U.S. Research Vessel Surface Meteorology Data Assembly Center
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1. Project Summary

The central activity of the U.S. Research Vessel Surface Meteorology Data Assembly Center (DAC) at the Florida State University (FSU) is the 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. In FY2014, 1 New Zealand-, 1 Australia-, and 28 United States-operated research vessels routinely transmitted daily emails containing one-minute averaged meteorology and surface oceanographic data to the DAC. Broadband satellite communication facilitates this daily transfer at ~0000 UTC. A preliminary version of the data is available in near-real time (within five minutes of email receipt) via the SAMOS web pages (http://www.coaps.fsu.edu/RVSMDC/html/data.shtml). The preliminary data are placed in a common data format, are augmented with vessel- and instrument-specific metadata (e.g., instrument height, type, units), and undergo automated quality control (QC). Visual inspection and further scientific QC result in intermediate and research-quality products that are nominally distributed on the SAMOS web site with a 10-day delay from the original data collection date. All data and metadata are version controlled and tracked using structured query language (SQL) databases. These data are distributed free of charge and proprietary holds and archived at the U.S. National Oceanographic Data Center (NODC) on a monthly basis.

Starting in October 2014, the DAC will develop a new ship-to-shore-to-archive pathway for full-resolution (sampling on the order of once per second) data collected by NOAA’s Scientific Computing System (SCS) software and will coordinate feedback and response related to SCS devices (starting with meteorology and flow-water sensors) between NOAA technicians, the
Office of Marine and Aviation Operations (OMAO), and the U.S. Voluntary Observing Ship scheme office. SAMOS observations from the recruited NOAA vessels represent only a fraction of the data collected by SCS while each vessel is at sea. The DAC will ensure that a complete record of the full-resolution (as sampled by the individual sensors) SCS data are received by NODC following each cruise and cross-referenced to quality-processed data subsets derived from the original SCS observations (e.g., SAMOS datasets). Data collected by SCS on NOAA vessels represent a significant investment by the American taxpayer. Archival at NODC ensures these data are preserved for future generations of scientists, policy makers, and the public.

The DAC activities focus primarily on NOAA Climate Mission and Technology and Mission Support goals by providing high-quality weather and near-surface ocean data to validate 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, being mobile observing platforms, are an essential component of the global ocean observing system. They are equipped with computerized data systems that continuously record navigational (ship position, course, speed, and heading), meteorological (winds, air temperature, pressure, moisture, rainfall, and radiation), and near-surface ocean (sea temperature and salinity) parameters while a vessel is underway. Research vessels travel to remote, hard-to-observe ocean locations far from the shipping lanes sampled by merchant vessels. Research vessels also provide essential observations between the fixed locations of surface moorings and support side-by-side comparison to mooring data when moorings are deployed or serviced.

The DAC provides data that quantify the physical and thermodynamic processes governing the interaction between the ocean and atmosphere, 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 DAC provides high-quality marine meteorological and surface ocean measurements to the research and operational community so that they can identify and model the interactions between the ocean and atmosphere. Societal benefits include improved weather and climate models and forecasts that provide the public and private sector with the tools to make decisions affecting agricultural productivity, the energy use, and daily life.

Our user community includes scientists developing algorithms to retrieve marine observations from Earth-orbiting satellites, those working to define the range of air-sea exchanges in extreme environments (e.g., the Southern Ocean), and atmospheric and ocean modelers seeking to verify model analyses and 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.
2. Scientific and Observing System Accomplishments

In FY14, the project focused on deliverables that include the following:

1. Continue daily monitoring and automated quality control of data received by all vessels contributing to the SAMOS DAC.
2. Continue routine research-quality evaluation of meteorological data for all NOAA vessels contributing to the SAMOS DAC.
3. Distribute all quality-controlled SAMOS observations via web, ftp, and THREDDS services and ensure routine archival at NODC.
4. Develop and test new automated quality control methods.
5. Engage OMAO to augment instrumental metadata for all recruited NOAA vessels.
7. Continue liaison activities with U.S. and international (limited) government agencies, archives, climate programs, and throughout the marine community

Additionally in FY14, we began planning for a new aspect of the RV DAC, specifically a new role to evaluate the completeness, documentation, etc. for post-cruise, full-temporal resolution data packages collected by NOAA vessels using the Scientific Computer System (SCS) software and the timeliness of delivery for these packages to NODC.

These deliverables center collectively support an ongoing effort to ensure that the highest quality marine meteorological and near surface oceanographic data are collected by research vessels, primarily from the U.S. fleet, and that they are distributed and archived in a manner that makes the data accessible and useful to a diverse research and operational user community. Unlike the standard marine weather reports collected and transmitted to support operational marine weather forecasting, the data collected in near-real time by vessels recruited to the Shipboard Automated Meteorological and Oceanographic (SAMOS) initiative and the post-cruise underway data collected by SCS on NOAA vessels are primarily used in marine climate studies, numerical modeling, and surface oceanographic data analyses. Examples include creating estimates of the heat, moisture, momentum, and radiation fluxes at the air-sea interface, improving our understanding of the biases and uncertainties in global air-sea fluxes, benchmarking new satellite and model products, and providing high quality observations to support modeling activities (e.g., reanalysis) and global climate programs. Recently, underway meteorological and surface oceanographic data have been used to improve algorithms that retrieve air temperature and humidity near the ocean surface using space-based satellite observing platforms (Jackson and Wick 2014). These improved satellite retrievals can then be applied to develop improved estimates of air-sea exchanges of heat, momentum, and freshwater and can further be incorporated into numerical weather prediction and climate models that are used by NOAA for forecasting and decision making for the general public. Similarly, wind observations and sea surface temperature data from SAMOS and SCS datasets can be used to evaluate satellite ocean vector wind products (and derived surface currents) and SST products that are subsequently used to model the circulation and temperature structure of the ocean (e.g., ocean heat content and transport). In summary, the U.S. research vessel DAC at FSU provides the high-quality meteorological and near-surface oceanographic data to support an expanding research and operational user community, which in turn is addressing many questions of primary interest to COD and NOAA.
2.1 FY2014 Achievements

A quick note on FY2014 budget: FSU receives its funding via the Northern Gulf of Mexico Cooperative Institute at Mississippi State University. Through this arrangement, there is a one-year delay between when funds are allocated by NOAA and the time they are received for spending by FSU. This means that our FY14 allocation by NOAA COD and OMAO was not available for use by FSU until 1 October 2014, the start of FY15. For that reason, we will report herein on the plans for the SCS data stewardship activities that were funded by OMAO in FY14, but for which the bulk of the work plan will not be executed until FY2015 by FSU.

The primary achievement in FY 2014 is the continuation the SAMOS initiative, founded by COD in 2005, which collects, evaluates, distributes, and archives underway meteorological and near surface ocean observations from research ships. Collection statistics for FY14 (compared to FY13) are included in Table 1 and a map of the spatial sampling for FY14 is shown in Figure 1. The total number of vessels routinely transmitting meteorology and surface oceanographic data to the SAMOS DAC remained stable in the past year and yielded a slight increase in the number of days of data received. The only new recruit was NOAA’s Ferdinand Hassler and the Aurora Australis stopped transmitting as a result of technical challenges in Australia. These data span the global ocean, extending into poorly sampled regions of the South Atlantic, South Pacific, and Southern oceans (Fig. 1). For the first time in several years, we received significant data from the eastern Indian Ocean (rarely visited by U.S. RVs). The extent of these data from the tropics to the polar latitudes, along with many reports on the U.S. continental shelf, provide observations from the wide range of environmental conditions required by our users to meet objectives in satellite, air-sea exchange, and physical oceanographic studies.

Our lead analyst, Jeremy Rolph, continues to conduct daily (not 24/7) visual inspections of all SAMOS observations [deliverable 1]. This inspection, a quick-look, does not allow for adding/altering quality control flags on the data, but ensures 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 problem notification results in a quick resolution of sampling issues and adds value to the public investment in expensive shipboard observing systems by ensuring the highest quality data are available to research and operational users.

Over the past year, Kristen Briggs completed visual QC for all recruited NOAA vessels (deliverable 2 under COD funding) and the RV Falkor (SOI funding). Visual QC allows the analyst to review, add, or modify data quality flags on the merged files. Visual data QC identifies a number of problems (e.g., stack exhaust contamination of temperature/humidity sensors, water flow problems in scientific sea water system, diurnal ship heating errors) that are difficult to capture reliably with automated QC. The result is data from ships only receiving automated QC likely have erroneous data reaching data users without being marked/flagged as problematic.

We again produced an annual report (Briggs et al. 2014) that summarizes the data quality for all vessels contributing data for the calendar year 2013. The report has been distributed to all operators of SAMOS vessels and posted to the SAMOS web site.
Table 1: Ships transmitting observations to SAMOS DAC during FY 2013 and FY 2014. Seven vessels recruited with funds from NSF’s Ocean Instrumentation and Technical Services program and one recruited via a contract with the Schmidt Ocean Institute are shown for completeness. Operators include NOAA, the Bermuda Institution of Ocean Sciences (BIOS), the Woods Hole Oceanographic Institution (WHOI), Australia and New Zealand via the Integrated Marine Observing System (IMOS), the U.S. Coast Guard (USCG), the U. S. Antarctic Program (USAP), the Scripps Institution of Oceanography (SIO), the Schmidt Ocean Institute (SOI), the University of Hawaii (UH), the University of Rhode Island (URI), the University of Washington (UW), and Oregon State University (OSU).

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Operator</th>
<th>Number of ship days with data 1/10/2012–30/9/2013</th>
<th>Number of ship days with data 1/10/2013–30/9/2014</th>
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<tr>
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<tr>
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<td>WHOI</td>
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<td>Falkor</td>
<td>SOI</td>
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<td>Thomas Jefferson</td>
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<tr>
<td>T. G. Thompson</td>
<td>UW</td>
<td>--</td>
<td>297</td>
</tr>
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</table>

1No research-quality visual QC completed.
2Visual QC discontinued at the end of 2012 as a result of NOAA budget reductions.
3NSF funding supported recruitment (part of UNOLS Rolling Deck to Repository program).
4Falkor recruited to SAMOS via contract with the Schmidt Ocean Institute. Leveraging COD-funded SAMOS infrastructure at FSU.
5Recruited to SAMOS in FY14.

The DAC also developed a prototype air-sea flux product derived using the quality controlled SAMOS observations. This new flux product provides estimates of latent and sensible heat exchange between the ocean and atmosphere and the wind stress at the ocean surface using three different surface flux algorithms. Unlike most flux products, the derived fluxes are provided along ship tracks and are not interpolated to a grid. This allows users to compare the derived
fluxes at a point location to other methods for deriving air-sea exchange estimates (e.g., using satellites or numerical models). We engaged the air-sea flux community [Deliverable 6], presenting preliminary results and receiving user feedback, at the European Geophysical Union (April 2014) and CLIMAR (June 2014) meetings and a manuscript is in preparation.

Figure 1: Cruise tracks showing data provided to the SAMOS DAC for FY2014. Data are color coded by the primary data providers. All university-operated vessels are shown in blue.

DAC personnel also achieved a number of technical enhancements to the SAMOS data processing, distribution, and archival systems. Our software team, led by Jocelyn Elya, began streamlining and upgrading our automated data quality processing and web services in preparation to migrate our data management system to four new virtual machines. This will separate operational from developmental code for both data processing and web services, which will support effective testing of new quality control methods [deliverable 4] and provide mirroring of the operational data and metadata on the developmental machines. Processing and web codes have been streamlined for simplified maintenance, portability, and efficient operation. Additional documentation and error logging has been developed. All of these upgrades will become operational when the server migration is completed in early 2015. Another technical enhancement is the preliminary use of Google analytics to determine who is using the SAMOS observations. In FY14, we started tracking visitors to the SAMOS data download pages (29 countries) and are exploring how to track actual data downloads.

Our final achievement of FY2014 was initiating planning for the SCS data package evaluation and SCS issue tracking system. A face-to-face meeting occurred between FSU, OMAO, and NODC personnel on 14-15 July 2014 (Silver Spring, MD). The team reviewed ongoing activities by OMAO and NODC to support direct submission of post-cruise SCS data packages to NODC. The meeting resulted in several action items for FSU (downloading and examining sample SCS
packages from NODC), OMAO (selecting first candidate vessels, providing candidates for issue tracking focus group), and NODC (usage of issue tracking in the past). The discussions laid the groundwork for FSU to move forward once FY14 funds were received on 1 October 2014.

2.2 Facilitating Science

The nature of our project is providing high-quality, continuous, instrumental observations to a diverse user community. Distributing data without restrictions and via multiple electronic access protocols (See section 2.4) makes it difficult to identify specific instances of scientific advancement achieved using the data we provide. We generally rely on users to voluntarily acknowledge the application of SAMOS observations from FSU. In FY14, the DAC had direct interactions with William Landing (FSU, personal communication, 2013) who is using SAMOS pressure and temperature data to calculate aerosol sampling flow rates on select cruises and Byron Blomquist (NOAA, personal communication, 2014) who compared SAMOS data to those from the WHOTS mooring and the independent NOAA ESRL portable flux standard during a research cruise in July 2014. We also have replied to inquiries for using SAMOS observations in a new version of iQuam (a NOAA in situ SST quality monitoring project to support satellite cal/val). Our new along-track SAMOS flux product has also been requested by Lei Shi (NOAA, personal communication, 2014) for their development of near-surface air temperature and humidity retrievals from satellites.

A search of Google Scholar also revealed five new publications that directly use SAMOS observations or examine some aspect of the SAMOS data processing system. Two of the manuscripts (Hauri et al. 2013, Jackson and Wick 2014) addressed problems related to ocean carbon cycles while Reul et al. (2014) focused on salinity variations along the meandering Gulf Stream. Jackson and Wick (2014) and Reul et al. (2014) used SAMOS data to evaluate measurements made by satellites. Hauri et al. (2013) used SAMOS winds to calculate localized carbon fluxes as part of their efforts to constrain the carbon flux budget in the Chukchi Sea, a region thought to be an important atmospheric carbon sink in the ocean. Two additional manuscripts (AbdulAzeem 2014a, 2014b) examined aspects of the SAMOS data processing system as it applies to the field of computer informatics, specifically the distribution and uncertainty in designing database applications.

We also actively participate in national and international meetings and general email exchanges to collect information from potential users of SAMOS data to plan future improvements to our data distribution practices [Deliverables 6 & 7]. In FY14, we had an extensive email exchange with G. Reverdin and N. Martin from the Pierre- and Marie- Curie University in France who are examining sea-surface salinity variability. These users noted a need for additional geospatial search tools and access to SAMOS observations in ASCII formats. Development of geospatial search tools is being funded by complementary NSF funding and we are planning a submission of SAMOS data into Release 3.0 of the International Comprehensive Ocean-Atmosphere Data Set in early 2015 (which requires adoption of a standard ASCII data format). The latter will provide the SAMOS data to a wider user community, including those working on the next generation of atmospheric and ocean reanalyses, which typically use ICOADS as their primary source of in-situ marine climate data.

2.3 Impediments
Visual quality control is manpower intensive and flat budgets from NOAA resulted in the loss of this capability for all non-NOAA vessels at the end of CY2012. When comparing data for the Knorr in CY2012 vs. CY2013, we noted a reduction of nearly 11% in the number of quality flags added to the data in CY2013 because the Knorr only received automated (not visual) QC in CY2013 (see Briggs et al. 2014). This means that the CY2013 datasets likely include suspect data that are reaching the user without application of QC flags. The loss of visual QC for 5 vessels (Table 1) affected 1307 ship days of data, including data from the L. M. Gould, the Nathaniel Palmer, and the Healy, which primarily operate in the Southern and Arctic oceans. The reduction in the quality assessment of these high-value observations may adversely affect climate and ocean circulation studies in these extreme environments.

2.4 Data and Information Dissemination and Archival

The core mission of the DAC is data stewardship. This includes ensuring all data, reports, and documentation are readily available and data and metadata are submitted to a national archive for long-term preservation [Deliverable 3].

All near real-time (preliminary, 5-min delay from receipt) and delayed-mode (intermediate or research, 10-day delay from receipt) data are available via web (http://samos.coaps.fsu.edu/, under “Data Access”), ftp (samos.coaps.fsu.edu, anonymous access, cd /samos_pub/data/), and THREDDS (http://coaps.fsu.edu/thredds.php) services. The most recent data can be identified by selecting “preliminary” data at http://samos.coaps.fsu.edu/html/data_availability.php. Most recent data vary depending on which ships are transmitting data on a given day, but are typically available within a few minutes of 0000 UTC. We routinely test our web services and respond rapidly to failures of the system. In addition to data access, the SAMOS web site includes our mission statement, data policy, and acknowledgements under the “About” tab on the SAMOS home page. The web site also provides access to recruitment materials for vessels, a subscription service for operators to access monthly data reports, desired SAMOS parameters and accuracy requirements, best practice guides, and training materials. SAMOS publications and technical reports supported by COD are available at http://samos.coaps.fsu.edu/html/publications.php and acknowledgements are included in each document.

SAMOS data are not distributed via the Global Telecommunication System. The DAC has an ongoing collaboration with the managers of the U.S. Voluntary Observing Ship scheme at the National Data Buoy Center (NDBC) to assess the quality of data records transmitted via the GTS from the same vessels that contribute to SAMOS. The majority of the U.S. research vessels contributing to SAMOS provide irregular 1-, 3-, or 6-hourly reports to the GTS via other National Weather Service- (NWS) supported programs (e.g., AMVER SEAS). Preliminary results reveal that the SAMOS data can be used to trouble-shoot the GTS data feeds from the NWS programs. The collaboration with NDBC personnel (J. Rolph, FSU, visited the U.S. VOS coordinator in Pascagoula, MS in April 2014) has also allowed SAMOS to receive updated instrumental metadata for several NOAA-operated RVs (deliverable 5). The PI notes that our major user community continues not to require SAMOS data to be delivered via GTS. Our current web, ftp, and THREDDS systems meet their needs.

SAMOS data are archived at the U.S. National Oceanographic Data Center on a monthly schedule using automated submission protocols. To ensure integrity, each archival set includes
files that contain the original, preliminary, and research-quality data and metadata (e.g., file naming and format descriptions); a file manifest; and a message-digest algorithm 5 (MD5) checksum for each file. NODC makes the archival sets available online via two types of Dissemination Information Packages: the public may download either individual files in the archival set—each file has a unique URL—or the entire archival set in one “tarball” file. Users may find all the SAMOS data by searching for SAMOS under “Contributing projects” on the Open Archive System at [http://www.nodc.noaa.gov/cgi-bin/OAS/prd/accession](http://www.nodc.noaa.gov/cgi-bin/OAS/prd/accession). A check on 14 November 2014 located 1499 monthly SAMOS ship archive sets at NODC. Periodically, the PI downloads SAMOS data from NODC to ensure system integrity.

Back in 2005, the SAMOS acronym was adopted and has been very successful for tracking our data, particularly when searching the NODC archives. The SAMOS initiative has been recognized at international meetings and symposia such as the ESA/SOLAS Earth Observation for Ocean-Atmosphere Interactions Science 2014 and WCRP and EUMETSAT sponsored Climate Symposium 2014. In the SOLAS meeting, SAMOS data were widely used in gas flux calculations and noted in an introductory talk for the session. At the WCRP and EUMETSAT meeting, SAMOS data were noted for their value in validation of satellite retrievals. The SAMOS acronym provides a mechanism to identify use of these data in manuscripts in catalogs like Google Scholar. In FY14, we also initiated a discussion with NODC to assign a “collection level” digital object identifier to the FSU SAMOS data in the archive. Finally, we do acknowledge CPO/COD support for the SAMOS project on the SAMOS web site ([http://samos.coaps.fsu.edu/html/ack.php](http://samos.coaps.fsu.edu/html/ack.php)), but need to provide a more prominent “how to cite these data” somewhere near or on the data download pages. As noted in section 2.1, we are also exploring Google analytics to better track data downloads from FSU.

### 3. Outreach and Education

We continue to train the next generation of marine and data scientists. Neely Fawaz and Jocelyn Elya are both undergraduate students studying computer science. Through COD funds they have been exposed to the complex and diverse ways that marine climate data are disseminated to the user community. Each has developed or augmented operational data processing and web distribution codes for the SAMOS project. Rachel Weihs, PhD candidate, has been working on one of the outstanding issues in using SAMOS data to estimate air/sea fluxes. Ship-based SST observations may lead to errors in the fluxes in cases where (a) the upper ocean exhibits strong diurnal heating from solar radiation or (b) the depth of the measurement is subsurface (SAMOS SST typically from 1 to 5 m depth). For flux calculations the surface skin temperature is desired. Ms. Weihs is developing a parameterization for converting sea temperatures from depth to a skin temperature, that accounts for diurnal variability. If this parameterization proves to be accurate, we will utilize it to improve our SAMOS-based flux estimates.

We also continued our professional development series for in-service marine technicians with a short course for NOAA (and university) technicians on 09 December 2013 in Norfolk, Virginia ([http://samos.coaps.fsu.edu/html/mt_shortcourses/shortcourse_12_09_2013.php](http://samos.coaps.fsu.edu/html/mt_shortcourses/shortcourse_12_09_2013.php)). The training was led by Jeremy Rolph (FSU) and Daniel Wolfe (NOAA/CIRES) and was part of an extended annual training program conducted by NOAA’s Office of Marine and Aviation Operations.
Informing the wider community of DAC activities was primarily limited to the international scientific community. In particular, presentations with a focus on SAMOS and DAC activities were made at the 2014 Ocean Sciences Meeting (Honolulu, HI, Feb. 2014), EGU General Assembly 2014 (Vienna, Austria, May 2014), and the Fourth JCOMM Workshop on the Advances in Marine Climatology (CLIMAR-IV, Asheville, NC, June 2014). Also, the PI was invited to give a seminar at the Australian Bureau of Meteorology (Melbourne, Australia, 11 August 2014) describing a decade of success with SAMOS and an ongoing partnership with the Bureau to provide SAMOS data from RVs operating in Australia and New Zealand. Aside from our web presence, no additional outreach was made to the general public or mass media describing the activities of the DAC.

4. Publications and Reports

4.1. Publications by Principal Investigators

4.1.1. Published

4.1.2. Data Reports

4.2. Other Relevant Publications


