A New, Autonomous Current, Temperature, and Salinity Profiler for Storm Conditions

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LONG-TERM GOALS

We seek to provide to the Navy and worldwide users the capability to obtain detailed temperature, salinity, and velocity profiles from an autonomous instrument profiling frequently (< 10 day) and reporting in near-real time for durations up to five years.

Improved understanding of the oceanic processes, such as surface mixed layer (SML) deepening, property mixing, strong currents, and major temperature changes that occur in hurricanes and severe storms could lead to improved numerical models, environmental predictions and operations at sea, both naval and civilian. Unfortunately, there are few sensor systems of adequate performance, ruggedness, reliability, and deployment capabilities available. A family of observational tools, both in-situ and remote, could lead to substantial improvements in forecasting models, a clear benefit to ship operations, coastal communities, and the insurance and offshore petroleum industries. In creating a tool for the high sea state situation, we also expect to create both a more widely useful observational platform with associated measurement capability.

Finally, Webb Research Corporation (WRC) will build and maintain a stand-alone capability to manufacture EM-APEX floats and successor instruments for the Navy and other users worldwide. This is a significant transfer of technology and the establishment of a facility to produce needed instruments that will benefit the Navy and global users. Furthermore, WRC and APL-UW will continue to collaborate to support this product and make improvements.

OBJECTIVES

The objectives are to design, build, evaluate and deploy an inexpensive, low-power EF measurement system suitable for long duration operation. The EF system must be integrated into the APEX system, possibly for digitization and certainly for data storage and transmission. The new electronics and the modified APEX float will be evaluated in the laboratory (saltwater tank) and in the ocean. Iridium will support the communications channel for the floats. The addition of GPS receiver will provide accurate float location fixing every time it surfaces. The final design will be committed to circuit boards and be installed in seven APEX floats, now called EM-APEX floats. Finally, the floats will be deployed in a 2004 hurricane along with other CBLAST floats and assets. The deployments are likely to include floats dropped in the center of the hurricane as well as others in the forward, right quadrant where the largest upper ocean response typically occurs. A post-storm cruise will recover as many floats as possible.

APPROACH

The program is to build and deploy EM-APEX velocity and density profiling floats in a 2004 hurricane in support of the ONR program CBLAST. The effort entails the development of new low-power electronics for the measurement and recording of motionally induced ocean electric fields (EF). These electric fields will be converted to velocity profile based on the principles of motional induction (Sanford, 1971). The profiler will rotate as it traverses the water column. Velocity values will be determined for each rotation, perhaps every 5 m. Other sensors will measure pressure, temperature and salinity. The EF electronics will be integrated into the commercially produced APEX float. In this way, it becomes a float option, available to Navy and worldwide users, and benefits from the bi-directional data and communication link provided by the Iridium/GPS system. Floats will be programmed to continuously profile from their parking depth, say 200 m, to the surface. Each profile might require one-half to one hour to traverse 200 m, more if a deeper parking depth is chosen. Once on the surface, the float will transmit profile data over Iridium. It is likely that surface conditions in the hurricane will be severe and prevent reliable communication. Therefore, these floats will store the data for post-storm transmission and for retrieval after float recovery. Recovery will allow for complete data recovery, including ancillary data of engineering interest, and the opportunity for the floats to be redeployed for longer or different missions of interest to the Navy, such as SML evolution in the North Pacific or flow structure in various sill or overflow situations.

To reach the overall goal of a viable EM profiler provided to all ocean researchers, the work has been divided equally between the two laboratories. The Applied Physics Laboratory, University of Washington (APL-UW) will develop and field test one complete prototype instrument, building on the Phase I EM electronic development. They will pass all procedures, schematics, software, etc. to Webb Research Corporation (WRC) for construction of six more profilers.

Six instruments will be tested locally and readied for shipment and deployment. This work will include all drawings, procedures, calibration routines, software files, etc. to be able to reproduce an effective, economical instrument for any user. In addition to the manufacture of the APEX float, their modifications to accept the EM subsystem and work with APL-UW, WRC personnel will:

- Participate in prototype field trials, Puget Sound
- Prepare dummy profilers for air deployment trials
- Arrange all shipping
- Lead in profiler recovery operations
- Participate in data analysis

Finally, the EM-APEX floats will be deployed in high-wind conditions in support of CBLAST. At this time we have made no arrangements for deployments but have discussed the matter with Eric D'Asaro

(APL-UW) who stated that we could deploy our floats along with his from a C130. WRC is arranging for participation in air certification. Our plan is to rely on the satellite data link, but we would probably want to participate with D'Asaro, who intends to recover his floats. The work will include the scientific interpretation of the profile data and publication of results in either or both scientific and technical journals.

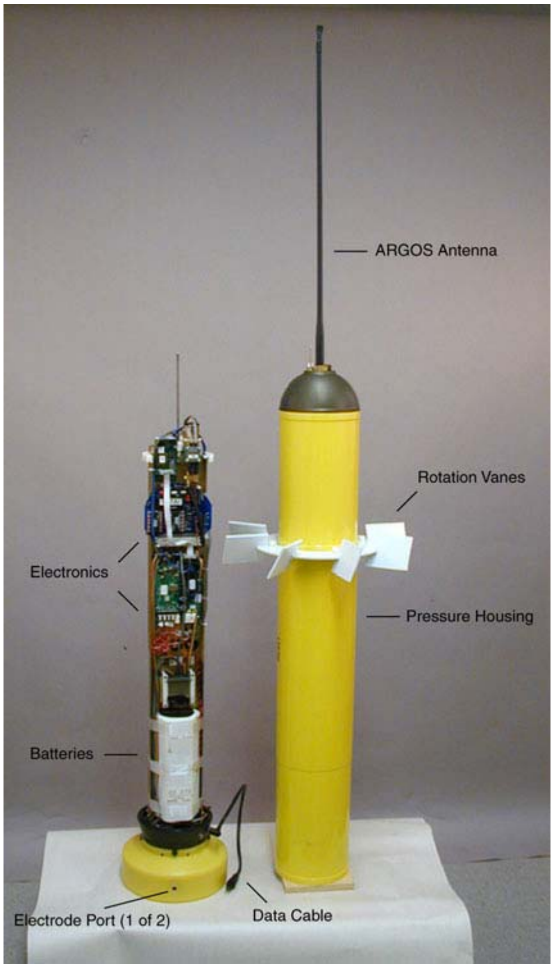
WORK COMPLETED

In Phase I, which occurred just prior to the Phase II award, we installed the following to the WRC APEX float:

1. The HEF subsystem was built as a stand-alone module including a low-noise preamplifier, magnetic compass, A/Ds, microprocessor with flash memory, and batteries. (This assures electrical isolation from some APEX noise and ground-loop problems.)
2. Two electrodes were installed on diametrically opposite sides of the plastic bellows housing on the lower end of the standard APEX. (The HEF is determined from the potential difference between these electrodes by using the compass as the direction reference.)
3. Small vanes were installed to rotate the float as it profiles. (Rotation modulates the ocean HEF, converting the DC signal into one that is sinusoidal at the rotation frequency.)

The APL-UW-made Ag/AgCl electrodes were installed in the plastic bellows cowling on the lower end of the APEX float (Fig. 1). The intention was to make the least modification to the APEX. This was not only to minimize modification costs but also to maximize the chance for the EM-APEX to be deployed from C130 aircraft under the present USAF certification for the APEX float. Of course, the addition of the rotation vanes changes the outline of the new instrument. It is thought that this will not interfere with the use of the certification.

The preliminary design developed in Phase I is to make the HEF system completely isolated from the APEX system. This was done to eliminate the possibility that "ground loops" would influence the operation. This problem is severe in our case because the motionally induced voltages are typically only 1–10 μV, and the Ag/AgCl electrodes have an electrochemical potential of about one volt with respect to the system ground of the aluminum case. The electrodes are connected through a bulkhead connector to a low-noise preamp built around the AMP-01 amplifier. The electrode signal is amplified by a gain of 500 and sent to a post-amplifier board that provides additional amplification, digitization and storage on a microprocessor with Compact Flash memory (Fig. 2). For a development unit, the data are downloaded from the microprocessor via a RS-232 connection. The instrument does not have to be opened to recover the observations. Later units will rely on Iridium, but the contents of the CF memory can be extracted if the unit is recovered.



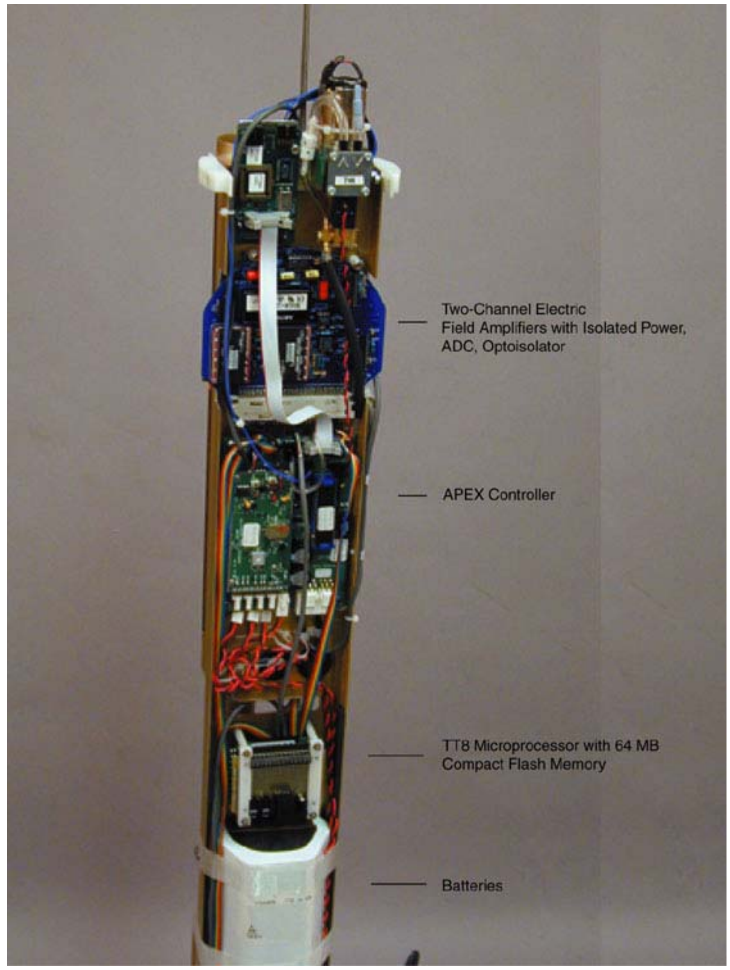


Fig. 1: Complete EM-APEX showing major components. Data cable is means for downloading EM data.

Fig. 2: The 2-channel electric field amplifier board (including power isolation, amps, ADC, opto-isolator chips) and the micro-processor and CF memory.

RESULTS

The program began in mid-May 2003. Since then, the principal engineering activities have been devoted to studies of the EM-APEX energy budget (e.g., how to keep power below 70 mW while profiling), electronic design and component acquisition and testing. Jim Carlson, who worked on various EM instruments when part of Sanford's group before, has been hired to lead the electronic engineering effort.

The program has been involved in CBLAST meetings and communication this year. Sanford attended the CBLAST meeting in Miami in February and has been monitoring the 2003 hurricane planning and deployment activities.

IMPACT/APPLICATIONS

Improved understanding of storm dynamics will benefit storm forecasters, naval and commercial ship operations, coastal communities, and the insurance and offshore petroleum industries. There is the expectation that many of these velocity profiling floats will be used in the international ARGO float program. The result should be improved weather prediction, storm detection, SML evolution and basic research.

Navy operational environmental assessment, using information from covert platforms, could be enhanced. The instrument can be programmed for a wide range of applications other than storm conditions and could become a useful addition to the inventory of tools of many oceanographers. More sensors are likely to be added and the utility of autonomous profilers, already in widespread use, could be further enhanced. Measurement of currents and other environmental variables in inaccessible sites, due to ice cover or uncooperative territorial situations, will be made possible.

Examples of notable benefits in studies of the upper ocean under high wind conditions are:

- Provides v(z) measurements from an autonomous, profiling platform capable of withstanding high sea states
- Complements T and S measurements in profiling floats
- Provides estimates of directional SGWs, SML slab motion, and SML shear
- Provides potential for direct observations of Reynolds stress <u’w’> profiles
- Provides shear and stability through the "transition zone" at the SM base: i.e., Richardson numbers and parameters for mixed layer deepening
- Provides velocity deep in the water column uninfluenced by high surface winds and SGWs
- Suited to rapid profiling over a few days with internal storage of data
- Bi-directional communication permits mission modification and “store and forward” data communication
- Suitable for rapid deployment, such as from aircraft
- Can use GPS for accurate float location without dependence on ARGOS
- Cost-effective and valuable addition to standard, commercially produced instrument (with payoff to the civilian community)

TRANSITIONS

By its very nature, the SBIR involves a transition of ONR sponsored technology to an instrument manufacturer, namely Webb Research Corp. It is WRC’s intention to make the technology developed under this SBIR into a commercial product, available to the science and technology community.