165	184
Henry B. Bigelow	NOAA	145	144
Hi'ialakai	NOAA	203	150
Ka'imimoana	NOAA	202	154
Knorr	WHOI	306	359
Lawrence M. Gould	NSF/Raytheon	260	331
Miller Freeman	NOAA	190	121
Nancy Foster	NOAA	178	147
Oceanus	WHOI	113	264
Okeanos Explorer	NOAA	-	35

[1] Kent, E.C., and Coauthors, 2010: "The Voluntary Observing Ship Scheme", in Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. and Stammer, D., Eds., ESA Publication WPP-306, 2010

Oregon	NOAA	85	183
Oscar Dyson	NOAA	214	201
Oscar Elton Sette	NOAA	-	99
Polar Sea	USCG	-	2
Rainier	NOAA	110	20
Ronald Brown	NOAA	161	173
Southern Surveyor	IMOS/Australia	85	168
		2928	3451

3.2 Data quality evaluation [Deliverable 2]

Automated quality processing is completed on every set of data received from recruited vessels (Table 1). The automated processing continues to be a smooth operation with each data set being versioned and tracked via an SQL database. In FY2009, we evaluated 3451 days of underway meteorological and sea surface temperature data (an 18% increase from FY2008). These data cover most of the coastal regions around North America and extend into poorly sampled regions of the South Pacific, North Atlantic, and Southern Ocean (Fig. 1). The extent of these data from the tropics to the polar latitudes, along with many reports on the continental shelf, provide observations from the wide range of environmental conditions required by our users to meet objectives in satellite, air-sea exchange, physical oceanographic studies. The data collected and quality controlled by the DAC directly support the OCO program deliverables related to sea surface temperature, currents (via wind data), and the air-sea exchange of heat, momentum, and fresh water.

Our lead analyst, Jeremy Rolph, continues to conduct daily (not 24/7) visual inspections of all observations. This inspection is a quick-look and does not allow time to add/alter quality control flags on the data. The inspection is a means to ensure the data received from the vessel are free of major sensor failures or other problems that would require notification of the vessel at sea. These at-sea notifications are highly desired by the vessel operators and onboard technicians and are the core benefit to the vessel operator. Prompt notification of problems results in quick resolution of sampling issues and adds value to the investment made by the operators in expensive marine observing systems.

Most observations received since January 2009 underwent visual quality control to create a research-quality product. The visual analysis is accomplished using SVIDAT, a graphical user interface developed by COAPS programmers. SVIDAT allows the analyst to review, add, or modify data quality flags on the merged files. Once the analyst is satisfied with the data quality, the file is saved and posted automatically to the SAMOS ftp and web sites. This process also updates all necessary tracking information in the ship database and creates the copies of the original, preliminary, and research quality files for delivery to a national archive (see section 3.6). Visual quality control is manpower intensive and has only been successful for 2009 due to the DAC securing additional funding via the National Science Foundation. These new funds are focused on vessels from the U.S. academic fleet, so our OCO funds have been focused on the quality evaluation of SAMOS observations received from the NOAA, USCG, and polar vessels. Visual QC for the Southern Surveyor is conducted by the Australians using SVIDAT. Even with

the additional funding from NSF, we are unable to provide research quality visual QC for newly recruited vessels, with the exception of any new NOAA vessels that come on line.

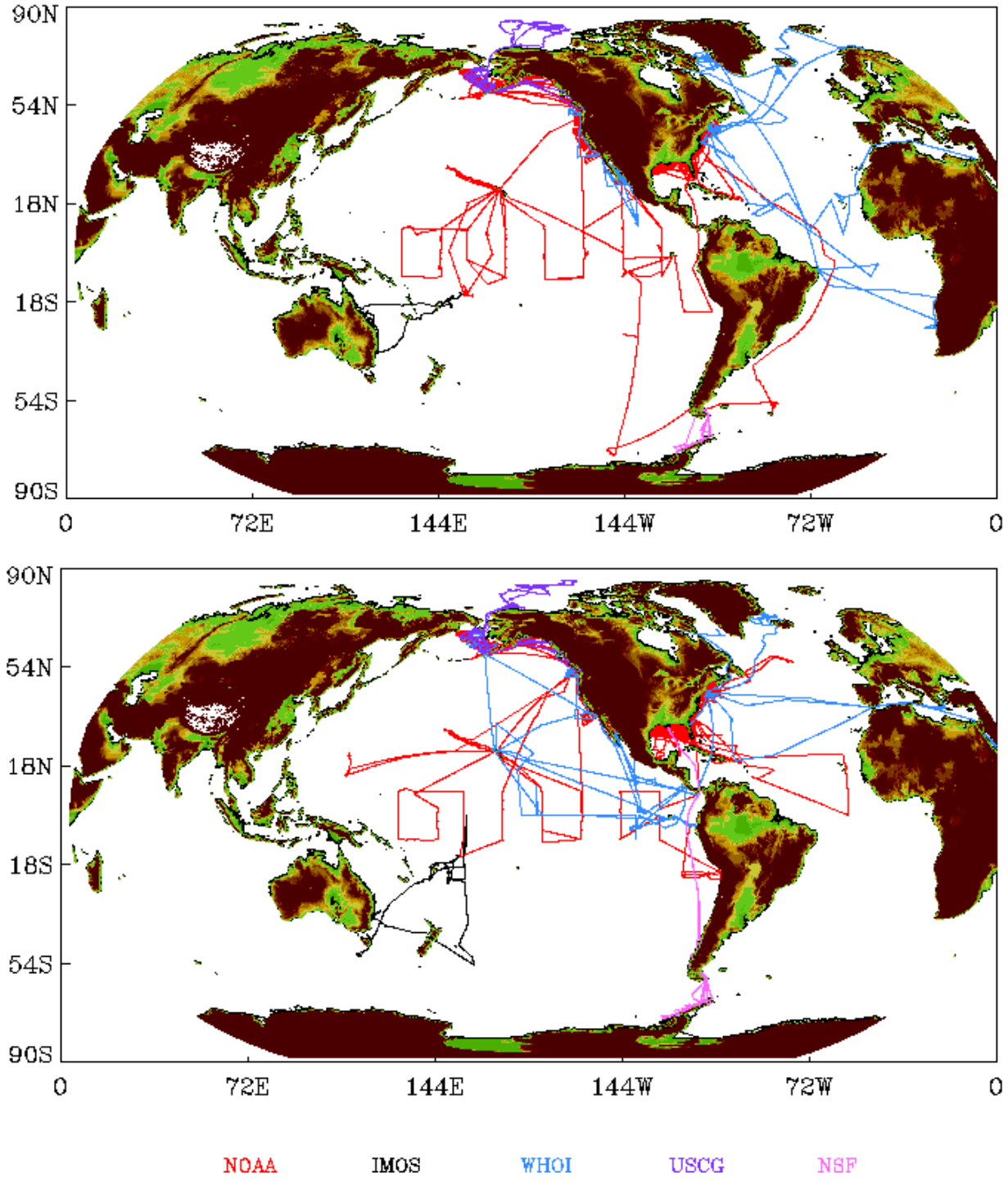

***Figure 1**: Cruise tracks showing data provided to the SAMOS DAC for FY2008 (top) and FY2009 (bottom). Data are color coded by the primary operating institution.*

3.3 Metadata collection [Deliverable 3]

Collecting accurate and up-to-date vessel metadata continues to be a challenge. We increased the completeness of our metadata records by providing each of our data providers with a template listing the metadata values we had for their vessels. This survey, conducted in early 2009, resulted in some updates to our metadata content and we received some new digital imagery from several vessels. Several new vessels successfully used a graphical user interface developed at the DAC to upload their metadata via the web. We continue to actively work with our data providers to educate them on the importance of providing accurate metadata.

The DAC is an active participant in metadata discussions within the domestic and international community. We continue to pursue development of an automated ship-to-shore metadata transfer protocol and will coordinate this activity via separate NSF funding. We anticipate that automated transfers will not occur for at least another 2-3 years. On the international level, SAMOS is an active participant in the JCOMM Ship Observation Team and has had initial discussions with the U.S. Voluntary Observing Ship (VOS) coordinator (Robert Luke) to develop necessary metadata to deliver the SAMOS observations via the global telecommunication system (GTS). The delivery of data to the GTS would be enhanced by more interaction between SAMOS, the U.S. VOS program, and the VOS port meteorological officers. At present, these interactions are completed on an ad-hoc basis.

3.4 New quality control methods [Deliverable 4]

A major time constraint on the visual quality evaluation is the identification of spikes and discontinuities within data time series. A new automated statistical spike and stair step indicator (SASSI) code was developed in FY2009 and has undergone successful initial testing. The code will be fully implemented in the coming months and should significantly reduce the workload of our visual data analysts (allowing them to process more vessels in less time). Through testing we learned that SASSI will have to be tuned for each individual vessel, due to variations in the precision at which each vessel makes atmospheric measurements. The vessel specific tuning parameters will be stored in our ship profile database, allowing the parameter to be altered if changes are made to shipboard instrumentation.

Although not directly related to the quality control, the DAC has also reprogrammed several aspects of our automated data processing system. The code has been migrated from our old IRIX computer architecture to a faster LINUX architecture. Several sub-processes and database queries have been updated, resulting in a twenty-fold increase in the speed of the overall automated data processing. We have also developed new data ingest codes to read and process the Joint Global Ocean Flux Study format data we have received for the past 3 years from the *Nathaniel Palmer*. With this code, we will be able to back process these highly-valued observations from the Southern Ocean.

3.5 Liaison activities [Deliverable 5]

The central liaison activity of the DAC in FY2009 was preparing contributions for the OceanObs'09 conference. The PI was lead author on community white papers focusing on the SAMOS data stewardship and a broader contribution on underway data collection from ships. The manuscripts emphasized the ability of ships, particularly research vessels, to make concurrent measurements while on another mission (e.g., commerce, science, deploying buoys and floats), making vessels an integral part of the global ocean observing system. Automated observing systems provide underway observations, like the meteorological data provide to the DAC, from shipping lanes and coastal regions (mostly commercial vessels) and the sparsely observed Southern Ocean (research and resupply vessels). Such data are not routinely assimilated into numerical weather prediction (NWP) models, however, due to their high-temporal sampling and independence from NWP, they are ideal for applications including air-sea interaction studies, model validation and satellite calibration and validation. **The need for additional shipboard observations was noted in these (and other) community white papers and directly affects most all of NOAA's program deliverables.** Without ships, the program cannot collect a wide range of essential climate observations and has limited ability to deploy moorings, drifters, floats, and other ocean observatory components. There is a need in for the Office of Climate Observation to support mechanisms to track research vessel operations, whether as part of a repeat hydrographic program (e.g., Hood et al. 2010) or simply a mission to conduct fishery assessment or a vessel repositioning transect on which additional secondary measurements can be collected. There needs to be a better connection between all aspects of U.S. research vessel operations (NOAA, Navy, University fleet, USCG) and the activities conducted by our international partners.

The SAMOS DAC serves as the project office for the entire SAMOS initiative. In this capacity, DAC personnel facilitate U.S. and international collaborations on topics ranging from data accuracy, data acquisition and exchange, training activities, and data archival. Meetings attended in FY2009 include the UNOLS Research Vessel Technical Enhancement Committee (host institution, Oct. 2008), Gulf of Mexico Coastal Ocean Observing System DMAC (invited; Feb 2009), Data Integration and Management on the Gulf of Mexico (May 2009), and JCOMM Ship Observation Team (invited, May 2009).

3.6 Data distribution (including website enhancement: deliverable 7)

All near real-time (quick) and delayed-mode (research) data are available via the web (http://samos.coaps.fsu.edu/, under "Data Access") and ftp (samos.coaps.fsu.edu, anonymous access, cd /samos_pub/data/) sites. The SAMOS web site also includes an overview of the initiative, provides links to relevant literature and best practices guides, and access to past SAMOS workshops. The DAC provides access to the preliminary quality controlled data for all 22 ships currently recruited to the SAMOS initiative, and new research quality data are available for all ships from 1 January 2009 to present. We have improved our searchable metadata portal, which allows users to access ship- and parameter-specific metadata, by providing all information in a clear tabular format. The user may also download PDFs of the metadata and digital imagery.

The web site also provides access to recruitment materials for vessels, desired SAMOS parameters, accuracy requirements, and training materials.

New in FY2009:

- A THREDDS catalog (http://coaps.fsu.edu/thredds.php) which includes not only the SAMOS observations, but previous underway data from WOCE and other research vessel cruises. This server will facilitate the ingestion of SAMOS observations into the Observing System Monitoring Center.
- The DAC is participating in an ongoing dialog with the U.S. VOS program (at NOAA NDBC) and several JCOMM SOT working groups to establish a protocol for placing SAMOS data onto the Global Telecommunication System (GTS). SAMOS data are not presently distributed via the GTS. We have an agreement in principle with JCOMM and U.S. VOS to create a "SAMOS call sign" that can be used to clearly identify a SAMOS record from a lower quality report from the same vessel on the GTS. This differentiation is essential to downstream data users. It also allows for a secondary set of metadata, from SAMOS, to be provided to the VOS program for participating vessels (even if they also provide data to VOS using National Meteorological Service provided instrumentation).
- An agreement has been established with the National Oceanographic Data Center (NODC) and the co-located World Data Center for Oceanography, Silver Spring, preserve and disseminate SAMOS and other ocean data in their Ocean Archive System (OAS). To enable long-term preservation and dissemination of the SAMOS data with the OAS, SAMOS (the producer) and NODC (the archive) generate Submission, Archival, and Dissemination Information Packages (SIP, AIP, and DIP). Each SIP, generated by SAMOS, includes files that contain the original, preliminary, and research-quality data and metadata (e.g., file naming and format descriptions), and a message-digest algorithm 5 (MD5) checksum for each file to ensure their integrity. SAMOS copies each SIP to a server for NODC to pull. After pulling an SIP, each consisting of data collected during a month from one ship, NODC generates an AIP. Each AIP contains all the data and metadata of its associated SIP, plus information that NODC adds to manage the AIP and to facilitate the dissemination of the data. For example, NODC adds an accession number (for tracking an AIP) and a Federal Geographic Data Committee standard-metadata record. After each AIP is completed, NODC makes it available online via two types of DIPs: the public may download individual files in the AIP–each file has a unique URL–or the entire AIP in one "tarball" file. In addition, users may find all the SAMOS AIPs by searching for SAMOS under "Contributing projects" on the OAS at http://www.nodc.noaa.gov/Archive/Search.

3.7 Deliverables pushed forward to FY2010

Several deliverables will be pushed forward simply due to shifting priorities for DAC personnel and the continued increase in vessels providing data to the DAC. In FY2010 we will address the actions from the 2008 GOSUD/SAMOS workshop [Deliverable 6] in preparation for a SAMOS technical workshop sometime in late 2010. To address deliverable 8, we have a conceptual design in place for routinely producing air-sea fluxes from the SAMOS data and will implement this in the next year. We will also conduct a comparison of SAMOS data to several new NWP products.

4. Education and Outreach

The U. S. is experiencing a shortage of personnel with the combined technical (e.g., electronics, fabrication, computer technology, etc.) and marine geosciences training needed to support offshore marine operations in the public and private sector. DAC personnel are engaged with the Marine Advanced Technology Education (MATE) Center at Monterey Peninsula College to better define technical careers in the marine sciences. The PI was invited to participate in the Ocean Science, Technology and Operations (OSTO) Workforce Workshop (November 2008) to help define the challenges facing the ocean technical workforce in the U. S. More recently, the DAC has contributed to workshops focused on the job functions, tasks, and necessary knowledge and skills for Oceanographic Instrumentation Technicians (March 2009) and Operational Marine Forecasters (September 2009). The overarching goal of these workshops is to define these emerging marine occupations and develop strategies to enhance/improve available educational opportunities at technical/community colleges and universities. The information collected will also be used to provide information on marine technical careers to secondary school students.

COAPS personnel also presented information related to the research vessel data center at two north Florida outreach events. The first was WeatherFest, held in Tallahassee, FL (January 2009) and organized by NOAA's National Weather Service Tallahassee Forecast Office, the Florida State University Department of Meteorology, and the North Florida Chapter of the American Meteorological Society. WeatherFest was attended by 500-700 people of all ages. The second activity was the FSU Coastal and Marine Laboratory Open House in April 2009. The open house was attended by ~1200 people of all ages.

5. Publications and Reports

5.1. Publications by Principal Investigators

Bourassa, M. A., S. Gille, C. Bitz, D. Carlson, I. Cerovecki, M. Cronin, W. Drennan, C. Fairall, R. Hoffman, G. Magnusdottir, R. Pinker, I. Renfrew, M. Serreze, K. Speer, L. Talley, G. Wick, 2009: High-Latitude Ocean and Sea Ice Surface Fluxes: Requirements and Challenges for Climate Research. Bull. Amer. Meteor. Soc. (submitted).

Fairall, C. W., B. Barnier, D. I. Berry, **M. A. Bourassa**, E. F. Bradley, C. A. Clayson, G. de Leeuw, W. H. Drennan, S. T. Gille, S. K. Gulev, E. C. Kent, W. R. McGillis, G. D. Quartly, V. Ryabinin, **S. R. Smith**, R. A. Weller, M. J. Yelland, H.-M. Zhang, 2010: Observations to quantify air-sea fluxes and their role in climate variability and predictability. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2)*, Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. and Stammer, D., Eds., ESA Publication WPP-306. (in press)

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Kara, A. B., A. J. Wallcraft, C. N. Barron, E. J. Metzger, R. Pauley and **M. A. Bourassa**, 2009: Comparisons of Monthly Mean 10m Wind Speeds from Satellites and NWP Products over the Global Ocean, J. Geophys. Res., 114, D16109, doi:10.1029/2008JD011696.

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Woodruff, S., S. Worley, S. Lubker, Z. Ji, E. Freeman, D. Berry, P. Brohan, E. Kent, R. Reynolds, **S. R. Smith**, and C. Wilkinson, 2009: ICOADS Release 2.5: Extensions and Enhancements to the Surface Marine Meteorological Archive. *Int. J. Climatology.* Submitted.

Worley, S. J., S. D. Woodruff, S. J. Lubker, Z. Ji, E. Freeman, E. C. Kent, P. Brohan, D. I. Berry, **S. R. Smith**, C. Wilkinson, and R. W. Reynolds, 2010: The role of ICOADS in the sustained ocean observing system. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2)*, Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. and Stammer, D., Eds., ESA Publication WPP-306. (in press)

5.2. Other Relevant Publications

Rettig, J. T., M. A. Bourassa, J. Hu, E. M. McDonald, J. J. Rolph, and **S. R. Smith**, 2009: Data management system to collect, quality control, distribute, and archive near real-time marine data. *E-journal of Data Integration and Management on the Gulf of Mexico*, 4 pp. Available from http://cs.tamucc.edu/dim/docs/papers/Jacob%20Rettig.doc.