Autonomous Measurements of Oceanic Dissolved Nitrate from Commercially Available Profiling Floats Equipped with ISUS

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Award Number: N00014-09-1-0052
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LONG-TERM GOALS

The goal of this work is to design, build, and produce a commercially available version of the In Situ Ultraviolet Spectrometer (ISUS) suitable for use on commercially-built profiling floats. Moored versions of ISUS already exist, and a profiling float version has been built and deployed, with excellent and exciting results. However, fabrication of the sensor and integration with the float have been to date difficult from an engineering perspective, and as a result possible by only a very few technical groups. The goal of this work is to simplify the design so that a commercial version of the float/ISUS can be produced and ultimately be widely used in the physical and biogeochemical oceanographic communites. The partnership involved here collectively has the skills to meet this goal.

OBJECTIVES

The 3000 profiling floats deployed and maintained by the Argo project have provided a global-scale ocean observing system that samples the ocean at 10 day and 300 km scales to depths of 2000 m. Argo floats make observations of temperature and salinity as functions of pressure. In recent years dissolved oxygen and optical sensors capable of measuring chlorophyll and particulates have been added to some floats in the array. These measurements have shown that, in addition to Argo's utility in observing basic physical parameters, profiling floats are likely to become an important tool in observing biogeochemical parameters. Such work is in its infancy, as sensors for use on floats must be small and lightweight and consume minimal power. Several types of such sensors are now under development, and the use of profiling floats in biogeochemical studies in the ocean is likely to increase greatly in the coming years as this sensor technology matures. One parameter that is crucial to many biogeochemical studies is nitrate; measurements of dissolved nitrate in the ocean have long been made from shipboard platforms, and in recent years the MBARI group developed the ISUS technology as an optical measurement of nitrate. ISUS has been used in moored applications for several years, and in 2007 the MBARI and UW groups teamed up to deploy the first ISUS on a profiling float, which was deployed at the Hawaii Ocean Time Series (HOT) site. This float is now near the end of its second year of operation and has provided an outstanding record of the evolution of nutrients, dissolved oxygen, and temperature and salinity at the HOT site during this time. Results from this deployment have been submitted for publication (Johnson et al., 2009b). While the float is providing a wonderful dataset, the construction of such floats has proven to be quite difficult and pushed the technical capabilities of the MBARI and UW groups to near their limits. Based on this preliminary success, we are now in the process of modifying our design so that it could be made simple enough to be produced commercially, and that such instruments can be widely used in the oceanographic community. Our objectives in this study are to produce a simplified electronics package, a simplified internal fiber optics package, and a simplified external sensor so that such a float/nitrate sensor unit can be produced commercially and purchased and deployed by any user with basic technical skills and biogeochemical interests. The industrial partners Satlantic (sensors) and Webb (floats) have important expertise in such commercial ventures, and all members of the consortium are working towards transitioning the float/nitrate technology that is presently based in the academic community to a commercial setting where it can become more widely used.

APPROACH AND WORK PLAN

Our approach has been to modify the ISUS electronics used successfully on moorings to fit inside a float pressure case, to modify the ISUS fiber optics to fit the float, and to design a new mounting for the ISUS external sensor. The results of this work is shown in Figure 1, included at the end of this report. In this case the ISUS sensor is mounted on the bottom of the float. This is due to the fact that upper endcap of the float is mounted, removed, and remounted many times during construction, in order to carry out the required CTD checks and calibration. If the ISUS were on the upper cap, the position of the fiber optics, and the resulting ISUS calibration, might change each time the endcap was removed. To get around this problem, in the initial float the sensor was bottom mounted. Due to the extra weight of ISUS, a carbon fiber hull was substituted for the usual aluminum hull used on most Argo floats. Since all the ISUS floats use Iridium communications, a CTD sample is collected at 2 meter intervals. Since the float is less than 2 m in length, it means that the pressure (depth) of the nitrate values inferred from ISUS are within one pressure bin (ie, within 2 meters) of the nearest CTD saple; this does not seem to be a serious limitation. On later floats the ISUS unit has been completely redesigned and is now on the upper endcap (see Figure 2). After refining this upper endcap design on several more floats, it appears that commercial production can begin on a trial basis.

WORK COMPLETED

Five ISUS units similar to the one shown in Figure 1 have been fabricated by UW and MBARI and deployed at various locations in the Pacific and Indian Oceans. Most of this work was done prior to receiving this grant, with each float having some refinements from its predecessors . We now have designed and built a second generation version of the float/ISUS unit, with the ISUS sensor placed on the upper endcap of the float in the data stream of the SeaBird CTD unit; this float, shown in Figure 2, was recently deployed at the HOT site and is functioning normally. In this case the same seawater flowing through the CTD unit and being measured for temperature and salinity is subsequently flowing through the ISUS unit just a few centimeters away. This design assures that all the relevant parameters here are measured nearly concurrently, and it also means that the ISUS is protected by the same biocide that is used to inhibit biological fouling on the CTD unit. In addition to this, we are now building a float using Satlantic's SUNA (Submersible Ultraviolet Nitrate Analyzer) technology. This sensor is similar to ISUS but contains no fiber optics, which is a possible advantage for float-based use. However, the unit is considerably larger than ISUS will require a totally different mount than has been used previously. The SUNA unit has to be mechanically stapped to the side of the profiling float as it is too large to fit on either endcap (Figure 3). This is a distinct disadvantage to SUNA. It appears that SUNA is somewhat simpler to manufacture than ISUS, which is the reason that we are assessing its utility. The fabrication and testing process for the float/SUNA is now underway and we intend to deploy such a float in the next 6 months.

RESULTS

An example of the data from one of the instruments (UW float 5143, near Station P in the Northeast Pacific) is shown in Figure 4. The plot shows data from 81 profiles to a depth of 1000 m, collected at 5 day intervals between August of 2008 and September 2009. The ISUS sensor is generally stable over the year with the exception of jump in calibration of ~1 μmol/kg after the first 3 profiles. The cause of this jump is under investigation and is likely due to a thin bacterical film growing on the sensor window, although other causes are possible. While this change is within the stated specifications for the instrument, we intend to take steps to eliminate such jumps with the goal of having precision and accuracy of the instrument below 1 μmol/kg. With the new ISUS design (inline with the CTD unit on the upper endcap), the CTD biocide should prevent even small amounts of biological growth.

IMPACT AND APPLICATIONS

It is clear that such instruments will likely have wide use in the biogeochemical oceanography community in the coming years. In April of 2009 a workshop was held at MBARI (with PIs Johnson and Riser on the organizing committee, which was chaired by Johnson) with 60 scientists and agency representative in attendance to assess the use of floats and gliders for making useful geochemical measurements. There was a great deal of excitement in the group concerning the future of such work. It seems highly possible that in a few years the deployment of a float-based global biogeochemical observing network will begin, in parallel with the Argo array already in place. A paper discussing the future of geochemical measurements from floats and gliders summarizing many of the discussions held at the meeting has recently appeared (Johnson et al., 2009a).

RELATED PROJECTS

In addition to the NOPP work discussed in this report, Riser and Johnson have another project supported by NSF to build and deploy 8 floats with ISUS sensors per year (over three years) at time series sites such as HOT, BATS, and Station P. In addition, some floats with this technology will be deployed in the Antarctic, Arctic, and elsewhere in order to get a flavor for the seasonal cycle of temperature, salinity, and nutrients with a temporal resolution that has been heretofore impossible, and at a cost considerably less than the cost of ship-based observations.

REFERENCES

Johnson, K., W. Berelson, E. Boss, Z. Chase, H. Claustre, S. Emerson, N. Gruber, A. Kortzinger, M.J. Perry, and S. Riser (2009a) Observing biogeochemical cycles with profiling floats and gliders: prospects for a global array. *Oceanography*, **22**, 217-225.

Johnson, K., S. Riser, and D. Karl (2009b) The nitrate supply to near-surface waters of the North Pacific gyre. *Nature*, under review.

PUBLICATIONS

Johnson, K., W. Berelson, E. Boss, Z. Chase, H. Claustre, S. Emerson, N. Gruber, A. Kortzinger, M.J. Perry, and S. Riser (2009a) Observing biogeochemical cycles with profiling floats and gliders: prospects for a global array. *Oceanography*, **22**, 217-225.

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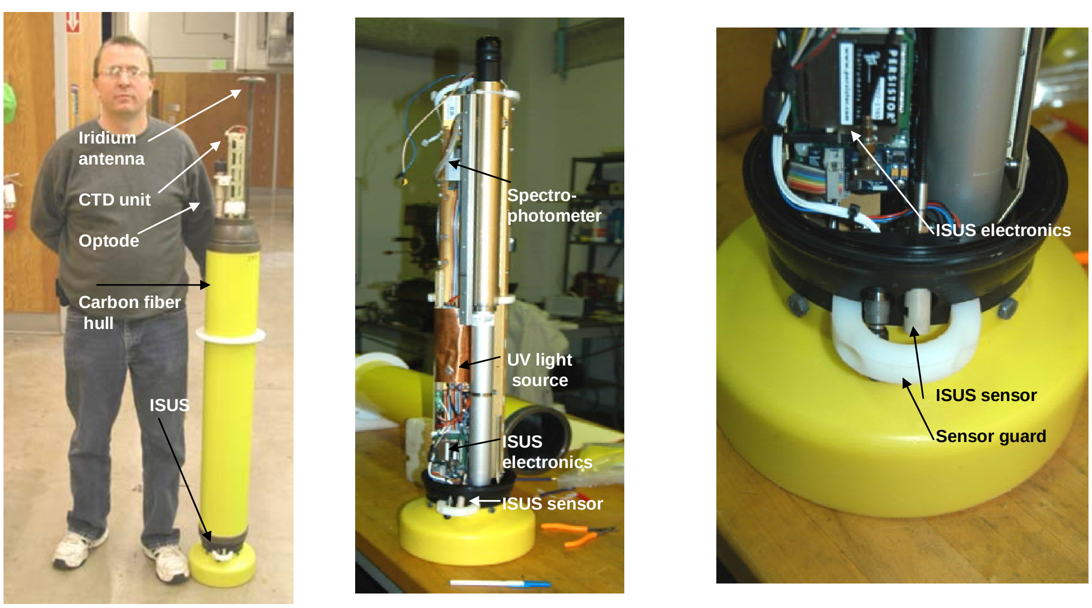

FIGURE 1. The initial design of ISUS for a profiling float. In this version the sensor is located on the lower endcap of the float. The float is also equipped with an Aanderaa Optode dissolved oxygen sensor and uses Iridium communications.

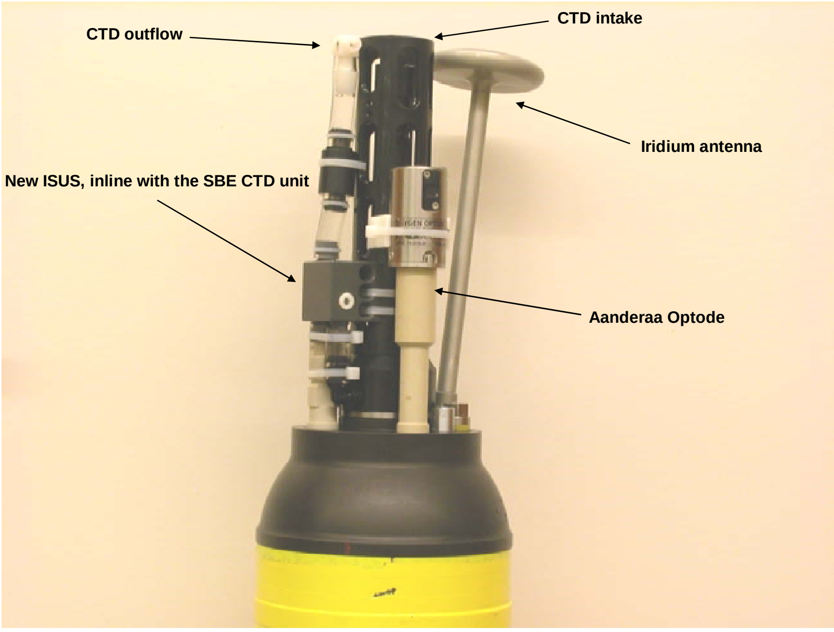

FIGURE 2. The upper endcap of a profling float with the newly designed inline ISUS unit. This float was recently deployed at the HOT site near Hawaii.

FIGURE 3. A mock-up of a profiling float with a Satlantic SUNA nitrate sensor unit attached. This design will be deployed and tested in the upcoming year.

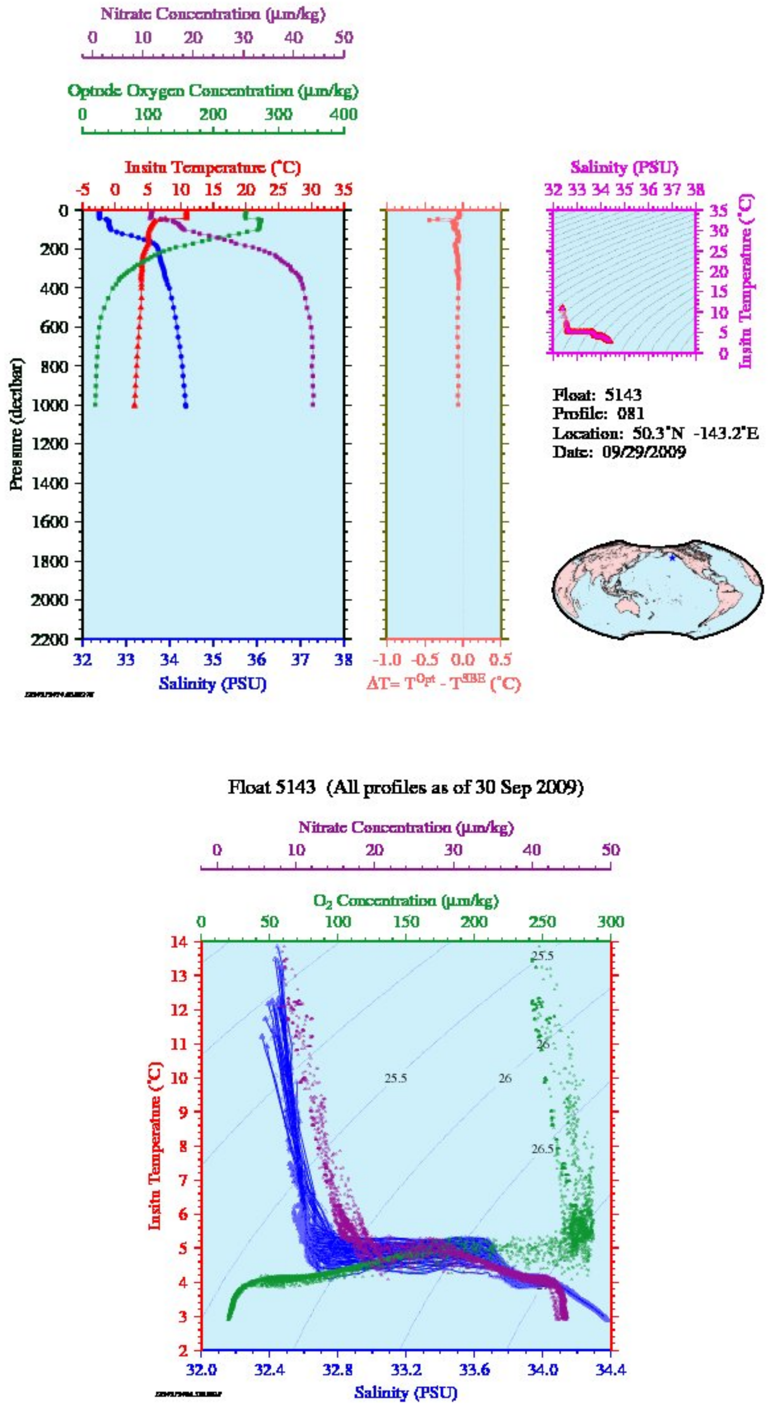

FIGURE 4. Top panel: Temperature, salinity, dissolved oxygen, and nitrate data from 81 profiles from UW profiling float number 5143 in the Northeast Pacific. The profiles were collected at 5-day intervals between August 2008 and September 2009 (the float continues to function normally through the end of 2009). Bottom panel: Salinity, dissolved oxygen, and nitrate plotted as functions of temperature from float 5143.