

# **Autonomous Profiler Measurements of the Air-Sea Interface in Very High Sea States**

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## **LONG-TERM GOALS**

Our goal is to better understand air-sea fluxes and oceanic response during extreme wind events using in-situ measurements.

## **OBJECTIVES**

Measurements of the air-sea interface in very high sea states present a difficult challenge for both remote sensing techniques and *in-situ* moored or shipboard instrumentation. While the satellite-based remote-sensing techniques generally lose accuracy in high sea-states due to a lack of understanding of the physics of the parameter that is measured and inverted (ie. microwave scattering, EM bias, passive microwave), *in-situ* measurements are difficult 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. With significant effort and cost, moorings and surface buoys can be designed to withstand the rigors of the sea-surface during these conditions. However, 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 in order to raise the probability of the instrumentation being in the right place and at the right time. The recent improvement of synoptic, predictive models of storm events now presents the opportunity for adaptively sampling the upper ocean during storms through strategic placement of light-weight, low-cost instrumentation in the path of incoming storm events. The objective of this program is to develop and deploy a class of low-cost instruments that can be deployed into extreme weather.

# Report Documentation Page

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## **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 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 for it to undertake missions specific to studying the air-sea boundary during the hurricane high wind/wave conditions. Analysis of data from the sensor suite will allow a better understanding of the following:

- Surface wave heights
- Wave breaking statistics
- Average void fraction
- Heat fluxes
- Wind-speed
- Rainfall
- Temperature and salinity structure of upper ocean
- Lagrangian Currents

In addition, measurements of the parameters listed above will be done with the aid of data obtained from the P3 aircraft component of CBLAST.

The mission designed for the CBLAST hurricane float includes the following:

- Profile temperature and salinity to 200m which we anticipate is below the mixed layer
- 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.
- Profile to surface to obtain GPS position and transmit data to satellites. Simultaneously burst sample the conductivity and temperature probes at the surface to measure entrained air and temperature fluctuations.
- Repeat cycle every 4 hours for 200 dives.

## **WORK COMPLETED**

Several milestones have been achieved as part of this program. These include:

- 1) Successful implementation of mechanical modifications to make the buoyancy controlled, deep-diving SOLO float (nominal 2000m dive depth) to a shallow water profiler. This has involved the design and fabrication of a new gear motor, drive train, motor brake, and limit switches. These changes were required to make the unit more responsive in its ability to displace 200cc of volume and the efficiency in how long the motor must be run to fully displace is

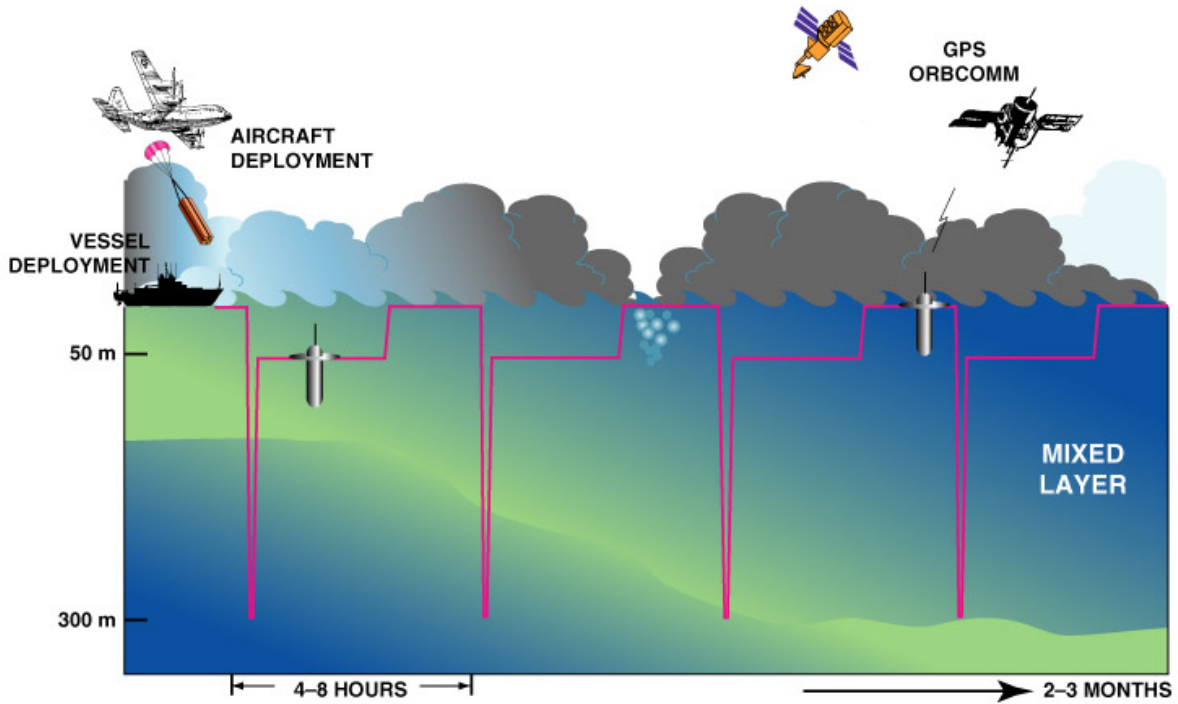
- 2) Development of an air-deployment system which allows the SOLO float to be deployed from suitable aircraft. Development and testing of the deployment system has been carried out with participation of the AERO Corporation (Apple Valley, CA) using a Shorts Skyvan which has a similar rear door configuration to a C130. This involved test deployments both in the desert and in waters offshore San Diego.
- 3) Development of the CBLAST Hurricane sensor package which interfaces to the SOLO float. This includes a DSP based ambient noise recording system which allows on-board processing of acoustic spectra at rates up to 2Hz with a 95kHz bandwidth which exceeds the 50kHz bandwidth of the -145dB hydrophone custom built for the project. A microcontroller which controls this and other sensor allows the sensor suite to operate independently from the SOLO controller which provides mission and telemetry control.
- 4) Air deployment testing was conducted with the Air Force 53<sup>rd</sup> reserve unit using a C130J model. This was the first air drop tests that have ever been conducted with a J model C130, presenting a After several test deployments at a DZ nearby Keesler AFB, an interim certification was received from the Air Mobility Command.
- 5) Two CBLAST SOLO units were fabricated and deployed into the path of Hurricane Fabian on September 4, 2003 using the AFR 53<sup>rd</sup>. Both survived the storm and were able to send portions of their data using ORBCOMM telemetry.
- 6) One of two CBLAST SOLO floats was successfully recovered using the R/V Hatteras. The second float is still adrift and intermittently reporting. A second recovery attempt may be staged if the platform drifts closer to land.

## **PRELIMINARY RESULTS**

Given the recent successful deployment and survival of the floats through Hurricane Fabian, we are now presented with the opportunity to examine a very unique data set. Our current efforts are focused on quality control of the sensor data. In addition, the engineering data stored is being analyzed to guide us further in our development efforts for the 2004 Hurricane season.

## **IMPACT/APPLICATIONS**

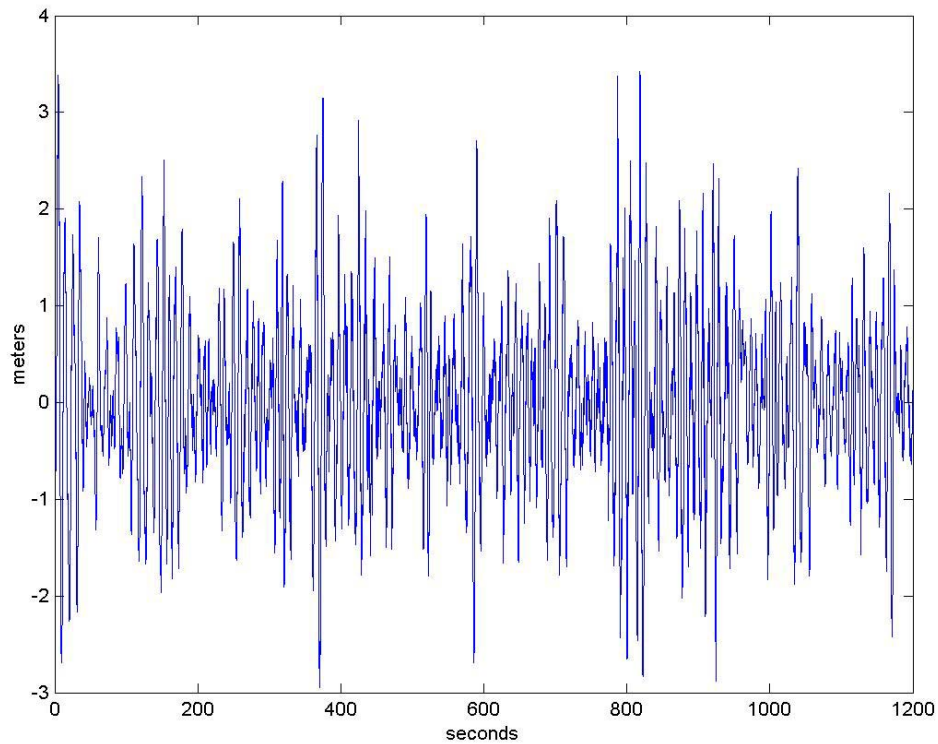
The demonstration of our ability to air-deploy an autonomous platform using military aircraft should provide a number of additional of scientific and applied applications that are of DOD interest. The ability to receive time series of in-situ measurements of oceanic conditions during storm events should also be of interest to the USWRP for operational weather model data assimilation.



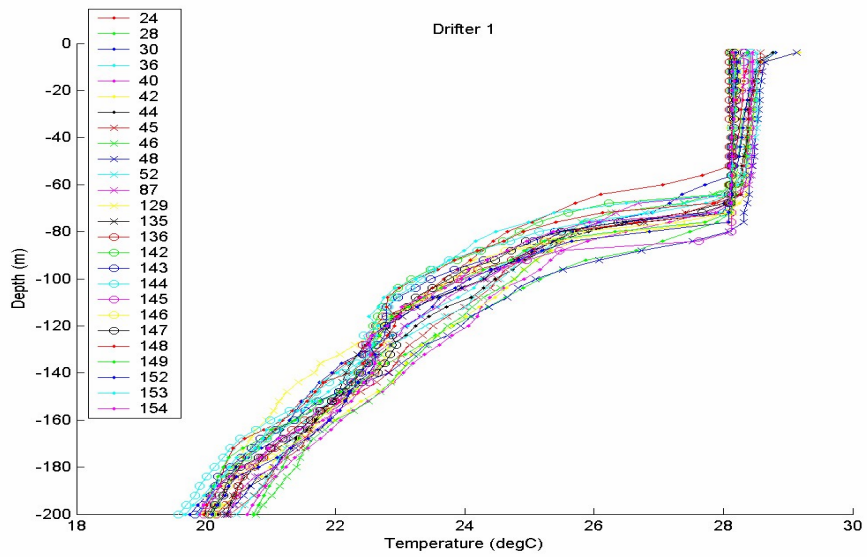
*Figure 1. A schematic of the mission schedule for the CBLAST HURRICANE SOLO FLOAT. While at hover depth, the system measures surface waves and the ambient noise field. Conductivity, temperature and depth is measured during the decent portion of the cycle.*



***Figure 2. Top left. The top of the CBLAST Hurricane SOLO float. The hydrophone, acoustic altimeter, Orbcomm antenna, and pressure sensor port are visible on top. Top right. The C130J used by AFR 53<sup>rd</sup> to deploy buoys into the path of Hurricane Fabian. Lower left. An air-deployed SOLO using its custom built cruciform parachute. Lower right. The two CBLAST SOLO floats secured within the C130 prior to takeoff for Hurricane Fabian.***



***Figure 3. Time series of ocean surface wave elevations measured by SOLO float #2's altimeter while the system was in hover mode at depths ranging from 30-70m. The data shown was obtained on 9/5/03, 04:12:19GMT before Hurricane Fabian passed overhead the instrument. Note the group structure of the wave field. The data shown has been passed through a 3<sup>rd</sup> order high pass filter (cut off frequency of 0.03) to remove the drift motion of the float from the signal. The data was obtained by successfully recovering the instrument from the Atlantic just after Hurricane Isabel and downloading the flashcard memory.***



***Figure 4. Temperature profiles telemetered from CBLAST Float #1 (still in the Atlantic). The figure shows the mixed layer extending to depths of 80m just after the passage of Hurricane Fabian. At later times, as indicated by the dive number, the mixed layer warms and becomes a little more shallow (shift from 80m to 65m).***