# Progress of the Shipboard Automated Meteorological and Oceanographic System (SAMOS) Initiative

Shawn R. Smith

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

http://samos.coaps.fsu.edu

## Objectives

The shipboard automated meteorological and oceanographic system (SAMOS) initiative aims to improve the quality of meteorological and near-surface oceanographic observations collected in-situ on research vessels (R/Vs) and select volunteer observing ships (VOS). Scientific objectives of SAMOS include:

- creating quality 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
- providing high quality observations to support modeling activities (e.g., reanalysis) and global climate programs

To achieve the science objective, the SAMOS initiative seeks to:

- improve access to quality assured SAMOS data for scientific and operational users by providing free and open access to data and metadata
- expand availability of SAMOS observations collected in remote ocean regions (e.g., Southern Ocean)
- improve the accuracy and calibration of SAMOS measurements
- provide standards for data and metadata collected on SAMOS equipped vessels
- ensure routine archival of SAMOS data at world data centers
- develop documentation and training materials for use by data collectors and the user community
- support comparison studies between in-situ platforms (e.g., R/Vs, VOS, buoys)
- develop partnerships within the international marine community

## What is a SAMOS?

SAMOS have been deployed on research vessels (Fig. 1a) for several decades and are now being deployed on VOS (Fig. 1b). The typical SAMOS is a continuously recording, computerized data logger connected to sensors that record navigation, meteorological, and near-surface ocean parameters while the vessel is at sea. To achieve the science objectives of the SAMOS initiative, the desired interval between sequential observations is one minute. Parameters of interest are listed in Table 1.


Figure 1: Bow masts with meteorological instrumentation on (a) R/V *Ronald H. Brown* and (b) VOS *Columbus Florida*. Photo credits: (a) Rik Wanninkhof, (b) David Hosom.

## Data Stewardship

Data stewardship activities are essential to improve access to and integrity of high-quality SAMOS measurements. In 2004 a data assembly center (DAC) was established at the Florida State University (FSU) to

- set standards for parameters to be routinely observed (Table 1), essential metadata, and uniform averaging methods;
- establish a protocol for data transport (ship-to-DAC-to-users);
- provide scientific data quality evaluation (DQE);
- distribute SAMOS data from participating vessels in a free and open manner; and
- preserve the integrity of the SAMOS observations through archival at world data centers.

Overall, SAMOS data stewardship activities are consistent with the GCOS climate monitoring principles. [Available at www.wmo.ch/web/gcos/Second_Adequacy_Report.pdf]

Table 1: Primary and secondary parameters for routine data acquisition from Shipboard Automated Meteorological and Oceanographic Systems (SAMOS) on research vessels.

| Primary data | Secondary data (desired if available) |
|---|---|
| • Observation time (UTC) | • Ship speed over water [9] |
| • Latitude | • Vessel pitch, roll, and heave |
| • Longitude | • Photosynthetically Active Radiation (PAR) |
| • Ship course over ground | • Ultraviolet radiation |
| • Ship speed over ground | • Total Radiation |
| • Ship heading | • Visibility[4] |
| • Ship-relative wind direction [1] | • Ceiling[4] |
| • Ship-relative wind speed [1] | • Salinity |
| • Earth-relative (true) wind direction | • Conductivity |
| • Earth-relative (true) wind speed | • Radiometric Sea Surface Temperature |
| • Atmospheric pressure | • Swell & wind wave heights and directions [4] |
| • Air temperature | • Weather, cloud cover, and cloud height [4] |
| • Atmospheric moisture [2] | |
| • Precipitation | |
| • Shortwave radiation | |
| • Longwave radiation | |
| • Sea temperature | |

[1] As measured by anemometer
[2] One or more measurements of wet-bulb temperature, dewpoint temperature, relative humidity, and/or specific humidity
[3] Fore-aft and along beam components
[4] If available from automated sensors

### *2005 Pilot Project*

- A partnership between the Scripps Institution of Oceanography (SIO), Woods Hole Oceanographic Institution (WHOI), and FSU
- Developed a data protocol for daily transmission of SAMOS observations from a vessel at sea to the DAC (Fig. 2)
  - •File transmission via email attachments
  - •Files contain all 1-min. averages sampled during one day at sea
  - •Using SAMOS version 1 data exchange format
  - •Daily transmission to occur just past 0000 UTC
- Initial vessels: R/V *Knorr* and R/V *Atlantis*
- Routine data transfers now underway and preliminary data are available on the SAMOS web page
- DAC continuing to develop research quality products, with distribution expected late in 2005
- DAC working to recruit additional vessels

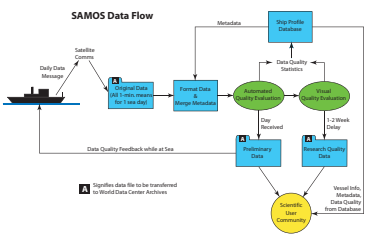


Figure 2: Schematic showing SAMOS data flow as planned for the 2005 pilot project.

### *Data Quality Evaluation*

Based on FSU experience with delayed mode R/V meteorology data from World Ocean Circulation Experiment

- Daily data from ships automatically combined with metadata from database
- Files pass through two automated quality evaluation programs
- The subsequent files are distributed to users as preliminary data (available within five minutes of receipt at DAC)
- Visual DQE will follow to produce research quality data (allowing ample time to receive delayed data)

### *Metadata*

Metadata are essential to the scientific application of SAMOS data. The SAMOS DAC has developed a ship profile metadata database for all participating vessels. The database is queried throughout the DQE. Users can now access metadata for participating vessels through the SAMOS web page.

- A SAMOS metadata specification is complete and was tested during the pilot project
- Standard includes:
  - •vessel contacts, identification, dimensions, images and plans
  - •instrument positions, make, model, calibration dates, exposure photos
  - •Data precision, sampling rate, averaging methods
  - •File history, version tracking, data quality statistics
- Still to be resolved is how to complete routine updates of vessel metadata.

## Improving Data Accuracy

The SAMOS initiative seeks to improve the accuracy of marine meteorological and near-surface ocean parameters by

- working with the scientific community to establish data accuracy standards for the parameters listed in Table 1
- developing a roving standard instrument system for shipboard evaluation of R/V SAMOS installations
- conducting air flow modeling of vessels
- providing guidelines for sensor calibration and deployment
- promoting routine comparison studies between SAMOS equipped ships, buoys, and flux reference stations (Fig. 3a)


### *Roving Flux Standard and Shipboard SAMOS Evaluation*

NOAA's Environmental Technology Laboratory (ETL) and WHOI have been collaborating on a project to evaluate and improve SAMOS observations from R/Vs in the U.S. fleet. Funding was sought by NOAA (ETL) and NSF (WHOI) to build a roving standard and deploy it on cruises of opportunity on NOAA, NSF, and U.S. Coast Guard R/V's.

- First year funds for ETL to construct a new roving standard for air-sea fluxes and start-up funds for WHOI activities have been approved.
- ETL made two cruises (2003:R/V *Roger Revelle* [SIO]; 2004:R/V *Ronald H. Brown* [NOAA]) associated with WHOI deployments to the Stratocumulus flux reference buoy (20˚S,85˚W). The existing ETL flux system (high quality data but not intended as a standard) was used (Fig. 3b).
- The 2003 *Revelle* cruise was a test case for the concept and a number of instrument issues were found. Due to short notice for the exercise and shipping delays in freshly calibrated ship sensors, the principal lesson learned was that planning needs to start months in advance for meaningful onboard comparisons.
- In 2004, comparison on the *Ronald H. Brown* looked very good, except for anemometer placement.

In an example of multi-platform comparison, ETL and PMEL are comparing data from the ETL flux shipboard system and the TAO buoys on the 95˚ and 110˚W lines.


Figure 3: (a) R/V *Roger Revelle* and WHOI flux reference buoy. (b) ETL direct flux sensors. Photo credit: Chris Fairall.

## Training Activities

Discussions at the first two SAMOS workshops revealed a need for additional training materials for technicians and users of SAMOS observations. Technicians noted that they were rarely trained in marine meteorological observation methods and that information on the scientific rationale for meteorological observations would be an encouragement to participate in SAMOS data acquisition. To address these issues, the SAMOS initiative is

- encouraging funding agencies to support human capital development through training and education.
- considering hosting training workshops or summer schools for marine technicians
- compiling a guide to the best procedures for making high-quality meteorological measurements at sea.

A first draft of the handbook is well advanced and will be reviewed at the 2006 SAMOS workshop. Plans call for the handbook to be distributed in hard copy and as a dynamic, on-line resource that can be expanded and updated as necessary. The handbook is aimed at a broad readership that will

- primarily provide guidance to scientists and technicians who are responsible for the installation and maintenance of meteorological equipment on board ships (or surface moorings),
- inform PI's studying oceanic processes who require air-sea fluxes as supporting data,
- serve as background material for users (e.g. modellers) allowing them to judge accuracy of datasets, and
- introduce students to the practicalities of ship-based flux measurement.

The handbook is evolving on two levels: a brief guide to the essentials of installing, maintaining and operating high-quality meteorological sensors, and a technical and scientific manual on the methodology and rationale for the measurement of air-sea fluxes. The latter section describes the environmental variables and why their measurement is more difficult at sea than over land. Sensors and procedures which optimize their performance are included. The importance of documentation is stressed, particularly of the location and status of the instruments, and of any event which may impair data quality. Issues of quality assurance, standardization of formats, metadata and archiving of the data are addressed.

Training activities are being spearheaded by NOAA ETL, the SAMOS DAC, and members of the WCRP WGSF.

## International Participation

The SAMOS initiative currently is focused on U.S. research vessels; however, expansion to include international vessels is desirable.

- Necessary to achieve SAMOS science goals and develop a sustained global network of high-quality SAMOS observations.
- A future focus on the polar oceans is one goal of SAMOS, and the International Polar Year provides an opportunity to include high latitude vessels from many countries.
- Securing funding for international vessel involvement is primary limitation.
- International vessel operators, scientists, and data users interested in the SAMOS initiative should contact: **smith@coaps.fsu.edu**

Figure 4: U.S. Coast Guard Icebreaker. Photo courtesy of Philip McGillivary.

## Partnerships

Partnerships are essential to the success of the SAMOS initiative. The initiative thanks those who have already contributed and continues to seek new expertise and resources.

- **User Community:** Provides scientific input to establish sampling methods and accuracy targets. SAMOS will continue to engage a wide user community to develop products for both research and operations.
- **UNOLS:** Several vessel operators participating in the pilot project. Additional members have provided critical feedback on data exchange methods, metadata standards, etc.
- **VOSClim Program:** Participants continue to provide expertise to create the SAMOS metadata specification.
- **GOSUD:** The Global Ocean Surface Underway Data (GOSUD) pilot project provided input on data and metadata standards. Current discussions focus on the potential to exchange both data and technical expertise to increase access to marine meteorological and near-surface ocean data. Plans are developing for a Joint GOSUD/SAMOS Workshop in May 2006.
- **WCRP WGSF:** Interested in SAMOS goal to improve marine meteorological observations. SAMOS initiative will provide critical data for benchmarking air-sea flux products. WGSF contributing to marine handbook.
- **Others:** Constructive feedback has been provided by members of JCOMM, SOT, and the international research vessel community. The SAMOS initiative welcomes ongoing collaboration with the NOAA Office of Climate Observation (OCO) and the U.S. National Science Foundation (NSF).

### *Acknowledgements*

The SAMOS DAC at FSU is supported by the NOAA OCO. Additional funds for data center activities at the Center for Ocean-Atmospheric Prediction Studies (COAPS) are provided by the Physical Oceanography Section of NSF and the NOAA ESDIM program. COAPS receives base funding from the NOAA Office of Global Programs, through an Applied Research Center directed by James J. O'Brien.

The shipboard contributions to the pilot project are supported by the Operational Scientific Services at WHOI and NSF. ETL and WHOI funding for their contribution to the SAMOS initiative is provided by NOAA OCO.