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

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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 we have built and deployed several profiling float versions, with excellent and exciting results. However, fabrication of the sensor and integration with the float were initially quite 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 community. The partnership involved here collectively as the skills to meet this goal.

OBJECTIVES

In recent years 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

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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, lightweight, and have minimal power consumption. 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 in its third year of operation and has provided an outstanding record of the evolution of nutrients, dissolved oxygen, temperature, and salinity at the HOT site during this time. The first results from this deployment have recently been published in a jointly-authored paper in *Nature* (Johnson et al., 2010). While the float has provided a wonderful dataset, the construction of the float was quite difficult and pushed the technical capabilities of the MBARI and UW groups to near their limits. Based on this preliminary success, we proposed and were funded by ONR (through NOPP) to modify our design so that it could be made simple enough to be produced commercially, so that such floats could 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. Our industrial partners Satlantic (sensors) and Teledyne/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. In our initial design the ISUS sensor was mounted on the bottom of the float. This was 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. 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 sample; 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 1) in a way that eliminates problems with the fiber optics, even if the endcap is removed.

After refining this upper endcap design on several more floats, it appears that commercial production can begin on a trial basis.

WORK COMPLETED

Seveal ISUS units similar to the one shown in Figure 1 were fabricated by UW and MBARI and deployed at various locations in the Pacific, Atlantic, and Indian Oceans. With each deployment, refinements to the design were made. In the past 18 months we 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 (shown in Figure 2), and 5 floats of this design have been deployed. 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. The first of these units (shown here in the UW lab) was deployed at the HOT site in November of 2009. These second-generation floats are working well, and there is a general conclusion that this is a good candidate for the design of a commercially-available float that can be built and sold by Satlantic and Teledyne/Webb. In addition to this design, we are examining the alternative possibility of 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. It appears that the SUNA unit will have to be mechanically stapped to the side of the profiling float as it is too large to fit on either endcap. 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 considering building a float with SUNA and assessing its utility. We hope to have a float with the SUNA sensor deployed before the end of 2010; unless the results are strikingly superior to our existing results with ISUS, we believe that the present design will (within the next year) become the commercial design.

RESULTS

An example of the data from one of the instruments (UW float 5145, near the HOT site at Hawaii) is shown in Figure 2. The plot shows nearly 2 years of nitrate data, beginning in January of 2008. The ISUS sensor was generally stable over this period with the exception of jump in calibration of ~1 μmol/kg after the first 3 profiles. The cause of this jump is likely a thin bacterical film growing on the sensor window. While this change is within the stated specifications for the instrument, we intend are taking steps to eliminate such jumps with the goal of having precision and accuracy of the instrument below 1 μmol/kg.

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 representatives 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., 2009). In the past 12 months, the UW/MBARI group has received 20-30 requests from the scientific community to build floats with nitrate sensors for various projects and PIs. Given the amount of work involved, we cannot meet many of these requests. But the degree of interest in the community does show that there is likely to be a strong market for these floats once the Satlantic/Webb version is commercially available.

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 a three year period) 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. Additionally, Riser and Johnson are among the PIs on another NOPP/ONR project (N00014-10-1-0206) whose goal is to produce an accurate and stable pH sensor for use on profiling floats.

TRANSITIONS

The UW/MBARI consortium has been gaining experience in building and deploying profiling floats with nitrate sensors for several years now. Our plan when our NOPP proposal was submitted was to transition this work to our commercial partners, Teledyne/Webb and Satlantic, during the third year of our project. This third year began on October 1, 2010, and we are now having weekly conference calls that include all the partners in order to plan for this transition. By the spring of 2011 it is expected that Teledyne/Webb and Satlantic will have begun fabricating their first prototype float with a nitrate sensor, and by the end of 2011 it is hoped that the first commercial version will be available for sale.

REFERENCES

Johnson, K., S. Riser et al. (2009) Observing biogeochemical cycles at global scales with profiling floats and gliders. *Oceanography*, **22**, 216-25.

Johnson, K., S. Riser, and D. Karl (2010) Nitrate supply from deep to near-surface waters of the North Pacific subtropical gyre. *Nature*, **465**, 1062-1065. doi:10.1038/nature09170.

PUBLICATIONS (see REFERENCES)

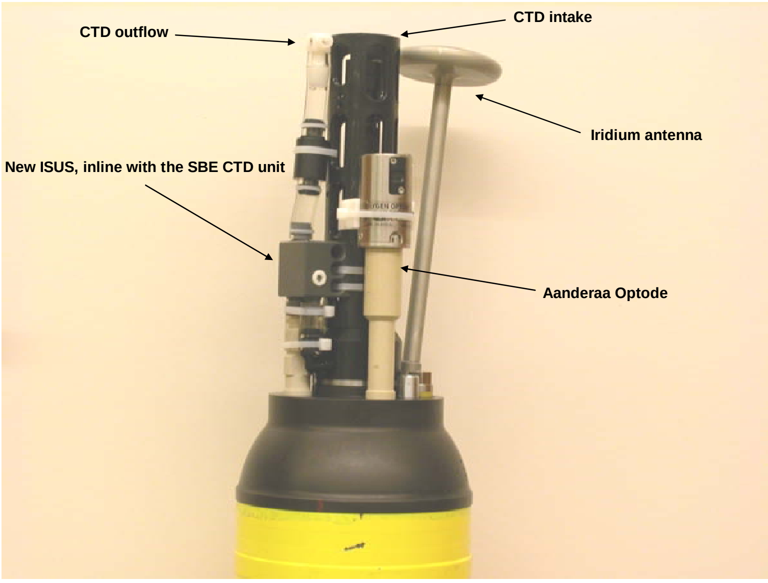

FIGURE 1. The upper endcap of a profling float with the second-generation inline ISUS unit.

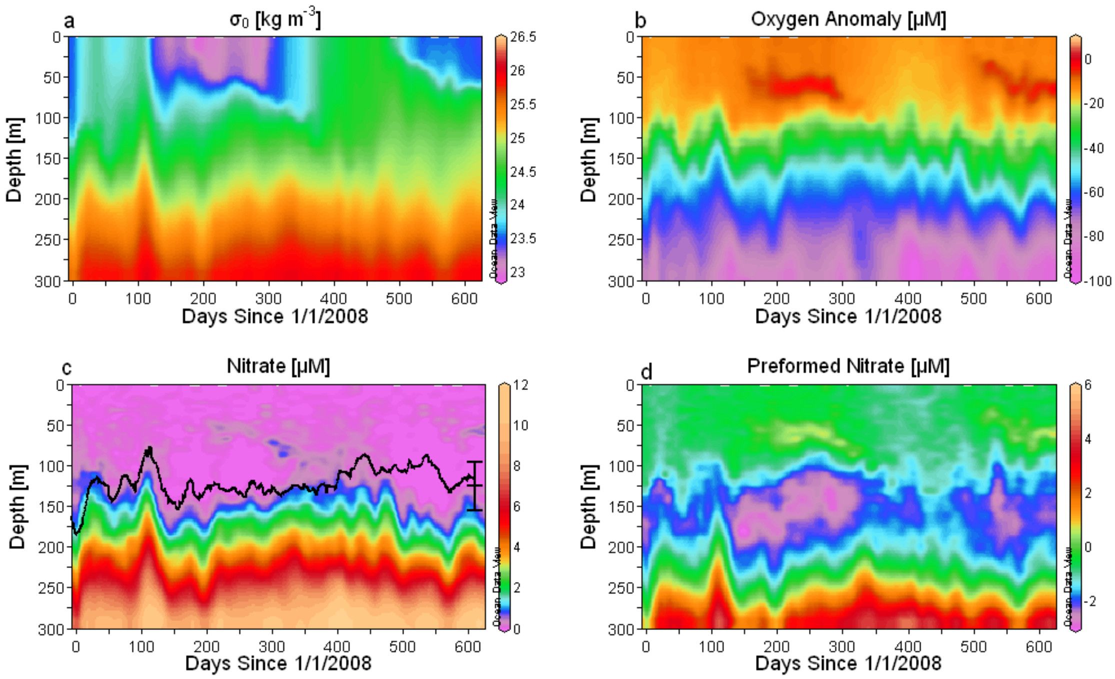

FIGURE 2. A time series of nearly 2 years of nitrate and dissolved oxygen data from near the HOT site, collected by UW float 5145 (reprinted from Johnson, Riser, and Karl, *Nature*, 2010).