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 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 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 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 will soon be submitted for publication. While the float is providing 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. 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

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 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. 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 (shown in Figure 2). 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. In addition to this, we are 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 will be mechanically stapped to the side of the profiling float as it is too large to fit on either endcap. While this is a distinct disadvantage to SUNA, it appears that SUNA is somewhat simpler to manufacture than ISUS. Both ISUS and SUNA floats have now been designed; ISUS floats have been built and deployed, and the first SUNA float will be deployed later in 2011.

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 2. 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 is likely to prevent even small amounts of biological growth. There are several stages to the design process. In the first stage (relevant to ISUS only), an ISUS sensor built at MBARI is added to an APEX float built at UW (now completed, with 8 floats fabricated and deployed). In the second phase, ISUS and SUNA sensors built at Satlantic are added to floats built at UW, with modified software provided by Satlantic (we will be deploying these first floats with Satlantic sensors before the end of 2011). In the third phase, Satlantic will add their sensors to commercial floats built at Teledyne/Webb. Current plans call for this step to be carried out in October of 2011. Once the third stage is complete, the totally commercial versions will be deployed, likely before the end of 2011. At that point, if the floats are operating properly, this project will be complete and the entire fabrication process will transition to the commerical versions, with work carried out solely by Satlantic and Teledyne/Webb.

IMPACT/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., 2009). In the summer of 2011 a second workshop was held at WHOI, with participation of over 100 scientists, for the purpose of beginning to plan for future global biogeochemical float and glider programs. It is clear that the there are a host of scientific problems that can be addressed by such floats (i.e., Johnson et al., 2010)

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

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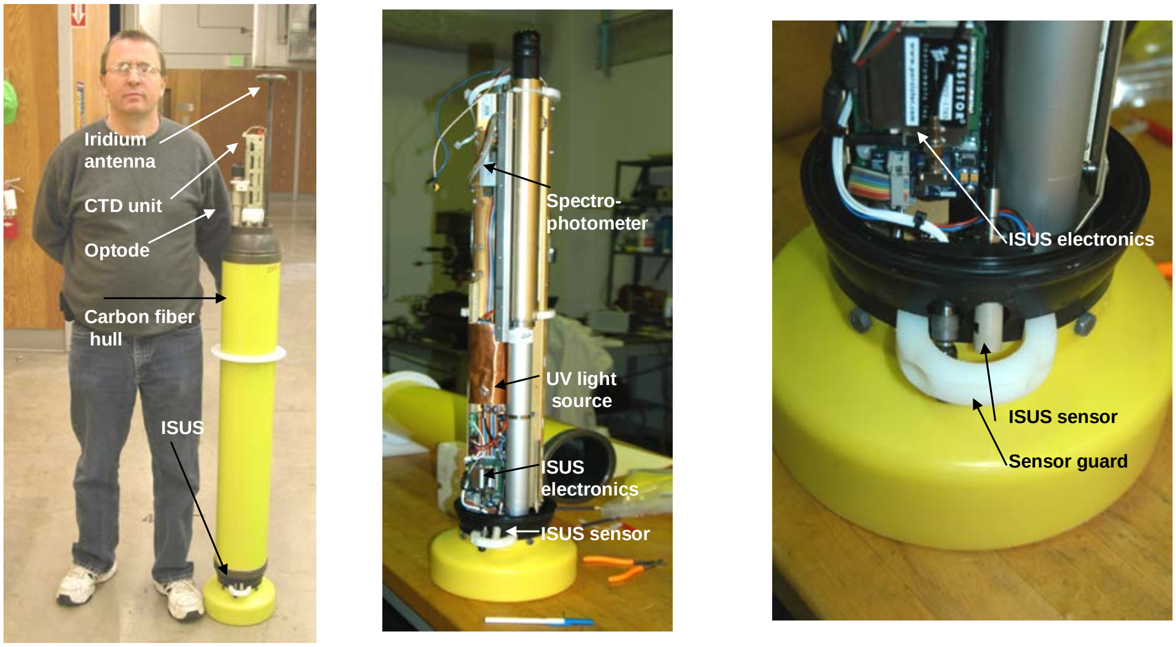


FIGURE 1. The initial design of ISUS for a profiling float. In this version the sensor is located on the lower endcap of the float. The float is also equipped with an Aanderaa Optode dissolved oxygen sensor and uses Iridium communications.

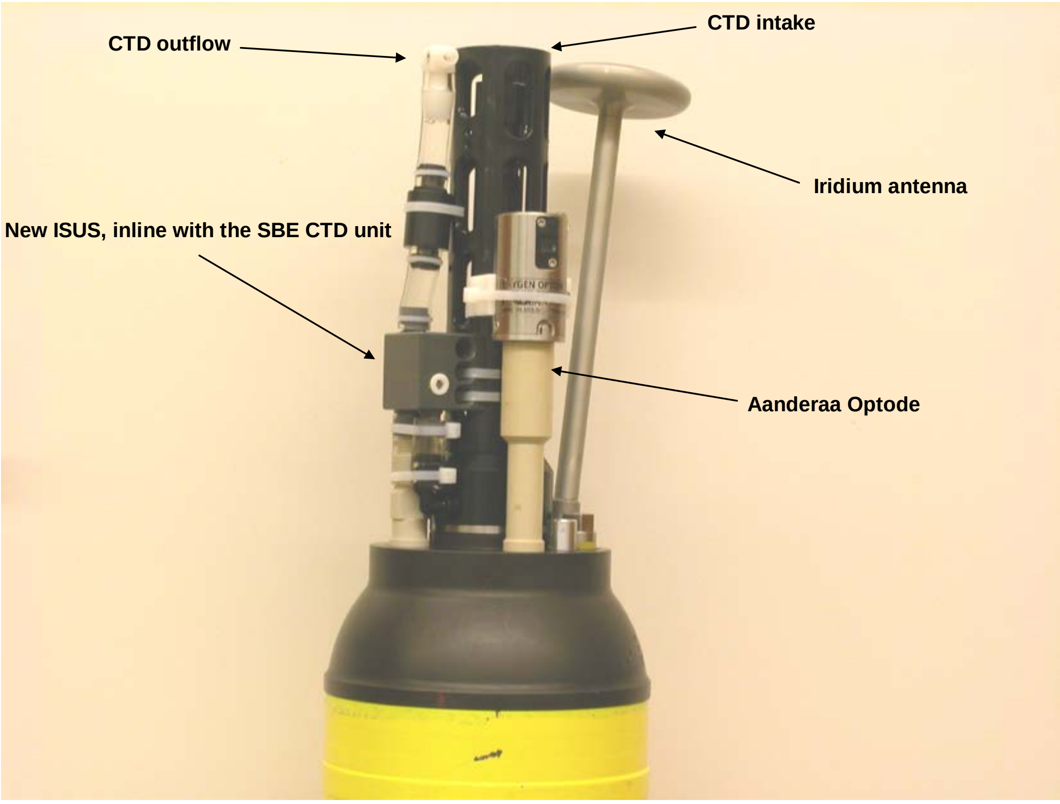
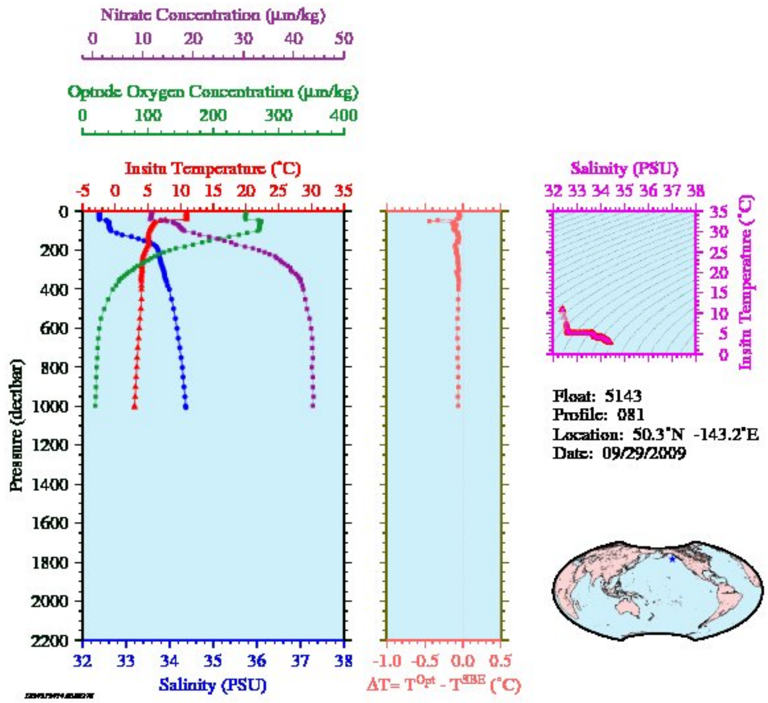


FIGURE 2. A photo of the upper endcap of a profling float with the newly designed inline ISUS unit.



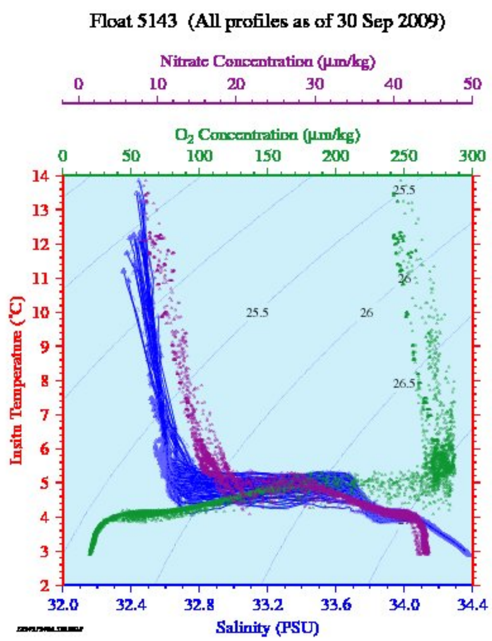


FIGURE 3. Top panel: Temperature, salinity, dissolved oxygen, and nitrate data from 81 profiles from UW profiling float number 5143 in the Northeast Pacific (inset shows the float position, near Station P). The profiles were collected at 5-day intervals between August 2008 and September 2009. Bottom panel: Salinity, dissolved oxygen, and nitrate plotted as functions of temperature from float 5143; note that the nitrate data are stable over the year, although there is a jump in concentration of about 1 µmol/kg after the first few profiles.