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Arvor-Cm: A Multisensor Coastal Profiling Float Real-Time Monitoring of Biogeochemical Parameters in Coastal Seas

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The Arvor-Cm profiling float in action
(Photo courtesy of Olivier Dugornay, Ifremer)

There is a growing scientific demand for instruments that can monitor the physical and biogeochemical processes of coastal water masses in real time. However, few platforms are available for this kind of monitoring, particularly for long-term observations that last from a few months to a few years.

To meet this need, the Department of Technology Research and Development at the French Research Institute for Exploitation of the Sea (Ifremer) developed a coastal profiling float named Arvor-C to monitor the change in temperature and salinity in coastal seas. A previous article in *Sea Technology* (February 2010) details its operation and performance.

Although this platform has offered valuable services for several years, researchers now need an enhanced coastal exploration instrument to record more parameters, including dissolved oxygen, turbidity, fluorimetry, etc. Due to its design, the standard Arvor-C profiling float cannot accommodate additional sensors.

For this reason, Ifremer, in collaboration with nke instrumentation, designed a new, multisensor coastal profiling float: the Arvor-Cm. Based on its innovative design, the Arvor-Cm can embed additional sensors easily in terms of mechanical integration, hardware architecture and software development.

From Arvor-C to Arvor-Cm

The Arvor-C profiling float was designed by Ifremer a few years ago to meet the needs of scientists for high-frequency data acquired over long periods of time at the same location in a coastal environment. It is based on the Arvor/Provor profiling floats, which have been deployed for offshore applications for more than 20 years, particularly in the frame of the Argo international program. Profiling floats are more reliable and easier to set up than instruments moving along moored cables, and do not require particular attention or skills to monitor their operation, in contrast to gliders.

The Arvor-C profiling float has been successfully operated in the Bay of Biscay since 2009, recording more than 2300 profiles (as of February 2016) as part of the Aquitaine/Armorican Shelves and Slopes Physics Experiment (ASPEX) project. The deployment positions, one in the northern part of the bay and one in the southern part, were chosen to collect profiles representing the hydrological properties of the "cold pool" extending above Armorican and Aquitaine shelves. The Arvor-C, equipped with a Seabird Conductivity-Temperature-Depth (CTD) SBE41CP sensor, has been used to study the annual cycle and the seasonal stratification over these regions with high temporal resolution (Charria et al., 2014).

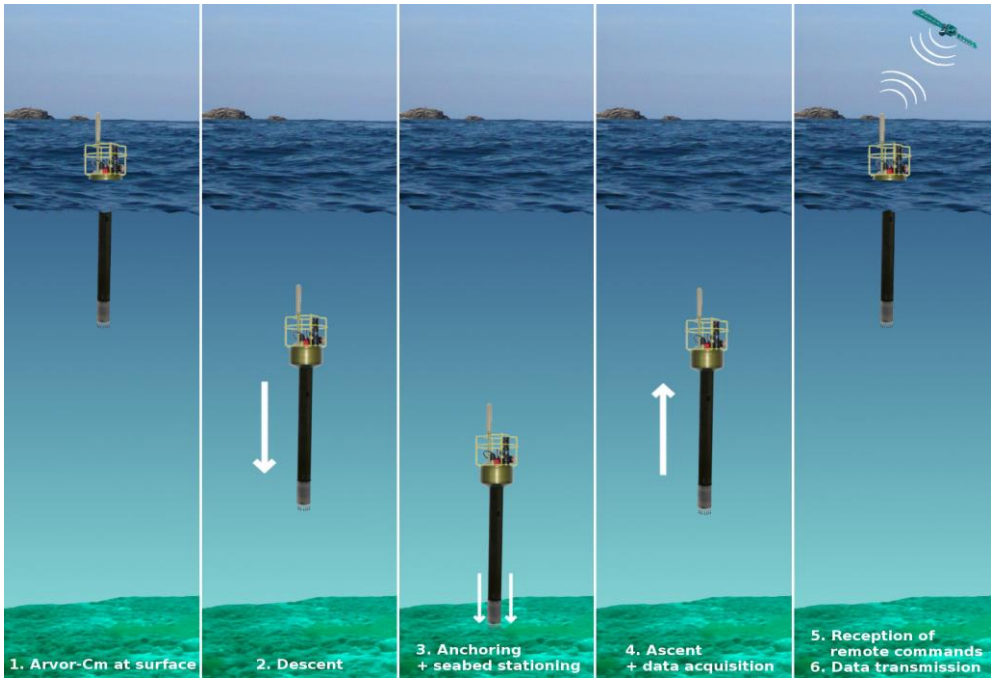
The anti-drift claws on the bottom-end cap of the Arvor-C float have proved effective at sea: the drift of the float is limited to 200 meters / day on average, making it appropriate for coastal applications.

These successful deployments show that the Arvor-C-type platform fulfils the scientific needs in monitoring coastal seas. To include other parameters, such as dissolved oxygen, chlorophyll and turbidity, a new platform based on the Arvor-C was developed: the Arvor-Cm multisensor coastal profiling float.

Design of the Arvor-Cm

Operation

The Arvor-Cm operates in similar fashion to the Arvor-C, recording a profile from the seafloor to the sea surface. First, the profiling float quickly descends through the water column using its ballast system, and anchors on the seabed with its claws, which limits its drift while parked on the seafloor until the next profiling time. Then, it starts its ascent, taking the scientific measurements at intervals specifically programmed for each sensor. When it reaches the surface, the Arvor-Cm is located via its GPS (Global Positioning System) and the data are transmitted through the Iridium satellite system, which also allows users to remotely control the mission.



Description of the Arvor-C / Arvor-Cm profiling cycle

Mechanical Design

The position of additional sensors on a moving platform such as a profiling float is a major issue with regard to the quality of the measurements taken, because the optical sensors record the parameters from the seawater that flows in front of them. Moreover, after a period of time on the seafloor, settled sediments can obstruct the sensors. Therefore, manufacturers' recommendations regarding the position of the sensor on the platform must be strictly followed. A study of the sensors of interest for coastal applications identified two main categories of sensors to be included on the Arvor-Cm: (1) sensors that must be integrated in a vertical position, such as the Aanderaa 3830 dissolved oxygen optode, or the Seapoint turbidity sensor; (2) sensors that must be integrated horizontally, such as the WetLabs Fluorometer & Turbidity (FLNTU) sensor or the Cyclops-7 sensor from Turner Design.

These considerations led to the design of a new upper-end cap, with the possibility of embedding a payload of four sensors in addition to the Seabird CTD sensor on the Arvor-Cm platform: two horizontally integrated sensors, and two vertically integrated sensors. A metal cage was designed to protect the sensors and the Iridium antenna from any damage during deployment and recovery.

The hull of the Arvor-Cm is made of epoxy - glass fiber, providing for a lightweight casing (~22 kilograms) compared with an aluminum alloy material. This is particularly important in coastal applications where deployments are often done by hand, without cranes or any other deployment support.

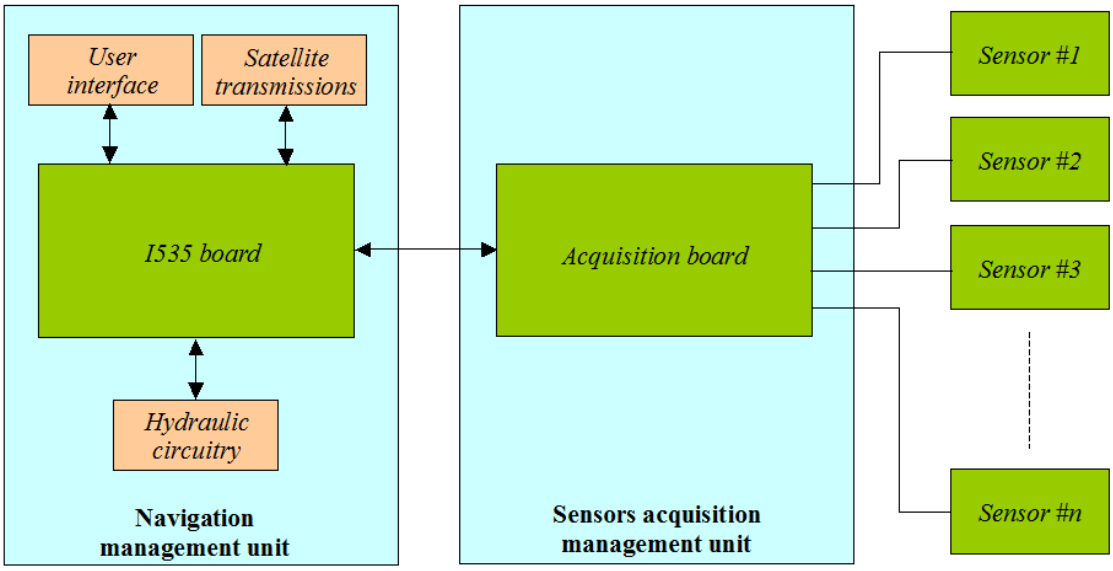
Moreover, the claws on the bottom-end cap of the profiling float are the same as those used on the standard Arvor-C profiling float, because they effectively limit the drift of the float towards the shore or off the continental shelf.

Electronical Design

The central element of the Arvor profiling float family is its I535 electronic board. It embeds an ATMega128 microcontroller that drives all the subassemblies of the float (sensors, satellite transmission, hydraulic engine, etc.), all of which are programmed sequentially.

The I535 board only offers two serial links that can be dedicated to adding extra sensors on the profiling float. Additional multiplexing boards can be used when more sensors are needed, but do not offer a flexible hardware solution. Moreover, the integration of new drivers in the existing software is intrusive, and requires many qualification and non-regression tests.

For these reasons, Ifremer improved the architecture of the Arvor-C to offer flexible hardware and software solutions. The main improvement consists of the separation of businesses into two functional logics: (1) a master board, dedicated to managing navigation; (2) a slave board, dedicated to managing sensor data acquisition.



Arvor-Cm hardware architecture

This double-board architecture was developed jointly for ProvBio floats, multisensor profiling floats of the Provor family used for offshore applications.

In this new architecture, the navigation unit is the same I535 board used in all Arvor/Provor profiling floats for more than 10 years. It is reliable, and its software is fully qualified at sea. This unit is in charge of the float's movements: it controls the hydraulic circuitry, the satellite transmissions and the acquisition board.

The sensor acquisition board was designed by Ifremer, and its software was developed by nke instrumentation. It can control up to five RS232-output sensors and two analog-output sensors, and compute their data. It offers a sequencing system that simplifies integration of the software drivers of each new sensor.

Sensor selection

The first three prototypes of the Arvor-Cm were fitted with the following sensors: an Aanderaa 3835 dissolved oxygen optode, and either a WetLabs ECO FLNTU fluorimeter and turbidity meter, or a Turner Design Cyclops-7 fluorimeter and a Seapoint turbidity meter.

Results at sea

As for each new profiling float architecture, the Arvor-Cm underwent a series of qualification tests in hyperbaric tanks and in the test tank facilities at Ifremer before being deployed at sea.

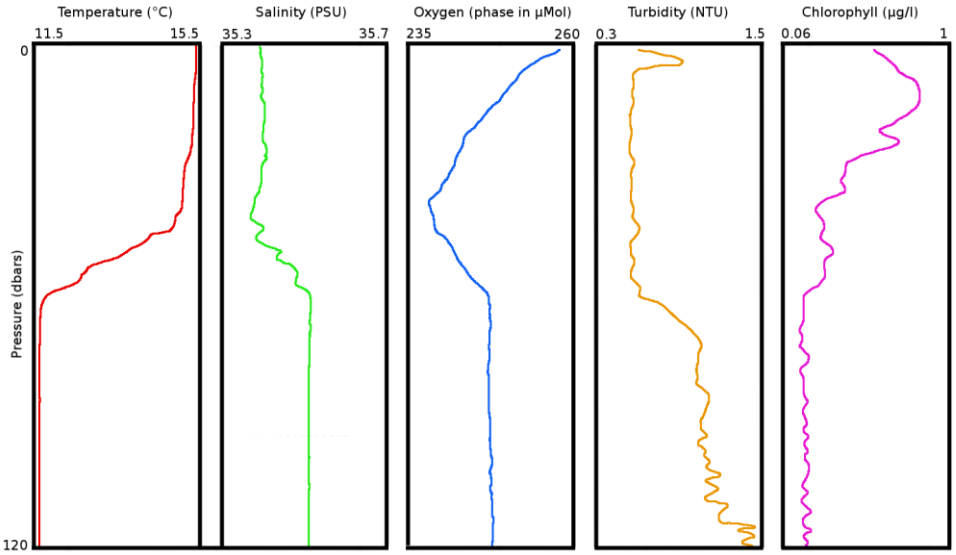
The first deployment of the Arvor-Cm was done at sea on 16 and 17 September 2014 in the Bay of Vilaine (France), as part of the Captiven project (Ifremer), and 12 cycles were successfully carried out. This first sea trial allowed comparison of the data acquired by the Arvor-Cm with those of the Molit station, an instrumented moored buoy equipped with similar sensors.

Arvor-Cm deployment in the Bay of Vilaine, France. (Inset) Close-up of the Arvor-Cm upper-end cap. (Photos courtesy of Olivier Dugornay, Ifremer)

The second operational deployment was performed in the Gulf of Lion (Mediterranean Sea) with two Arvor-Cm profiling floats, from 4 to 23 February 2015, during the Plumrho campaign. Two Arvor-Cm floats established a profile every 6 hours, for a total of 76 cycles each. Despite strong wind conditions, both floats remained on the continental shelf during this operation. Conductivity, temperature, dissolved oxygen, chlorophyll and turbidity data were successfully acquired from the seafloor to the sea surface, and sent to the Coriolis data center in real time.

Finally, one Arvor-Cm was deployed on 1 July 2015 on the shelf in the Bay of Biscay, as part of the ASPEX campaign. It recorded one multisensor profile every day at 12:00 UTC.

Moreover, more than 100 ProvBio profiling floats fitted with this architecture were also successfully deployed at sea as part of the Novel Argo ocean Observing System (NAOS) and Remocean projects to monitor the biogeochemical activity of offshore oceans.



Example of profiles for five different parameters acquired using the Arvor-Cm float during the ASPEX campaign (October 2015)

Conclusions and future developments

The Arvor-C profiling float has been successfully acquiring data profiles from the seafloor to the sea surface in costal environments since 2009. It was designed to have a limited drift so that it can be operated as a virtual mooring. To meet the growing demand for platforms equipped with additional sensors, Ifremer and nke instrumentation designed the Arvor-Cm profiling float.

The mechanical design of the Arvor-Cm includes the possibility of embedding up to four sensors in addition to the standard Seabird CTD sensor, while remaining lightweight and easy to deploy. The electronical and firmware design was carried out jointly for ProvBio floats and is based on an innovative design that uses two separate circuit boards for navigation and for data acquisition. This double-board architecture limits the impact of the addition of new sensor drivers, and reduces the time required for qualification testing. The Arvor-Cm profiling float is now marketed by nke instrumentation.

One Arvor-Cm was successfully deployed for a short-term experiment in the Bay of Vilaine in 2014, and three Arvor-Cm floats were deployed in the Gulf of Lion and the Bay of Biscay in 2015, for a total of about 400 cycles (as of February 2016). These experiments proved the value of the data acquired, and the simplicity of use. The cage that protects the sensors and facilitates the recovery of the float was also highly appreciated.

Moreover, one Arvor-Cm was fitted with two different chlorophyll sensors and two different turbidity sensors. For each type of sensor, we will compare the acquired data to assess the quality of their measurements at sea. This evaluation is scheduled for 2016.

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References

For a full list of references or additional information, please contact Xavier André at xavier.andre@ifremer.fr.

Bios

Xavier André is the head of the Arvor-C/Arvor-Cm project at Ifremer. He is an electronics and software engineer, and has been involved in the development of many multidisciplinary underwater systems, such as military sonars, underwater communication & positioning systems and scientific instrumentation.

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Serge Le Reste is an electronics engineer and the project manager for float instrumentation at the Department of Technology Research and Development at Ifremer. His activities include coastal and deep-sea developments for operational oceanography as well as other scientific applications.