Float Technology Development

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LONG-TERM GOALS

It is the long-term goal of the principal investigators of this grant to develop profiling floats with expanded capabilities in terms of better sensors, communications methods, greater operating depths, and ice capability.

OBJECTIVES

The objective of this work is to design, fabricate, and test 5 specific technological advances to profiling floats. These advancements include (1) adding Iridium communications to floats; (2) adding an acoustic rain gauge to floats; (3) adding a dissolved oxygen sensor; (4) producing a float that can operate to a depth of 2000 m anywhere in the world ocean; and (5) examining in detail methods for allowing floats to work under sea ice.

APPROACH

In order to carry out this work, several floats with the capabilities listed above were built and tested. In general these floats were Argo floats, purchased using funds from NOAA awarded to UW as part of the US Argo program. The funds from this ONR grant were used to design and carry out the technological modifications necessary to meet the project objectives. The floats were deployed as Argo floats and the data were made a part of the Argo data stream.

WORK COMPLETED

Progress has been made on each of the objectives listed above. 2 Iridium drifters were deployed in the Antarctic Circumpolar Current in 2003. In August of 2004, 3 profiling floats using the UW Iridium system were deployed near Hurricane Frances in the western N. Atlantic. These floats were purchased under a separate ONR grant by Dr. Thomas Sanford of UW/APL, and the Iridium software developed under this grant was installed in the floats. As of this writing, the floats have sent back a great deal of new data relevant to upper ocean behavior under strong hurricanes. The first Iridium Argo float will be deployed in October, 2004 using the technology we developed under this grant, and we expect to deploy roughly 20 Iridium Argo floats in 2005. A float with an acoustic rain gauge (ARG) has been constructed and has been deployed in the equatorial N. Pacific. 5 floats with dissolved oxygen sensors have been deployed in the N. and S. Pacific Oceans. 2 floats with deep capability have been tested and deployed. The historical CTD data for the Antarctic has been examined in some detail and an ice detection algorithm that can be used on profiling floats has been proposed.

RESULTS

We have carried out a series of experiments using with the Iridium communications system in order to test the utility of this system with profiling floats. Initially, an Iridium transceiver was placed on the roof of the Ocean Sciences Building at UW in Seattle. Test files were sent and received from this transceiver for several months, and the transmit/receive statistics were compiled. In general, it was found that the Iridium system could be used at near the 2400 baud (300 bytes/sec) rate that is advertised, independent of weather or any other factors. In most cases only one call was necessary to transmit/receive a 20 Kb file. As a second step, we built 2 Iridium surface drifters and deployed them in the Antarctic Circumpolar Current in January, 2003, south of New Zealand. These drifters were Webb/Apex floats, without the buoyancy engine; the floats were weighted to be similar to normal Argo floats. The idea was to put the floats in the Antarctic Circumpolar Current and allow the floats to be exposed to harsh weather and wind, in order to examine the performance of Iridium in poor weather conditions. Results are shown in Figure 1. As can be seen, even in these harsh conditions the effective data transfer rate is about 210 bytes/sec, or about 1700 baud. These results are similar to the roof tests; there is a certain amount of handshaking between the float and the Iridium satellite when the call is first initiated, and this tends to degrade the effective transfer rate somewhat. As the size of the file being transferred increases, the effective transfer rate also increases, as the handshaking is a smaller fraction of the total connect time. Overall, the results shown here are very encouraging. We have shown that a 20 Kb file can be transferred in about 5 minutes, for a cost of about $5. Transferring a similar file using the Argos system would require 10-20 hours, cost considerably more, and no 2-way communication would be possible.

We have built and deployed an ARG float (see Figure 2). The float was deployed in the western Equatorial Pacific in January of 2004. The collected and returned profiles of temperature and salinity; in addition, while drifting at a depth of 1000 m the float collected ambient acoustic noise data from which estimates of wind speed and rainfall were made. These estimates were made a 3-hour intervals. Unfortunately, the float ceased to operate properly after about 110 days because of a failure of the pressure sensor on the float. This failure was not related to the ARG sensors in any way; a number of US Argo floats have failed in the past 12 months due to faulty pressure sensors, and it is hoped that this problem has now been fixed by the sensor vendor.

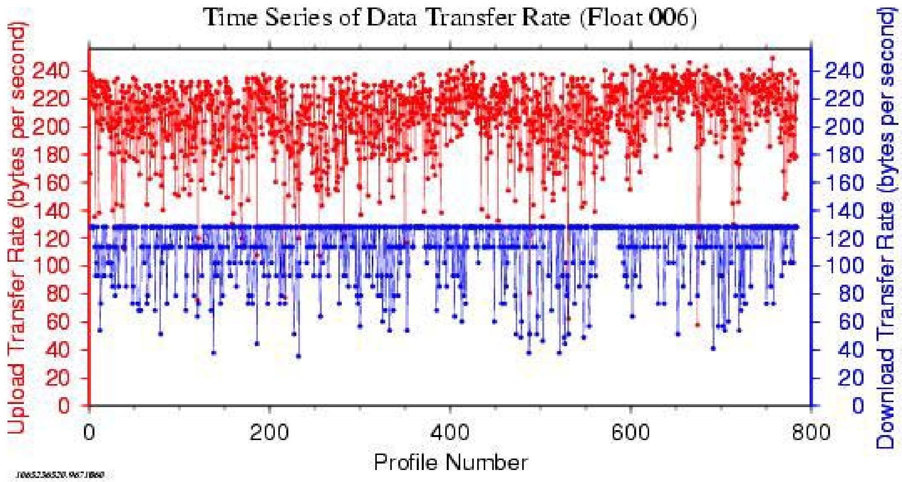

Figure 1. Time series of data transfer from Apex/Iridium drifter 006 in the Antarctic Circumpolar Current, 1/03-9/03. The float transmits data 3 times per day on the average.

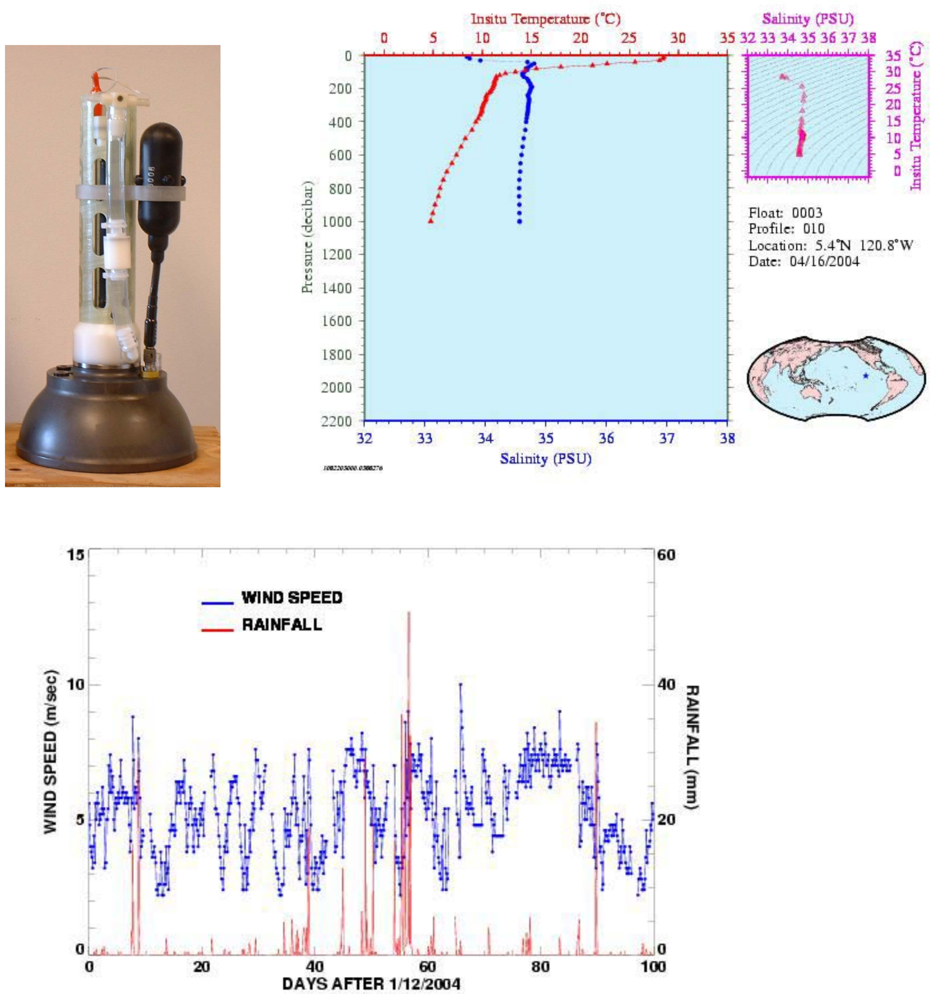

Figure 2. Top left: The head of a Webb/Apex float, showing a SeaBird CTD unit and a broadband hydrophone for an acoustic rain gauge. Top right: A profile from UW ARG float 0003, deployed in the eastern Equatorial Pacific in January of 2004 (the inset shows the float location). Bottom panel: Wind speed and rainfall measured from ARG float 0003, while the float was drifting at a depth of 1000 m in the eastern Equatorial Pacific. Note the episodic nature of the tropical rainfall events.

We have added dissolved oxygen sensors to several Argo floats. This sensor is a SeaBird-43 type of sensor that has been used in recent years on shipboard CTD systems. The first unit was on UW Argo float 894, deployed near the HOTS site north of Hawaii in August of 2002. This float has now been in the water for more than two years, and the data (see Figure 4) show very little drift in the measured oxygen over this time. This can be especially seen at deeper levels of the water column, below the oxygen minimum (ie, at temperatures less than about 5°C), in Figure 4. Where there is only very weak variability in the real oceanic values of oxygen, the float oxygen date likewise show very small variability. This is very encouraging and suggests that, due to the fact that the CTDO unit on the float contains a strong biocide and the float spends 99% of its time at stable, deep temperatures, sensor drift is very small, even over times longer than two years. Note that such oxygen sensor stability would be essentially impossible on shipboard CTD units. We have deployed such units on 4 other floats as well (with fewer profiles presently available than for float 894), with similar encouraging results.

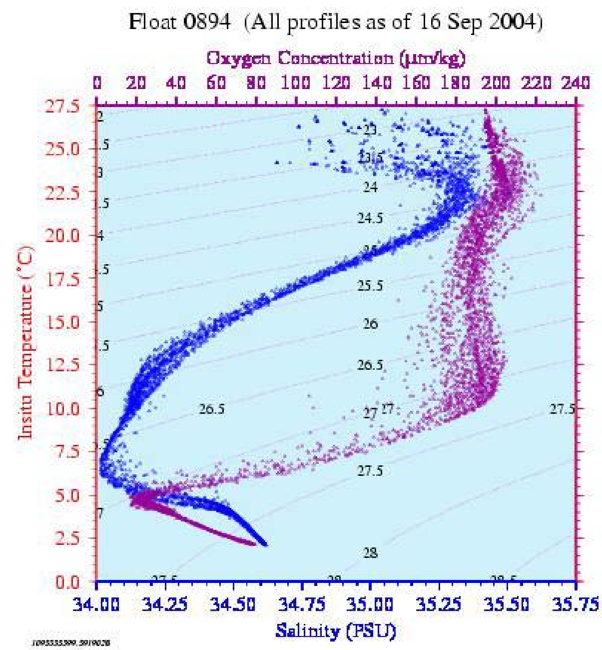

Figure 3. Dissolved oxygen and salinity plotted against temperature for UW Argo float 894. The data plotted here include profiles from 8/02-9/04, with data collected at 10 day intervals.

While Webb/Apex floats are in principle capable of withstanding pressures in excess of 2000 decibars, they can only be used to this depth in about 90% of the world ocean. In other cases, the buoyancy capacity necessary to cause the float to ascend from 2000 m to the sea surface is not sufficient, usually due to strong stratification near the sea surface. The regions where floats lack sufficient buoyancy for 2000 m operation are usually in the tropics, near the Equator. The problem is especially difficult in the Indian Ocean, in the vicinity of the Bay of Bengal. In order to alleviate this problem, the PIs of this grant have worked to modify the buoyancy engine on a standard Apex float in order to provide extra buoyancy. The extra buoyancy is provided through the use of an internal compressee inside the float. Webb Research Corp has submitted a patent application for this device. Two test floats of this type have been deployed, at Hawaii and southwest of India in the Equatorial Indian Ocean. The first has been performing well for over a year; the second, deployed in August 2003, appears to have no problem profiling between 2000 m and the sea surface in one of the most highly stratified regions of the world ocean. We expect to deploy another of these extended buoyancy floats in the Bay of Bengal in October 2004.

We have made an assessment of several methods of using profiling floats under ice, especially several different ice detection algorithms. For operation under ice, it is desirable for floats to sense the presence of sea ice and to avoid profiling all the way to the sea surface when ice is present. If floats do not stop, it is possible that floats will be damaged by hitting the underside of ice or will be crushed between floes. We have found that the simplest method of detecting sea ice (at least in the S. Atlantic and S. Pacific) is to monitor the temperature as a float ascends and to use the median temperature in the upper 100 m to decide whether to halt the profile or to continue the ascent. This can be seen by examining Figure 4.

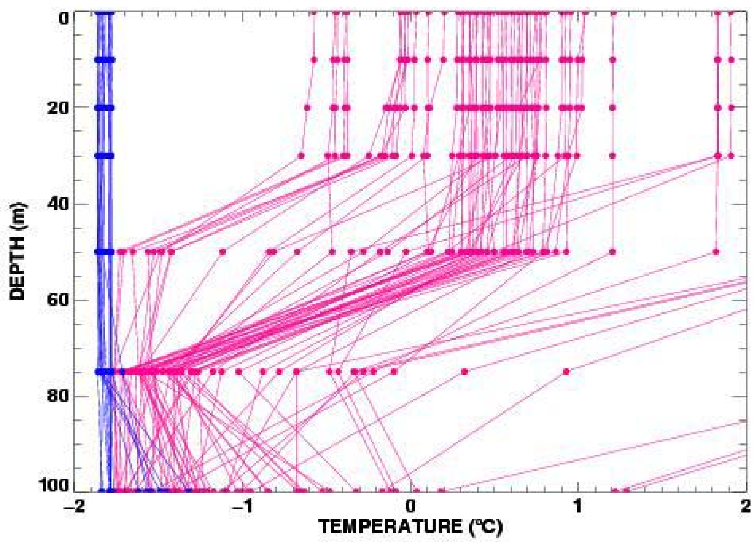

Figure 4. Temperature profiles from the seasonal ice zone in the S. Pacific. Blue profiles are from winter, under the ice; red profiles are from other seasons, when ice is not present. Note the difference in mixed layer temperature in the two sets of profiles at depths above about 50 m.

We have decided that a temperature-sensing algorithm is the simplest and likely best way to detect the presence of sea ice. Dr. Eberhardt Fahrbach of IFM/Kiel has used a similar algorithm with floats in the Weddell Sea, with good results.

IMPACT/APPLICATIONS

It is likely that each of the results shown above will become commercially available on profiling floats within the next 2 years. Floats with these added capabilities will be useful in Argo, but their largest impact will come in the future when profiling floats begin to be used in physical/biological and physical/chemical applications.

PUBLICATIONS

Riser, S. and D. Swift (2004) Long-term measurements of salinity from profiling floats. Submitted to *Journal of Atmospheric and Oceanic Technology.*

PATENTS

A patent for an internal compressee on a profiling float, capable of increasing the buoyancy without changing the volume of the float, has been applied for by Webb Research Corporation, and is now pending.