

Expanded Development of a Float for the Measurement of Ambient Noise and Air-Sea Interaction Processes

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LONG-TERM GOALS

The goal of this program is to expand our capabilities to make remote and unattended measurements of the upper ocean and air-sea interface using autonomous, in-situ instrumentation that can be deployed in a range of conditions and locations.

OBJECTIVES

Measurements of the upper ocean and air-sea interface present a difficult challenge for both remote sensing techniques and *in-situ* moored or shipboard instrumentation. While satellite-based remote-sensing techniques generally lose accuracy in high sea-states or near land due to a lack of understanding of the physics of the parameter that is measured or land contamination in the received signal (e.g. remotely sensed winds), fixed *in-situ* measurements are difficult to maintain due to the environmental loading placed on the instrumentation and survivability of moorings. Shipboard instrumentation in high sea-states is either too costly for long-term measurements or presents a danger to the personnel onboard the vessel. While moorings and surface buoys can be designed to withstand the rigors of the sea-surface during high sea states, the statistical nature of very high wind events such as hurricanes, typhoons, and large winter storms requires that moorings be deployed over long periods of time and in large spatial arrays in order to raise the probability of the instrumentation being in the right place and at the right time. The recent improvement of relocatable forecasting models of the ocean will now require rapid identification of initializing conditions for the model. Adaptive monitoring of the ocean anywhere on the globe will now be available through strategic placement of light-weight, low-cost instrumentation in regions of high interest. The objective of this program is to continue the development of a suite of sensors integrated into a class of low-cost instruments to enable these initializations as well as to develop a unique platform for scientific process studies.

APPROACH

Our approach to developing an instrument capable of air-sea interaction measurements in extreme environmental conditions is based on the addition of a few, low-cost instruments integrated into profiling SOLO floats that are modified for missions restricted to the upper ocean. The SOLO, a predecessor to the ALACE type float, is now a mature technology (Davis et al, 1991) which has been produced in very large numbers as part of the WOCE program. The profiling ability of the float is accomplished by changing the float's volume and buoyancy through the pumping of hydraulic fluid from an internal reservoir to an external bladder. Historically, the floats have been able to sample

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profiles of temperature and measure sub-surface currents by remaining at a pre-programmed depth where the float is neutrally buoyant.

Under this project, we are developing additional capabilities for the profiler to undertake missions specific to studying the upper ocean and air-sea boundary including the monitoring of wind and wave conditions and observations of internal waves. Data gathered from this significantly enhanced float will provide time series of:

- Surface wave heights
- Wave breaking statistics
- Average void fraction
- Heat fluxes
- Sound speed profiles
- Wind-speed estimates via ambient noise inversion
- Rainfall estimates via ambient noise inversions
- Acoustic ambient noise statistics in the bands from 100Hz – 50kHz
- Temperature and salinity structure of upper ocean
- Lagrangian Currents

Use of passive acoustics to spectrally characterize the signature of wind and rainfall also provides a potential dual use application for monitoring man made sources of ambient sound such as that generated by surface vessels. Our approach to monitor the sound field is via the development of a low noise recording system which uses a floating point DSP to compute power spectra of the sound field in real-time. Use of the DSP allows flexibility in sampling, windowing, and ambient noise bands processed. Nominal operation computes spectra from DC – 50kHz at a 1Hz rate.

A typical mission profile for the float includes the following:

- Profile temperature and salinity to 200m
- Rise to a neutrally buoyant depth of O(30-50)m and park enter a ‘hovering’ routine. While at this depth, the acoustic ambient noise field and surface wave field is sampled using the sonar altimeter, pressure sensors, and accelerometers.
- Onboard processing of the surface wave and ambient noise data to allow appropriate messages to be telemetered to shore
- Profile to surface to obtain GPS position and transmit data to satellites.
- Repeat cycle every 4 hours for 200 dives.

WORK COMPLETED

Activities conducted during the past year include:

- 1) Successful recovery of nine floats that were deployed into 2004 Hurricane Fabian.
- 2) Tear down and assessment of all mechanical and hydraulic components inside each of the nine floats. Identification of high wear items and development of a refurbishment plan. Initiation of the refurbishment of the lower end of each float to allow for future deployment.

- 3) Performance analysis of the Orbcomm telemetry system using data obtained in the 2004 Hurricane Fabian deployment.
- 4) Redesign of power conditioning system which supplies power to the hydrophone, pre-amp, and a/d system. In addition, optical isolators were implemented on digital lines to isolate high-frequency digital communication signals from contaminating the analog signal.
- 5) Software engineering to develop the capability for onboard processing of ambient noise statistics. Code has been written to allow the time averaging and statistics of sound spectra using an onboard Motorola based microcontroller (an embedded CF2 Persistor controller). These time averages will be coded to allow transmission as an Orbcomm message.
- 6) Software engineering to develop onboard processing algorithms to compute the 1-D surface wave spectrum and characterization of the sea state (significant wave height). Wave height computations are based upon the processing of data from the upward looking altimeter, vehicle pressure sensor, and three-axis accelerometer. Similar to the average ambient sound spectrum, the wave information will be concatenated into a formal suitable for transmission as an Orbcomm message.
- 7) At-sea testing on the R/V Sproul was conducted in late April, 2005 to evaluate improvements in the ambient sound analog system. Testing was conducted at a site south of San Clemente Island at a site referred to as the 43 mile bank. Situated in water of approximately 200m water depth, a nearby steep slope of approximately 1:1 extends eastward to water depths of 1000m. The strong slope results in strong internal tides and internal waves in the region. Also tested were the enhanced surface wave processing algorithms.

PRELIMINARY RESULTS

- Technical evaluation of the Orbcomm telemetry system during Hurricane Fabian indicates the viability of this telemetry link in high sea states.
- Improvements to the analog front end of the ambient sound system have resulted in a noise floor below sea state zero for the band from 70Hz – 40kHz. Narrowband noise notches exist at 120Hz and 40kHz from internal noise (predominantly switching power converter noise).
- At-sea testing of the system demonstrated significant improvement in our ability to make low-noise ambient sound measurements on this autonomous platform. During the at-sea tests, nearby boat traffic of varying size were recorded.

IMPACT/APPLICATIONS

Continued development of this technology will provide the capability to rapidly characterize the environment for a range of basic and applied science missions.

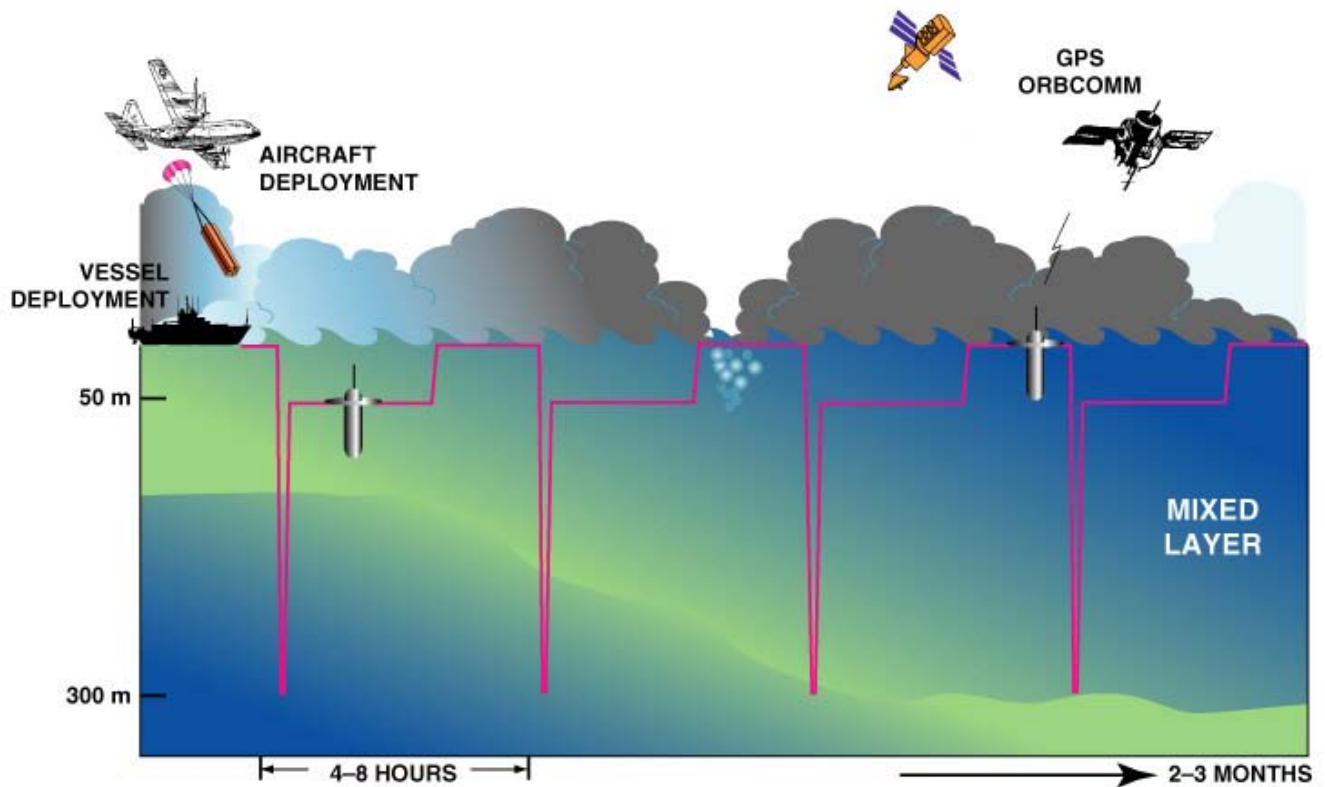


Figure 1. An idealized mission schedule for the instrumentation supported under this program. While at hover depth, the system measures surface waves and the ambient noise field. Conductivity, temperature and depth is measured during the decent portion of the cycle. Bi-directional commands will be developed for the float in the following year to allow the mission to be reconfigured after it has been deployed.

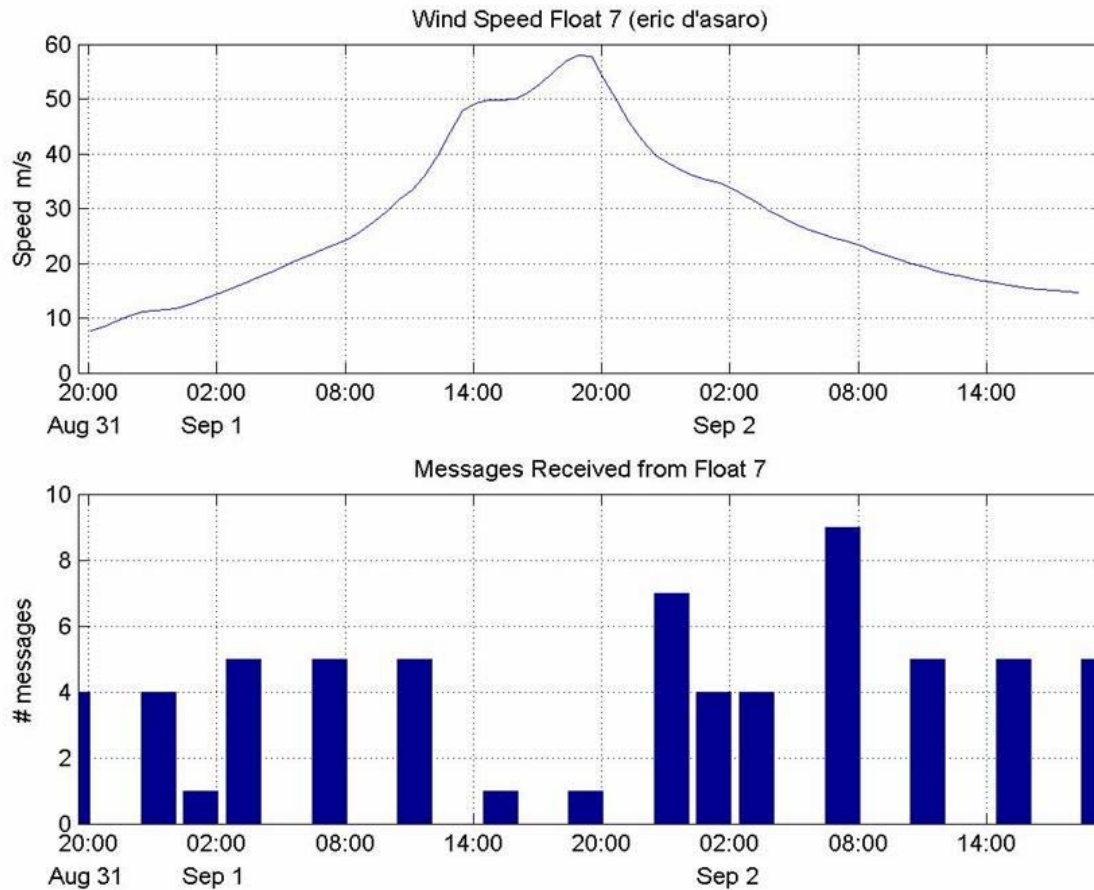


Figure 2. Performance analysis of one of the Orbcomm equipped floats during Hurricane Fabian. The top plot is a time series of the winds at the location of the float for 48 hours beginning August 31, 20:00. The bottom plot are the number of messages sent by the vehicle when it surfaced every 4 hours. In optimal communication conditions, four messages are sent each time the vehicle surfaces. Messages not sent are buffered and placed into a the message queue for transmission on the next surface interval. While reduced message transmission took place during the period of highest winds (> 50m/s), the buffer was able to begin catching up as the winds lowered beneath 30m/s. Wind analysis is based upon NOAA HRD H-WINDS reanalysis.

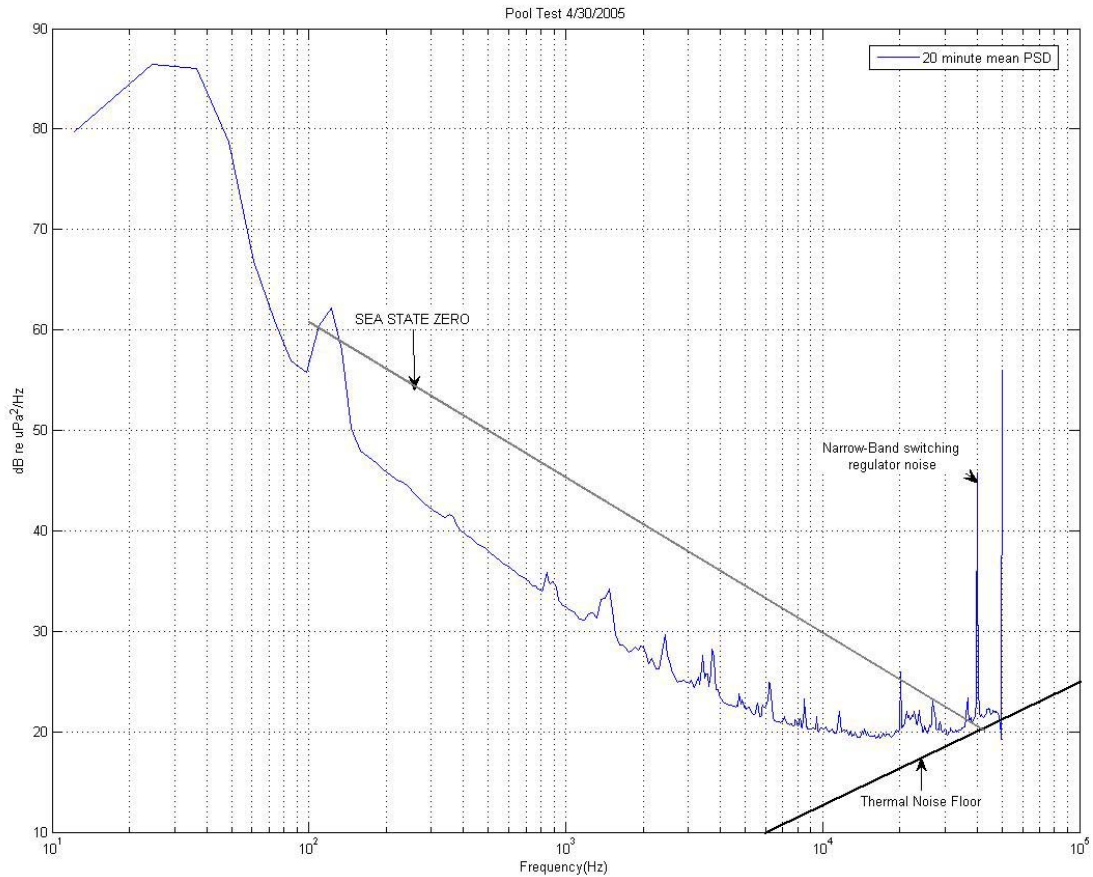


Figure 3. Ambient sound spectra (blue line) measured on the bench to evaluate the noise floor of the system. Shown for reference are the accepted values of 'sea state zero' sound levels characterized by Knudsen reference levels. The graph illustrates the performance of the system, with the self-noise of the system approximately 10dB beneath sea state zero.

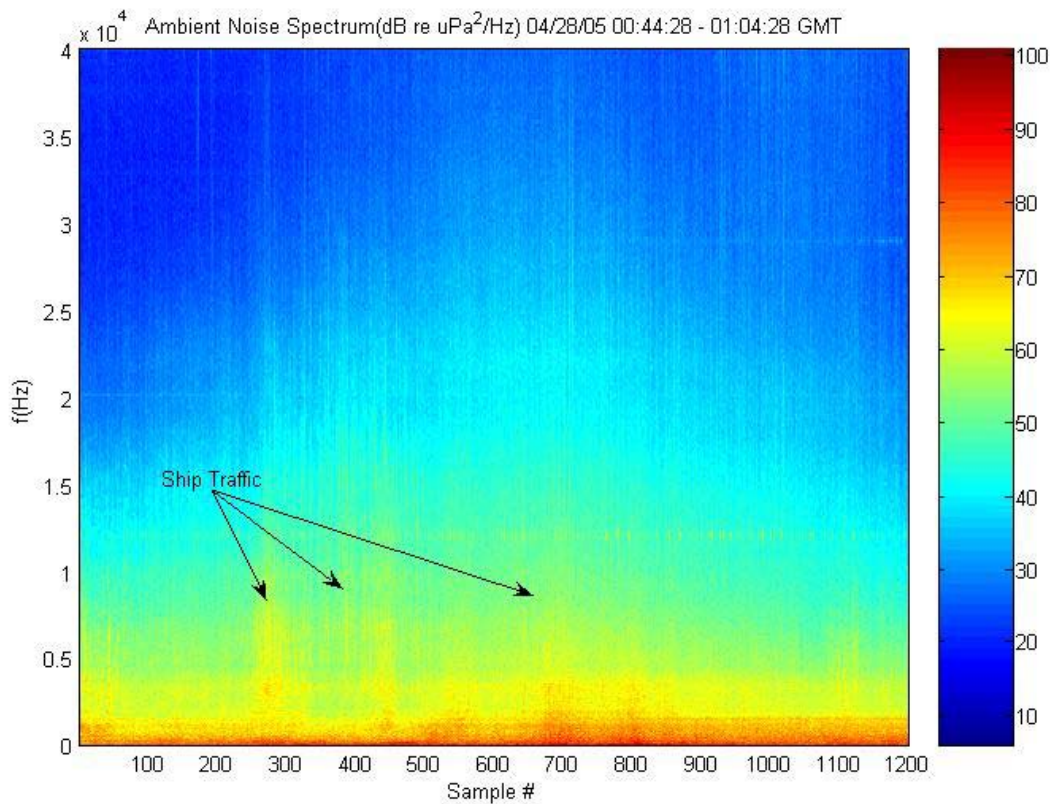
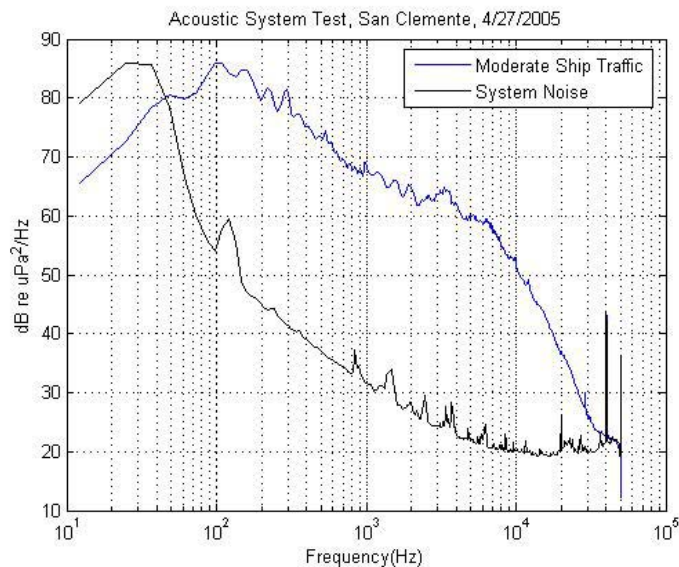


Figure 4. A 20 minute spectrogram composed of broadband ambient sound spectra recorded at 1Hz. Data shown was obtained at a site south of San Clemente Island in water of 200m depth on April 28, 2005. Short duration events at elevated levels are indicative of the small vessel traffic in the area (fishing boats). Below. Example line spectra of the system noise of the profiler float (black) and the sound levels attributed to ship traffic at the test site.



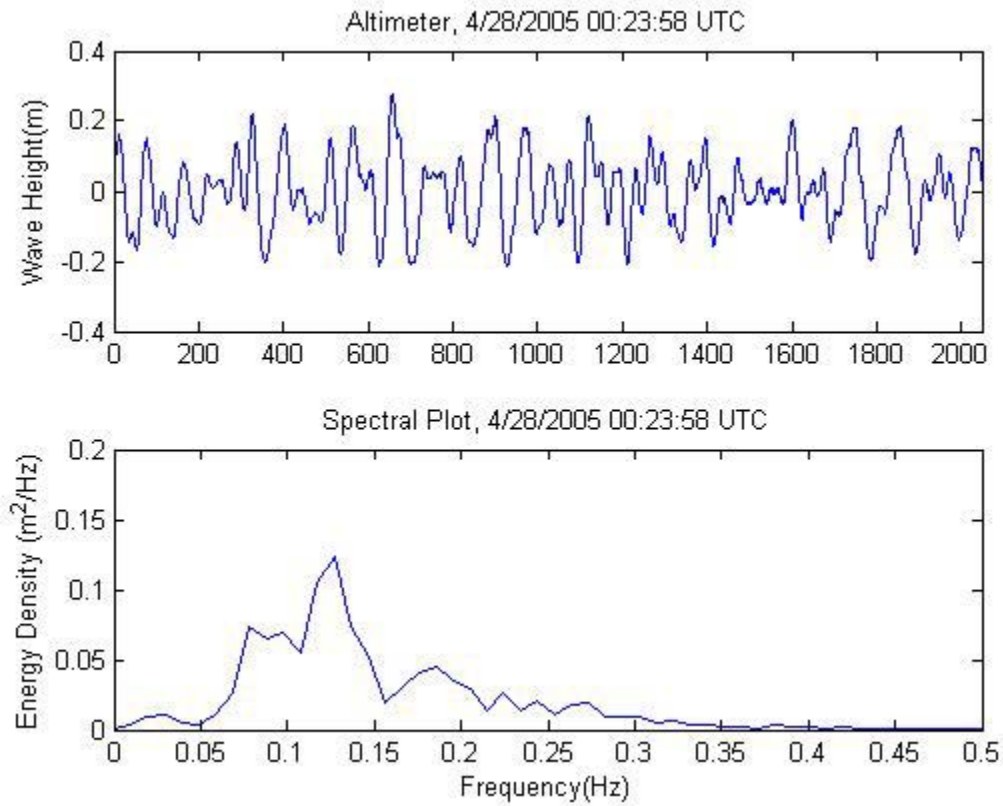


Figure 5. A time series of the surface measured at the study site during the 2005 test cruise. The development of algorithms for processing the surface wave conditions now allows the computation of 1-D surface wave spectrum using the onboard Motorola microprocessor that is part of the Persistor CF2 controller. Developments in the coming year will include the generation of Orbcomm messages that contain surface wave information.