Surface meteorology from Volunteer Observing Ships

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Introduction

Central to efforts to improve the predictability of climate is the need to understand the physics of how the atmosphere and ocean exchange heat, freshwater, and momentum and, in turn, to accurately represent that understanding in the models used to make predictions. At present, over much of the globe, quantitative maps of air-sea fluxes, derived either from ship reports, numerical model analyses or satellites, have errors that are large compared to the size of climatically significant signals. To address the need for accurate in-situ observations on broad spatial scales, the Upper Ocean Processes Group at WHOI has undertaken a program of observations using variations of the IMproved METeorology (IMET) sensor suite (ASIMET, AutoIMET) adapted for installation on Volunteer Observing Ships (VOS). These systems have been installed on 5 different VOS over the last 4 years, providing a wealth of data along repeated (or nearly repeated) tracks in the Atlantic and Pacific basins.

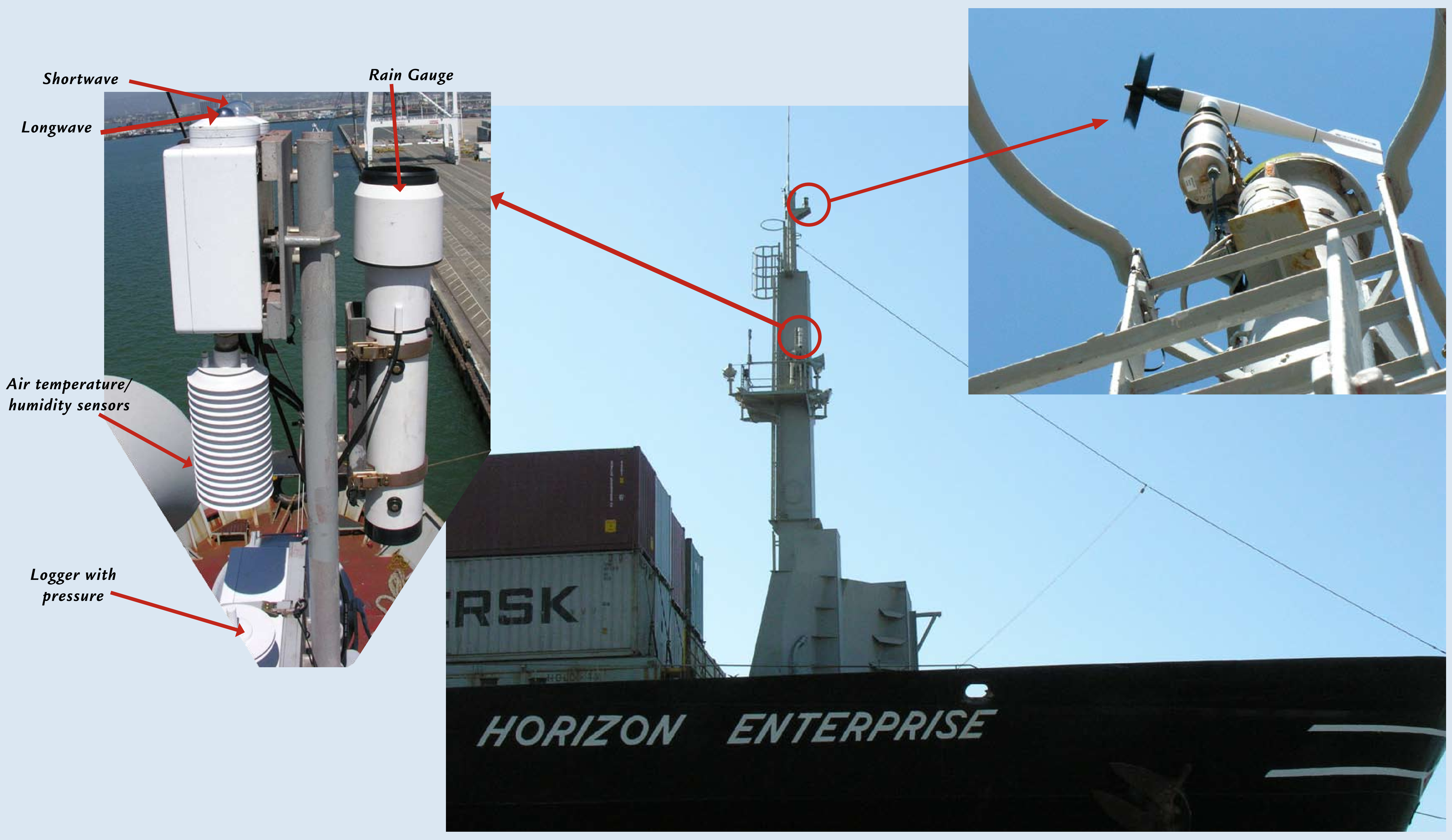
Observations made using IMET technology on long VOS routes that span the ocean basins are essential to providing the accurate, in-situ surface meteorology needed to:

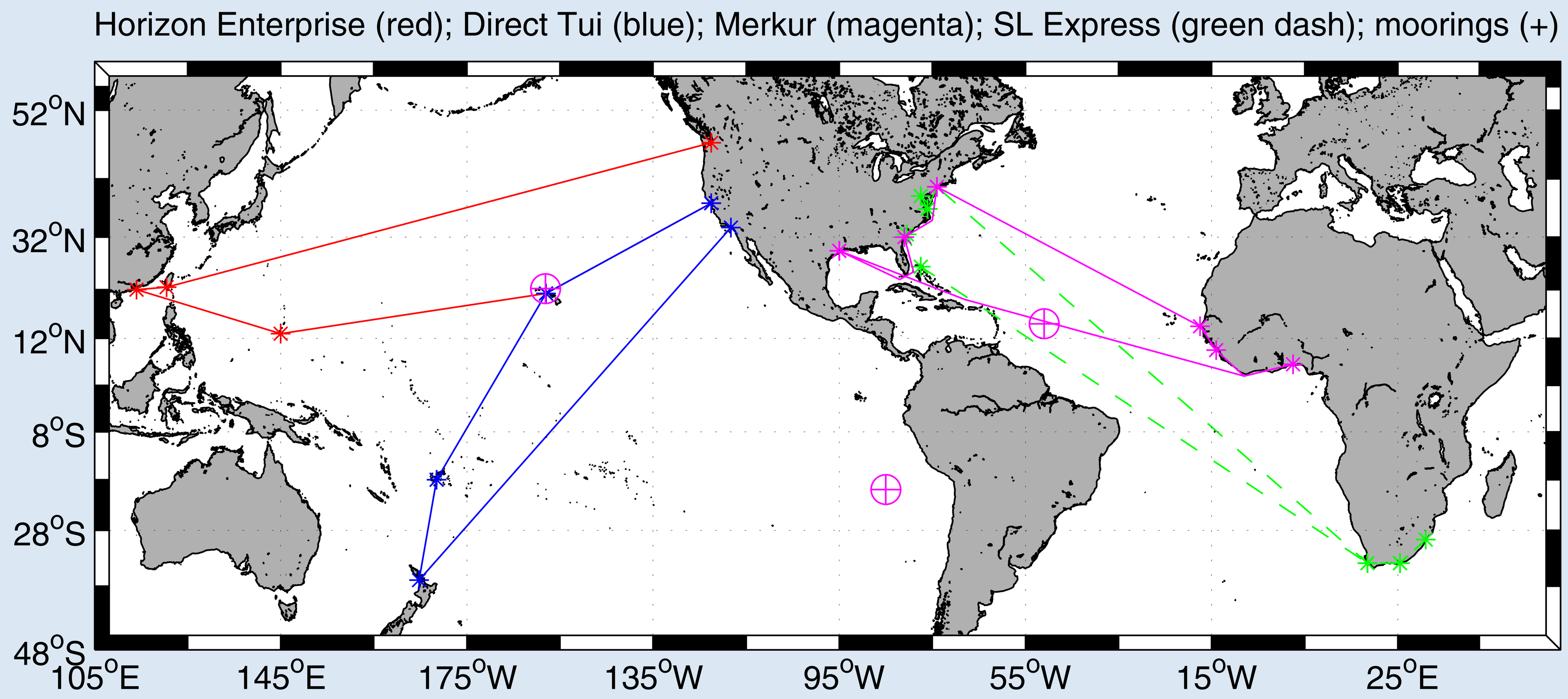
- Identify errors in existing climatological, model-based, and remotely-sensed surface meteorology and air-sea fluxes,
- Provide the motivation for improvements to existing flux parameterizations and algorithms,
- Provide the data needed to correct existing climatologies,
- Validate new model codes and remote sensing methods.

AutoIMET System

AutoIMET was developed at WHOI 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. The AutoIMET system interfaces to NOAA SEAS 2000 (Shipboard Environmental (Data) Acquisition System), which automatically receives meteorological data and transmits hourly satellite reports via Inmarsat C. This system will provide information about the heat uptake, transport, and release by the ocean as well as the air-sea exchange of water and the ocean's overturning circulation.

The AutoIMET sensor suite includes barometric pressure (mounted on the logger housing), shortwave and longwave radiation, humidity, air temperature, and precipitation (combined in the "LHPS" unit with an external rain gauge), wind (separately mounted on the highest point of the bow mast), and sea surface temperature (a hull contact sensor mounted frequently in the bow thruster chamber). A GPS unit provides backup position data, and a radio link from the bow mast to the ship's bridge transfers data every 6 minutes to SEAS2000.





NTAS Experiment

The Northwest Tropical Atlantic Station (NTAS) project for air-sea flux measurement was conceived in order to investigate surface forcing and oceanographic response in a region of the tropical Atlantic with strong SST anomalies and the likelihood of significant local air-sea interaction. The primary science objectives of the NTAS project are to determine the in-situ fluxes of heat, moisture and momentum, and then to use these in-situ fluxes to make a regional assessment of flux components from numerical weather prediction models and satellites.

Beginning in March, 2001, we have maintained a fully-instrumented surface mooring at 15°N, 51°W to collect accurate time series of surface meteorology and upper ocean temperatures, velocities and salinities. The data collected will improve our understanding of the air-sea fluxes and sea-surface temperatures in the Northwest Tropical Atlantic.

Between May 2004 and February 2005, six passages of the VOS ship *SeaLand Express* within 500 km of the NTAS buoy were used to compare buoy and shipboard IMET data.

Partnerships

- **NOAA SEAS Office** – Derrick Snowden, Janet Roseli
- **Scripps Institute of Oceanography** – Dean Roemich, Glenn Pezzoli
- **Southampton Oceanography Centre** – Peter Taylor, Margaret Yelland, Elizabeth Kent, Simon Josey
- **Southern California Marine Institute (SCMI)** – Carrie Wolfe, VOS coordinator

Web Sites

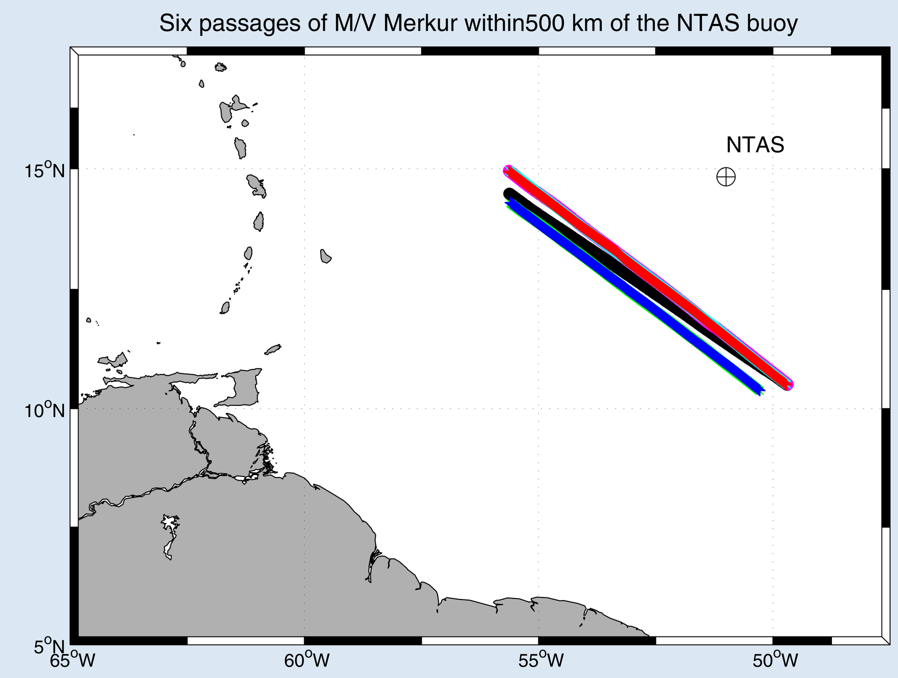
Descriptions and figures on VOS datasets are posted on the site http://uop.whoi.edu/vos. Currently, the data are only available via anonymous ftp at ftp.whoi.edu/pub/users/fbahr/vos, or contact fbahr@whoi.edu.

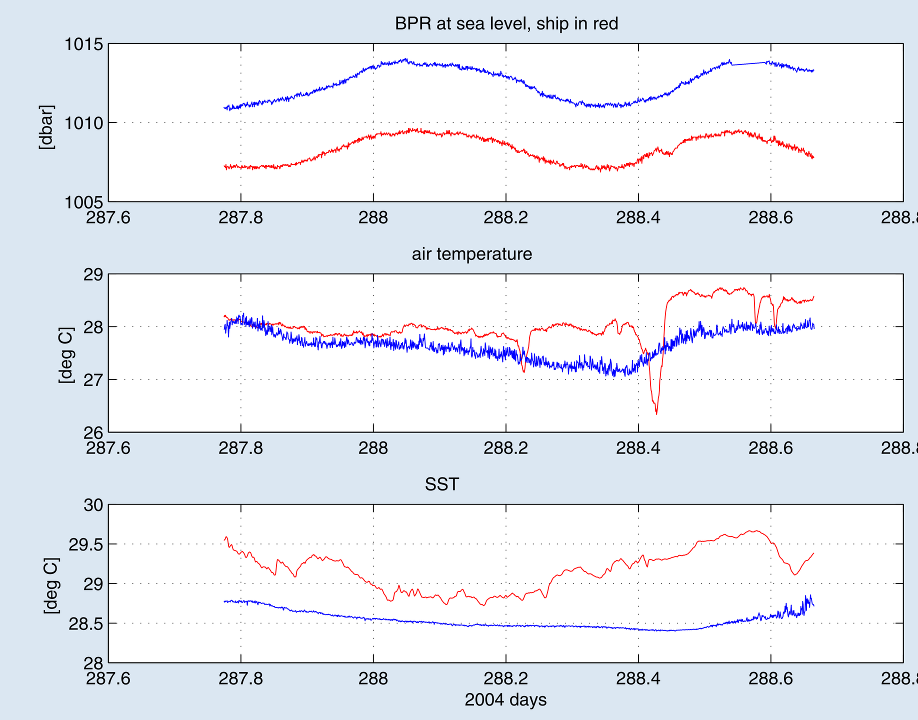
Detailed technical information on the AutoIMET (VOS) and ASIMET (NTAS) systems is available at http://frodo.whoi.edu. Instrument design questions can be addressed to David Hosom at dhosom@whoi.edu.

AutoIMET and ASIMET modules are available commercially from Star Engineering Inc of Foxboro, MA (508) 543 9144, attn: Mr. Bill Jobsky.

Data Analysis

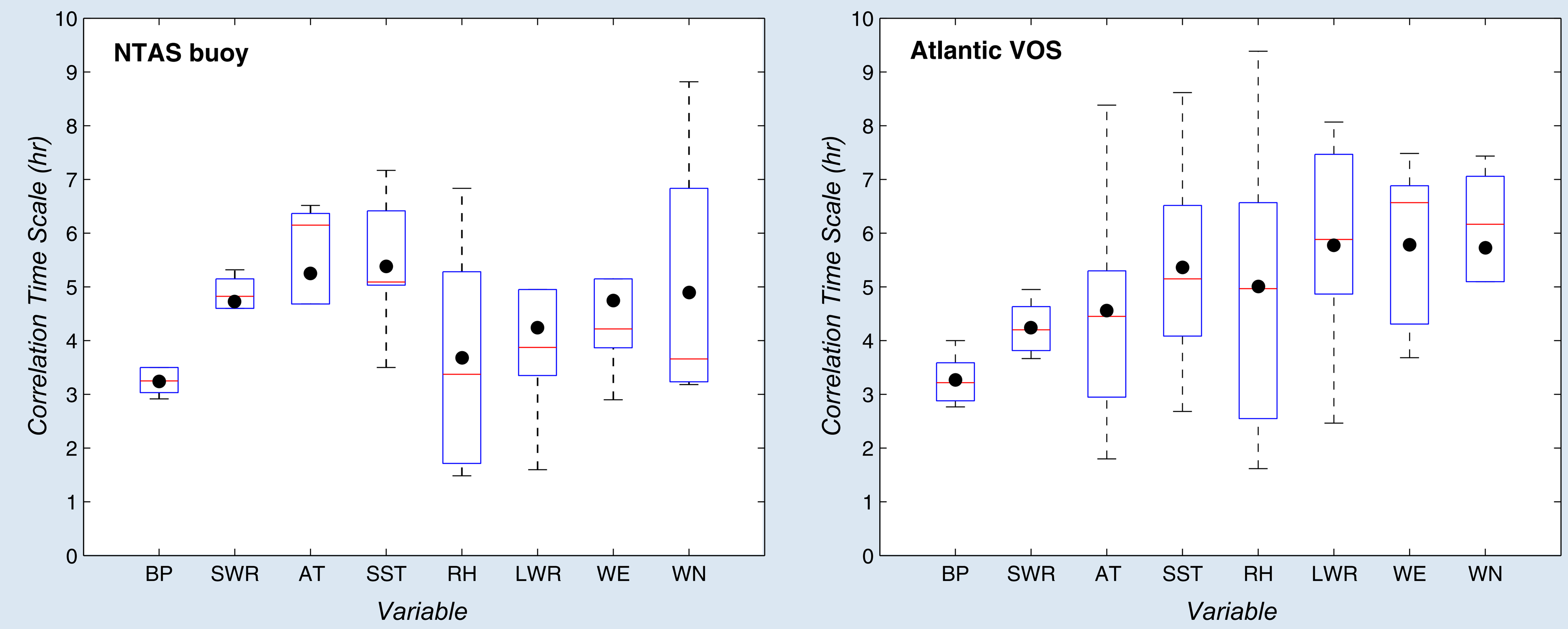
Our comparison is based on six passages of theVOS participant M/V *Merkur* near the NTAS buoy. We selected the subsets of the one-minute AutoIMET record when the ship was within 500km of the buoy, and then selected the identical time period from the buoy record.





Example time series from one ship passage on October 15th, showing barometric pressure with tides (top), air temperature (middle), and sea surface temperature (bottom), with VOS AutoIMET data in red, buoy data in blue.

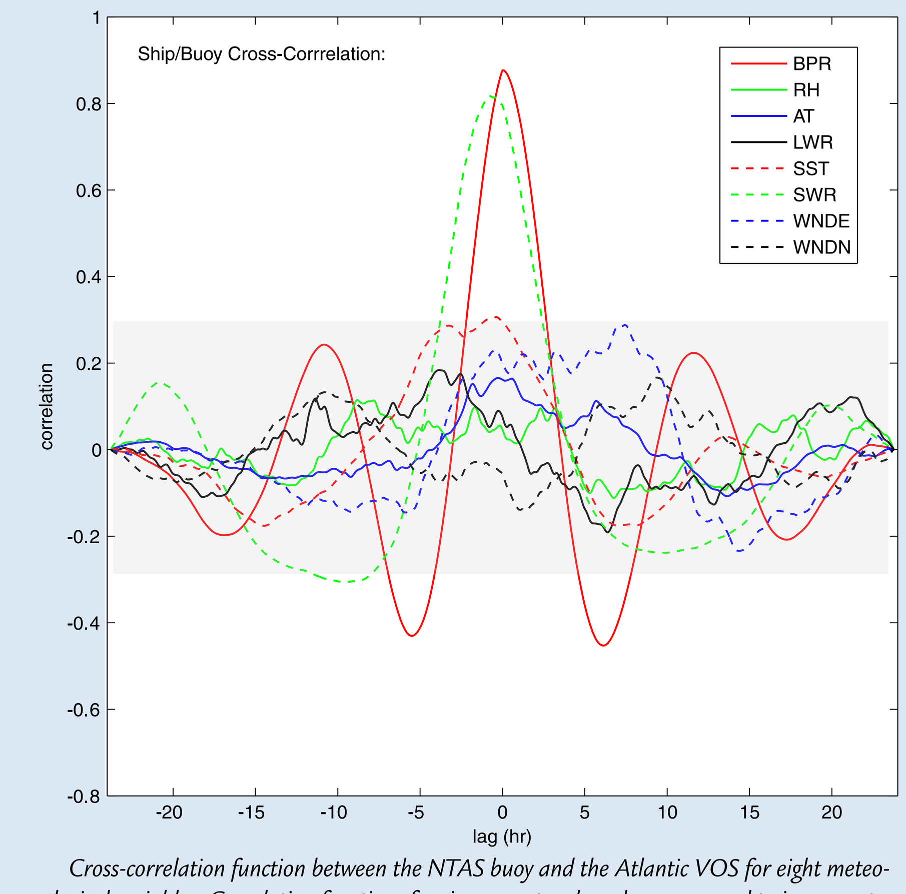
Evaluation of auto-correlation functions for the six "encounters" shows that typical correlation times are from 3 to 6 h. BP, dominated by the semidiurnal atmospheric tide, and SWR, dominated by the diurnal cycle, show the most consistent results. Shipboard AT and SST show correlation times similar to those of the buoy, but more scatter as a result of spatial variability. Shipboard RH, LWR and wind all show somewhat 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 is attributed to spatial variability.



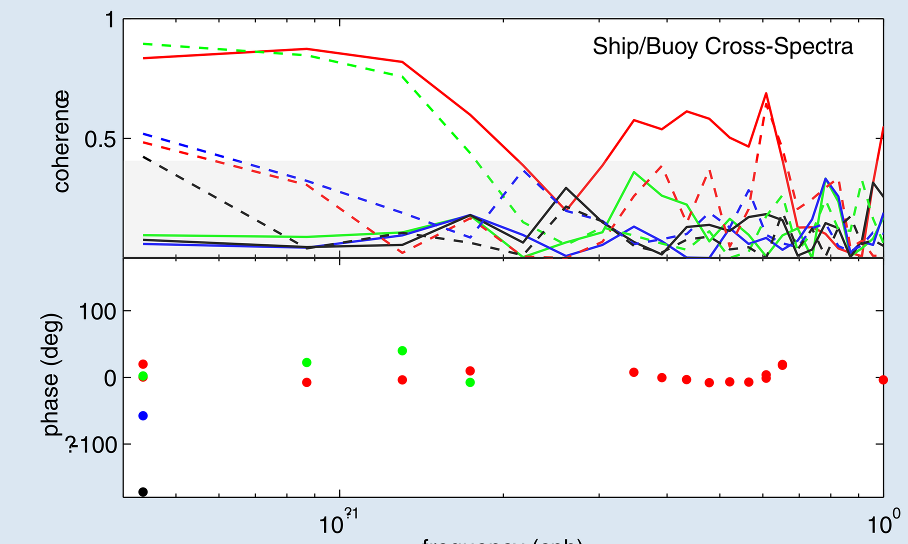
Correlation time scale for eight meteorological variables observed on the NTAS buoy (left) and the Atlantic VOS (right). Mean correlation time, as defined by the first zero-crossing of the autocorrelation function, for six "encounters" is shown along with box plots giving the median (red line), upper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

Cross-correlation results show only BP and SWR with statistically significant relationships between buoy and ship. However, note the significant anti-correlation in BP at 6 h and the weaker secondary peaks at 12 h resulting from the semidiurnal atmospheric tide. There are also indications of weak correlation for SST and East wind. For SST the high correlation is near zero lag and presumably due to the diurnal cycle of surface heating. For East wind the high correlation is at positive lags of up to 10 h, and appears to be due to similarities in the buoy and ship records during the first half of the encounters, i.e. in the region to the southeast of the buoy.

The Cross-spectra corroborate the cross-correlation results in that BP and SWR show the most robust coherence, while coherence for SST and East wind are marginally significant. Both BP and SWR show coherence out to f = 0.2 cph, or 5 h periods. BP shows a secondary coherence peak from 2-3 h period. The BP and SWR records are approximately in-phase where the coherence is significant. SST and East wind show coherence only at the lowest resolvable frequency (~24 hr).



Cross-correlation function between the NTAS buoy and the Atlantic VOS for eight meteorological variables. Correlation functions for six encounters have been averaged to improve statistical reliability. Values outside of the grey box are significantly different from zero at the 95% confidence level.



Coherence (upper) and phase (lower) vs. frequency from cross-spectra of the NTAS buoy and the Atlantic VOS for eight meteorological variables. Data from six "encounters" have been combined to improve statistical reliability. The legend is the same as for cross-correlation. Coherence values above the grey box are significantly different from zero at the 95% confidence level. Phase values are shown only where coherence is significant.

Summary

Multiple VOS transects passing within 500 km of the NTAS buoy were used to evaluate the similarities and differences between meteorological variables.

- Auto-correlation times for both buoy and ship meteorological variables are from 3-6 h
- BP and SWR show strong correlation between buoy and ship
  The semidiurnal atmospheric tide for BP, and the solar cycle for SWR, dominate both buoy and ship records.
- Other variables show weak or no correlation
  The short duration (20 h) of the VOS encounters at distances of 300-500 km from the buoy do not show temporal changes that are coherent with the buoy. This indicates that the VOS records are dominated by spatial variability.