Ships of Opportunity

Robert A. Weller
Woods Hole Oceanographic Institution, Woods Hole, MA

Project Summary

Ships of Opportunity, also known as Volunteer Observing Ships or VOS, are merchant marine ships that make repeated ocean passages. We focus on fast container ships that make regular crossings of broad areas of the ocean basins and, if possible, those that pass close to our Ocean Reference Stations (ORS), which are surface moorings at fixed locations. This provides broad spatial sampling of the regimes found across ocean basins that is an excellent complement to the high time resolution sampling at our fixed time series sites (ORS). We also select ships that are used by other groups for deployment of XBTs (expendable bathythermographs) and profiling floats, as sharing of logistic support facilitates the work. Our goal is to obtain from the selected VOS time series of surface meteorology and ships velocity and position that are complete and accurate and thus allow us to compute using the bulk formulae time series of air-sea heat (sensible, latent, shortwave, longwave, and net), freshwater, and momentum flux. These time series are used to quantify the spatial variability in the in-situ surface meteorology and air-sea fluxes, to identify spatial biases and other others in gridded meteorological and flux products (such as those from the National Centers for Environmental Prediction (NCEP) or those developed from remote sensing methods), to develop improved fields of air-sea fluxes over the oceans, and to support climate research.

The instrumentation used on the VOS is the ASIMET (Air-Sea Interface Meteorological system) we developed. It consists of a central data logger and sensor modules that communicate with the central logger via RS-485. It has been developed to collect one minute averaged values of wind speed and direction, air and sea surface temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming longwave radiation, and precipitation. It provides hourly averaged data for telemetry in near real time in addition to storing the one-minute data. The ASIMET hardware used in this project is also used on the surface buoys in the Ocean References Stations project. The ASIMET system produces high quality data, accurate enough to support calculation of monthly air-sea heat exchanges to an accuracy of better than 10 W

m^{-2}. The accurate data from the VOS are used to: 1) identify errors in existing climatological, model-based, and remotely-sensed surface meteorological and air-sea flux fields, 2) to provide the motivation for improvements to existing parameterizations and algorithms used in models and in preparing products from satellite data, 3) to provide the data needed to correct existing climatologies, 4) and to validate new model codes and remote sensing methods. The VOS data, due to the cross-basin, repeat sampling are a an important resource for work to improve the accuracy of global fields of the air-sea fluxes of heat, freshwater, and momentum and to document variability and change in the coupling of the atmosphere and the ocean.

The VOS provide a challenging operating environment in which to make high quality surface meteorological observations. Acceleration and vibration, radio frequency interference, freezing temperatures, and power surges are among the issues we have faced. Examination of failure rates of individual ASIMET sensor modules revealed where the present set of modules introduce reliability problems and negatively impact data return rates and flagged problems with anemometer performance. Examination of success at repeated pre- and post-deployment calibration and at getting close agreement (to roughly 2 W m^{-2}) in calibrated sensor modules has identified the incoming longwave radiation module as introducing the largest uncertainty in our heat flux estimates. In response we last year began efforts to improve the performance of these key sensors. We also last year increased work to analyze the surface meteorological and air-sea data collected in the past and on an ongoing basis and to meet the goals for utilization of VOS data. A subcontract to colleagues at the National Oceanographic Centre (NOC, formerly Southampton Oceanography Centre) in the U.K. has addressed another aspect of the challenge of working from VOS, that of flow distortion by the structure of the ship and its cargo.

The Ships of Opportunity Program is managed as three tasks: A) VOS Field Operations, B) Instrumentation Upgrades, and C) Data Processing.

Accomplishments

<u>VOS Field Operations</u>

The implementation of the ASIMET hardware on the VOS is the AutoIMET. AutoIMET was developed by the Woods Hole Oceanographic Institution to meet the need for improved marine weather and climate forecasting. It is a wireless, climate quality, high time resolution system for making systematic upper ocean and atmospheric measurements. This interfaces to the NOAA SEAS 2000 (Shipboard Environmental (Data) Acquisition System) that automatically receives meteorological data (from the AutoIMET) and sends in automated one hour satellite reports via Inmarsat C. This system will document heat uptake, transport, and release by the ocean as well as the air-sea exchange of water and the ocean's overturning circulation.

The basic deliverable is the data, supported by the appropriate metadata. Descriptions, technical information and data from the several VOS being serviced is posted on the site: http://uop.whoi.edu/vos/ Data (plots) are available for all ship sets. Data (numbers) are available via anonymous ftp for the last data set only: ftp.whoi.edu/pub/users/fbahr/VOS. Data from previous times are available from Frank Bahr at: fbahr@whoi.edu. There is a link to the site: http://frodo.whoi.edu where there is detailed information on the AutoIMET and ASIMET modules. Instrument design questions can be addressed to Dave Hosom at: dhosom@whoi.edu

Ship selection in the Atlantic and our interface to the NOAA SEAS system is via AOML (Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida). There is ongoing cooperation with Scripps Institution of Oceanography via the CORC (Consortium for Ocean Climate Research) program on Pacific ship scheduling; also we cooperate as well as Southampton Oceanography Centre (SOC) of Southampton UK on Computer Flow Dynamics (CFD) for evaluation of the flow turbulence around the ship and its effect on the sensor placement. A draft report from SOC is available (44 pages). Some logistic support is provided by the Southern California Marine Institute on ship turnarounds. There is ongoing cooperation with the Atlantic Marine Ocean and Atmosphere Laboratory (AOML) in Miami on the Atlantic VOS program. There is also ongoing cooperation with many sensor manufacturers and the VOS people at the German Weather Service (Deutsch Wetter Dienst) in Hamburg Germany.

We now support one ship in the Pacific and await assignment of a new ship in the Atlantic. During the year, several ships were in use but were discontinued due to route

assignments. The ships we collected data from this year are shown in Figure 1. The routes of these ships are shown in Figure 2.

Figure 1a. The VOS Horizon Enterprise

Figure 1b. The VOS Direct Tui.

Figure 1c. The VOS Sea-Land Express.

Figure 1d. The VOS Merkur.

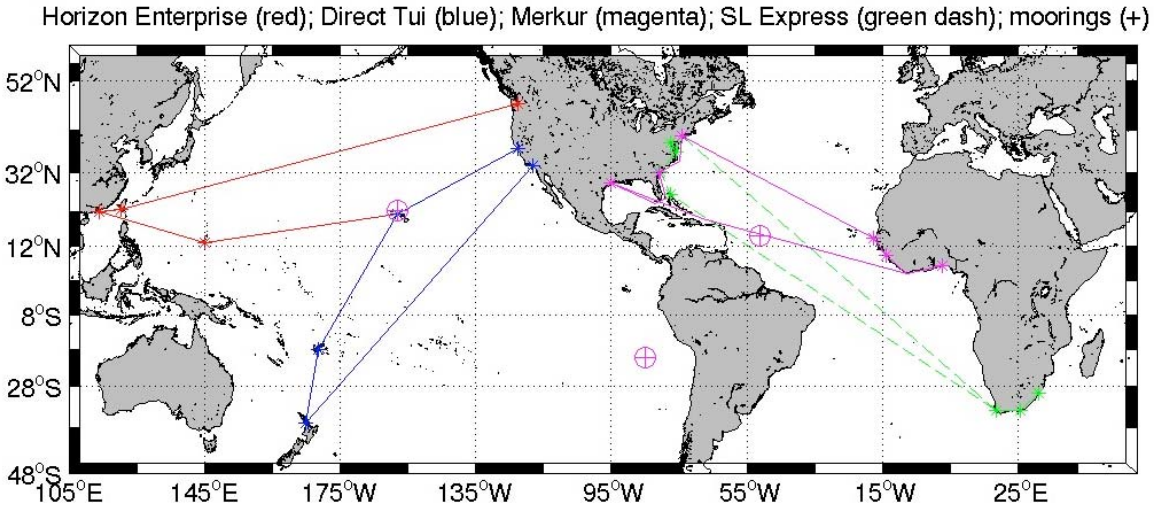

Figure 2. VOS routes for the Horizon Enterprise (red), Direct Tui (blue), which replaced the Columbus Florida, Merkur (magenta) and SeaLand Express (green). The Sealand Express route is presently open and waiting on a new ship assignment. Note the Ocean Reference Stations (circle with cross) being operated by WHOI.

Specific activities on these vessels during the reporting period are listed below. These illustrate the challenge of identifying stable platforms and the need for measurements systems that can be easily installed and removed.

June 2005. The Enterprise wind sensor had a problem and was replaced in Oakland CA.

June 2005. Visit Direct Tui in Los Angeles to install radio link in preparation for AutoIMET installation.

July 2005. AutoIMET installation on the M/V Merkur in Newark N.J. begun but not completed due to very short port stop.

August 2005. AutoIMET installation on the Direct Tui in Los Angeles CA.

August 2005. Repair wind and SST sensors on Horizon Enterprise. Installed battery for wind and SST to insure isolation from ship power surges.

September 2005. Complete installation on the M/V Merkur in Houston TX. Two sensors had problems wind and SST. Followed ship to Savannah GA and fixed wind sensor but not SST. Will meet ship on next cycle to fix SST.

October 2005. Meet the M/V Merkur in Savannah to repair SST.

January 2006. Maintenance of the Horizon Enterprise system in Tacoma WA. UPS had been turned off.

February 2006. System removed from the M/V Merkur in Houston TX because the ship has been sold and is no longer available for AutoIMET use.

February 2006. System removed from the CP Tui in Long Beach CA because the ship has been sold and is no longer available for AutoIMET use.

May 2006. Turnaround on the Horizon Enterprise in Tacoma WA and repair of the SST cable installation.

The challenges encountered this year in working to achieve two ships each in the Pacific and in the Atlantic have been significant. A first-order challenge is the short lifetime of a given ship on a given route. In addition, we have found that power supplied from the ship as well as the vibration and accelerations need to be addressed. We are doing so and having success. For now we have chosen to concentrate on the Pacific route, upgrade the hardware to address lessons learned, and to focus on analysis of the data we have collected. This approach will strengthen the effort by improving data return and by proving the utility of the data by using it in conjunction with data from the Ocean Reference Stations to improve our understanding of the surface meteorological and air-se flux fields. Our colleagues at NOC delivered a report on issue of making observations from VOS in the presence of flow distortion, which is listed below and attached as a PDF file.

<u>Instrumentation Upgrades</u>

The VOS provide a challenging operating environment in which to make high quality surface meteorological observations and we have moved to upgrade some sensor modules to address problems. At the same time, we have seen, since we started that

some of our components in our ASIMET circuit boards are no longer available or soon to be obsolete, including the digital memory cards used to log the data. In particular, we have found our highest failure rates are associated with mechanical failures in the propeller/vane anemometer sensor and abrupt loss of data in the ASIMET relative humidity modules. A final problem has been calibration stability in the incoming longwave radiation modules. Work under this task has produced a low-power sonic anemometer sensor that is under test now as a replacement for the current mechanical propeller/vane sensor. A Kipp and Zonen longwave sensor has been used to replace the Eppley longwave sensor and a new front end (preamplifer for the thermopile voltage from the longwave sensor) circuit board has been developed to be used in an upgraded longwave module. Upgrades are being made to the ASIMET electronics. The present flash memory (which is getting hard to obtain and is difficult to use) is being replaced by digital flash memory. Obsolete parts and cold sensitivities are being identified in conjunction with design of a new processor board.

Data Analysis

This work under this task is yielding information about the spatial coherence of the surface meteorological fields by examining data from VOS track lines that pass close to our Ocean Reference Sites. Initial effort was focused on tracks from the R/V Merkur that passed within 500 km of the NTAS site (Fig. 3).

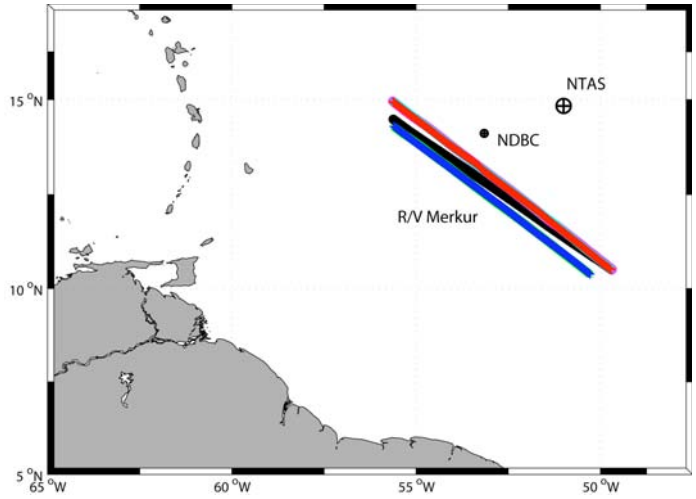

Figure 3. Ship tracks (color) for six "encounters" of the R/V Merkur passing within 50 km of the NTAS buoy. The NDBC 41041 station is also shown.

Auto-correlation functions for ship and buoy showed that typical de-correlation times are from 3 to 6 h (Fig. 4). Barometric pressure, dominated by the semidiurnal atmospheric tide, and shortwave radiation, dominated by the diurnal cycle, show the most similarity for ship and buoy results. Shipboard humidity, longwave radiation and wind showed longer correlation times and larger scatter compared to the buoy. This is the result of variation of the shipboard data on time scales of hours that is not seen in the buoy records, and was attributed to spatial variability.

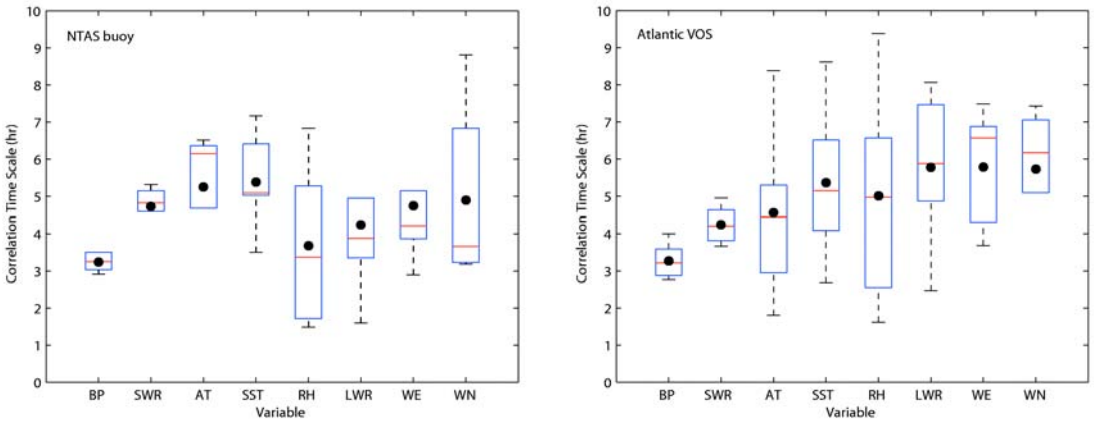

Figure 4. Correlation time scale for eight meteorological variables observed on the NTAS buoy (left) and the Atlantic VOS (right). Mean correlation time, as defined by the first zero-crossing of the autocorrelation function, for six "encounters" is shown along with box plots giving the median (red line), upper and lower quartile values (blue box) and extent of data within 1.5 times the inter-quartile range (dashed whiskers).

Publications and Reports

Plueddemann, A., F. Bahr, D. Hosom and R. Weller, 2006. Surface meteorology from volunteer observing ships, First Joint GOSUD/SAMOS Workshop, 2-4 May, Boulder, CO (poster).

Plueddemann, A., F. Bahr, D. Hosom and R. Weller, 2006. Surface meteorology from volunteer observing ships, NOAA Office of Climate Observation Annual System Review, Silver Spring, MD (poster).

Observations of Air-Sea Fluxes and the Surface of the Ocean. Report for Sub-contract Agreement A100239 between WHOI and the University of Southampton, Southampton Oceanography Centre.