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Mastodon Mooring System To Measure Seabed Temperature Data Logger With Ballast, Release Device at European Continental Shelf

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1. Introduction

Sea temperature is an essential environmental parameter because it influences both the dynamics of the ocean and the structure of the whole benthic ecosystem. For decades, sea surface temperature (SST)has been measured by satellites whose spatial resolution is constantly being improved. The spatial and temporal variability of SST is now relatively well known for most of the ocean.

In coastal areas, including the continental shelf (depths ranging from 0 to 150m), the vertical profile of temperature depends mainly on turbulence conditions. In some areas, such as the eastern English Channel, the strong tidal current constantly mixes the water column, and the SST can be extrapolated directly to the seabed. However, in most coastal areas, thermal stratification occurs seasonally from spring to autumn and assessment of seabed temperatures requires *in situ* devices. The deployment of a temperature sensor for several months on the seabed entails a mooring system, because most of the depths are difficult or impossible to reach by SCUBA diving. Although temperature data-loggers are now affordable, the deployment of a mooring system for several months is generally a risky and expensive operation. These barriers are probably the reason that seabed temperature time series are so scarce for coastal areas.

The goal of the Mastodon mooring system is to record the spatial and temporal changes in the seabed temperature during the stratified period that lasts for at least six months at middle latitudes. The required precision of the temperature measurement was set at 0.1°C, a commonly adopted value for coastal observatory systems. The low cost of the instrument was an important condition to meet so as to ensure sufficient *in situ* spatial resolution by deploying several instruments in the same area.

2. General description

A classic coastal mooring system with a surface float was not selected due to the cost of the whole mooring system and the accessories (chain, mooring line, anchor, etc.) required for the system to withstand six months in rough sea conditions.

We therefore chose to build a system involving a near-bottom temperature data-logger with a ballast and a release device. The most commonly used release devices are based on acoustic signals. This solution was also rejected due to its cost. Therefore, release of the mooring system from the seabed will not be activated by signals sent out from the ship mandated to recover the mooring, but will occur on a specific date chosen before deployment. Due to uncertainty in marine weather forecasts and ship availability, the temperature probe and its float must nevertheless remain fastened to the ballast after the release date to allow recovery, if necessary, a few days later.

The following conditions were considered in the design of a new system.

2.1. Mechanical design

The positive buoyancy for mooring floatation is provided by a 280mm diameter plastic fishing net float (Nokalon 511), with a central hole of 24mm. This float has a net buoyancy of 7.5 kg and a working depth of 950m.

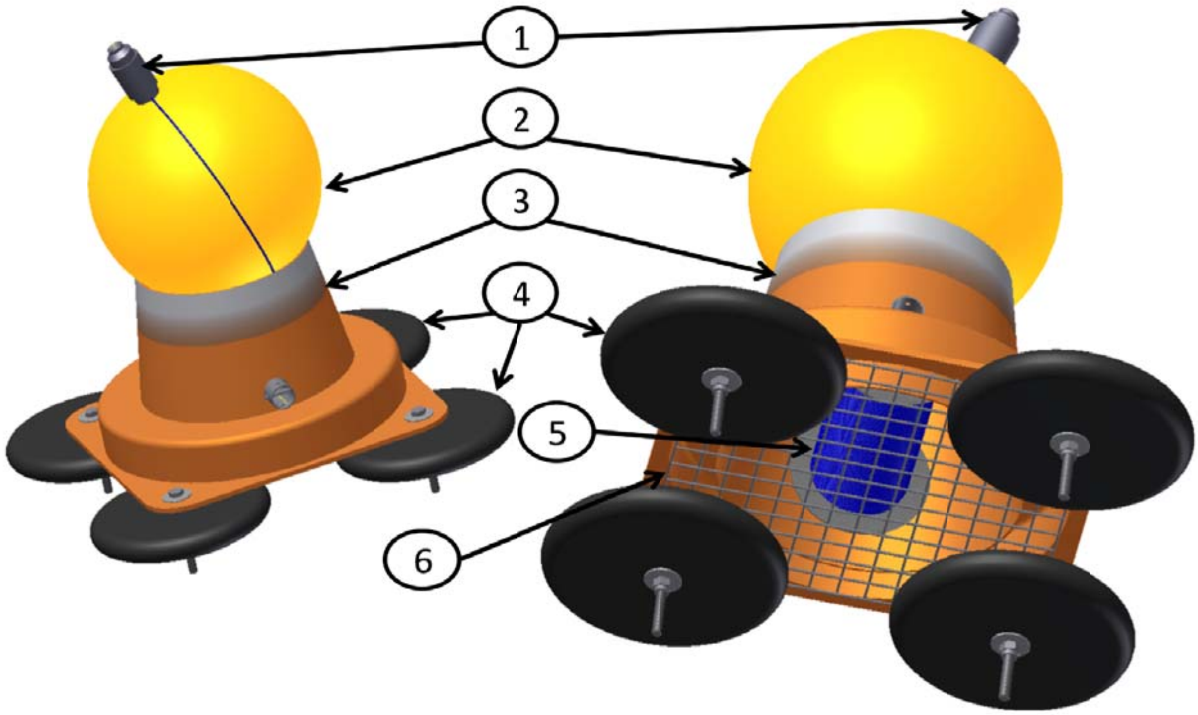

Figure 1: 3D diagram of the mooring system. (1) Electronics; (2) Float compartment;(3) Traffic cone;(4) Ballasts; (5) Rope spool;(6) Wire grate.

Located on the top of the float, the electronics are housed in a compartment made of standard PVC parts commonly used for plumbing. The compartment is connected to the release device via a flexible plastic tubing that passes through the central hole of the float (see section 2.2 for more details).

The frame is an ordinary traffic cone (75cm in height) cut 25 cm above its base. The ballasts consist of four dumbbell weights of 5kg each. The weights are fitted with stainless steel bolts that penetrate the sediment and are long enough to maintain the system on the seafloor even in strong current conditions.

A stainless steel tube (diameter, 30 mm) passes through the cone and is used to hold the spool of polyamide rope (diameter, 3 mm; nominal strength, 300kg). The rope is attached to the spool at one hand and to the float at the other end via a classic bowline.

A stainless steel wire grate is used to reinforce the frame and to protect the spool from stones that could hamper the unwinding of the rope upon release of the float.

The float and the electronic devices are securely attached to the frame with a polyamide cable clamp that fastens the loop of the release system to the wire grate.

The whole mooring system weighs 28 kg in the air and 10 kg in water.

2.2. Electronic design and release device

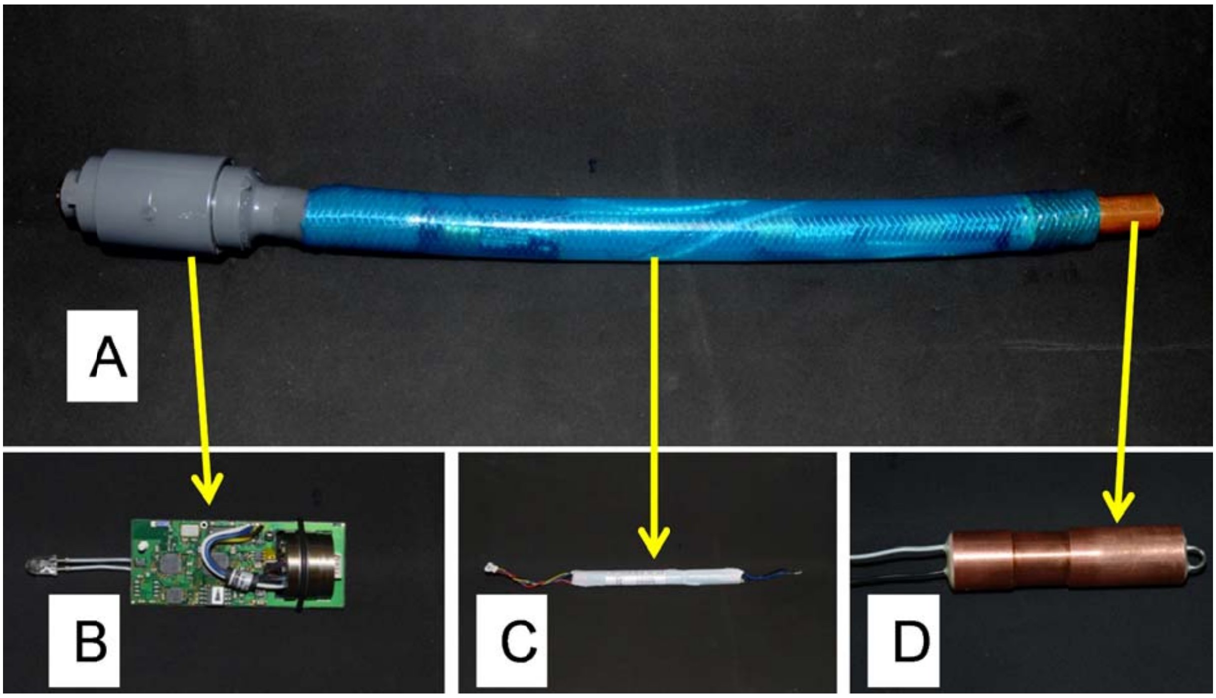

Figure2 : (A) : Central plastic tubing, electronic compartment on the left side, burn wire on the right side. (B) Electronic card. (C) Batteries. (D) Burn wire.

We developed a specific electronic card according to carefully considered technical specifications. A low power microcontroller with an 8 MB flash memory card is connected to a temperature and a pressure sensor. It can store up to 420,480 temperature and pressure data samples. The temperature sensor is a pre-calibrated electronic chip, featuring a 0.008°C resolution and requires no future re-calibration. One AAA 1.5Vcell is enough to take one temperature and pressure sample per minute for one year, or at longer intervals. There is an LED indicator at the top of the card to facilitate visual inspection of its operating status before deployment.

To program data sampling, start data collection or retrieve data samples, the system is placed in a dock that triggers a detection switch. Once detected, the LED indicator starts blinking and the high-frequency data link is powered on. Equipped with a high-frequency USB dongle a personal computer runs the Human Machine Interface that connects it to the data-logging system.

The plastic tubing, which houses the release mechanism, and the electronic compartment is filled with Marcol 82 insulating oil that allows ambient pressure housing, thereby drastically reducing the cost.

A low-cost "burn wire" release mechanism consists of electrolytic erosion of a copper wire loop under low voltage. The negative circuit is soldered to 16mm diameter copper tubing. The negative pole is soldered to a copper wire. The burn wire is mounted in resin to ensure insulation and water-tightness. When the electronic device switches on the current, electrolytic erosion is powered by two AAA batteries in series and is completed in about 1 h, releasing the float and its electronics compartment from the mooring frame. The batteries are located in the middle of the central hose.

3. System validation

3.1. Laboratory tests

We used the pull test to assess the resistance of the copper loop of the burn wire. Several copper wires of various lengths and shapes mounted in resin have been tested. The best configuration consisted of a 1.2mm diameter wire with several small loops inside the resin to enhance electrical resistance. In this configuration, the loop resists 50kg traction, largely sufficient in regard to the buoyancy of the float.

The major drawback of an integrated temperature sensor in an oil-filled compartment is the time constant. It was evaluated as the time required to reach a 63% (1-exp(-1)) change in temperature. This time was determined in the selected configuration to be 9 min. This duration, albeit long, is satisfactory for the description of bottom temperature, which is known to vary slowly in most environments.

More than 25 electronic cards were calibrated in the laboratory. The mean bias was 0.21°C with a standard deviation of 0.021°C. This bias appeared constant (with a range of 0.03°C) with temperature. This linear behavior allows low-cost calibration of new temperature sensors, because one single-point verification provides a final precision greater than 0.05°C,which is better than the initial specification.

3.2. *In situ* tests

Several tests were performed on the deployment of the system and it turned out that a simple drop of the Mastodon mooring system from the deployment ship (stationary) is efficient. The system descends at a constant speed of 0.8m/s.

The ageing of the release device was one of our concerns. Given that the mooring is dedicated to coastal measurements, biofouling may be troublesome because it can hamper electrolysis. A long-term experiment was set up. For more than 18 months, 50 burn wires were placed in a seawater tank at the IFREMER-Brest *in situ* testing site. The test tank was outside, exposed to natural light, and seawater was pumped in from the nearby sea. Every 3 months, a set of 8 burn wires successfully passed the test (electrolytic erosion of the copper wire completed in 1 hour), proving the reliability of the release device.

Our second concern was the ability of the mooring to stay in place under strong current due to the light weight of the system. An experiment was performed in Fromveur Passage in the Iroise Sea during a spring tide (28 February 2013-04 March 2013), where the current speed can reach 6 knots. The long bolts acted as clamps in the sea bottom, composed of coarse sand/pebble sediment, and the moorings stayed in place. However, after release, the float stayed mostly underwater and the recovery operation was only possible during slack tides.

The last experiment to qualify the system was a six-month *in situ* experiment with nine mooring systems deployed at 25m depth near the IFREMER *in situ* testing site. Every 2months, three moorings were scheduled to surface. After 6 months, the nine moorings were recovered and the data were verified and proved satisfactory.

3.4. Implementation in *in situ* experiments

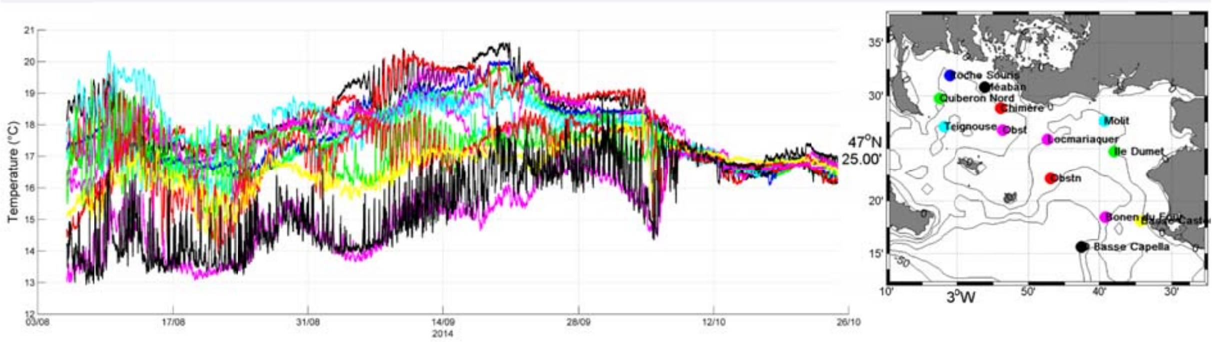

Figure 3. Time series of seabed temperature. Location of the stations is shown on the map in the right panel.

In the summer of 2014, the first experiment was set up in the Mors Bras region (southern Brittany, France) and 13 Mastodon moorings were deployed near traffic beacons to avoid fishing trawls, from August to the end of October. This region has weak to moderate tidal currents, causing summer stratification. All moorings (except one that was recovered on the shore before the end of the experiment) recorded seabed temperature for 3 months. Bottom temperature was highly variable on timescales ranging from the tidal cycle (12h) to several days. Some strong spatial gradients lasted a few weeks. Atthe end of the recording period, the temperatures became nearly homogeneous after several storms, indicating the end of the stratification season.

3.3. Cost breakdown for 10 Mastodon moorings

Table 1 shows that costs were indeed low, thereby meeting this specification: each mooring system cost around €330. This per-unit price can be further reduced by producing a greater quantity. In addition, most of the mooring’s components can be used for future deployments, in which case, new deployment only requires a new burn wire and new batteries, costing cost less than €100 for several months of measurement.

Table 1. Cost breakdown

Part description	Quantity	Total cost
Traffic cones + floats	10	€375
Stainless steel material	10	€570
Electronic cards with housing	10	€1200
Rope spool (average length of 100m)	10	€140

Burn wire	10	€235
Batteries	10	€770
Total cost for 10 Mastodon moorings		€3290

4. Conclusion and future developments

Here, we described the development of an inexpensive mooring system to measure the seabed temperature on the continental shelf with a precision of 0.1°C. To date, about 30 Mastodon systems have been deployed in southern Brittany. The maximum depth of deployment has not been precisely determined, and we have not tested the mooring beyond a depth of 130m maximum.

The next development will be to extend the system to measure temperature in the water column. To do so, the mooring system will be used as a vector, securing a vertical line on the frame with a subsurface float at about 10m below the surface. Several temperature sensors will be distributed on this line. This inexpensive temperature sensors string can then measure the variability of the isotherm along a vertical gradient under internal waves. A pressure sensor will be added to the electronic card to assess the depth of the temperature sensors, whose orientation can change with the tilting of the line due to currents and a new housing material will be necessary to decrease the time constant, because internal waves can show high-frequency variability.

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Figure captions :

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